Palestine Polytechnic University

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Graduation Project

Manual gear transmission design

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Abstract

This project aims to improve the manual gear transmission; this improvement includes reliability, durability, and noise reduction.
To ensure the improvement, we have to develop a manual gear transmission made of a more solid material.
An example of transmission development efforts relating to durability, reliability is to reducing transmission shift shock characteristics.
Finally we mentioned equations that will help us in our calculations and design.

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Chapter one: introduction

1.1 Preface

The main goal of the vehicle transmission is to convert the engine power into vehicle traction; this conversion will make the engine more efficient in fuel consumption and acceleration.

The critical constrains for the vehicle transmission designer are the vehicle, the engine and the operating environment. Basic knowledge of these factors is essential for meaning full development.

The first specific development task involving the gear box is the selection of the ratio range, or" overall gear ratio", to be covered.

The functioning of vehicle and transmission as a system can then be assessed, and decision made as to the number of speed, the ratio of the individual speeds, and the resultant gear stages. Taking into account the operating environment and the designers then to decide whether the vehicle has adequate acceleration, and the required climbing

Technical and technological advance have to be taken into account, as do operation reliability and adequate service life .its also essential to have regard for environmental and social consideration. Performance and the top speed stipulated in the specification, is also determined the transmission enables efficient motoring, especially in terms of fuel consumption.

1.2 Who should attend?

The project will be of benefit to those with some previous experience and also those who have recently become involved with gearing. Participants will need to bring their own scientific calculators.

1.3 Scope

The main goal of this project is to develop a new manual gear transmission design, this development includes improvement of efficiency, reliability, durability and performance which is related to the reduction of the weight by changing the material used in the conventional designs, that will reduce fuel consumption. Topics and notes have been prepared specifically for the current project is the analysis and safe design of various common elements of the gear transmission, bearing, and shafts, geometry of the involute tooth form and its appreciation to parallel axis gearing, geometric design of spur, helical and bevel gears, and the calculation of the load capacity gear failures.

On the other hand, by continuously using new software's to simulate the required final optimal design of the manual transmission like CATIA, SOLIDWORKS, ANSYS, and MITCALC that give us more knowledge and improve our experience, and to have the perfect understanding of the mechanical design especially the gearbox design, earned ideal ways of thinking to have a proper design.

Now a Completed transmissions are distinguished in terms of format and design the format of the transmission, this is primarily determined by the position of the transmission in the vehicle or in the power train and any additional geometrical constraints such as space limitations. The format is also affected by assembly considerations (both as regards the transmission itself and as regard its installation in the vehicle), by gearbox housing rigidity and noise emission transmission often comprise several individual gearboxes, which can be also housed in separate gearbox housing. In this case, the relative position of the individual housing is an important factor influencing the format of the transmission as a whole.

The transmission design is derived from the functional principles applied, to fulfill the main functions of the transmission. Their selection depends on the power to be transmitted, considering traction utilization and ease of operation. Especially in the case of new developments, the design engineer has to decide the design or combination of designs of the transmission. A preliminary selection can be made by assessing the design under consideration, and other alternatives. This preliminary selection follows on from the concept phase of transmission development.

There are unlikely to be any further fundamental innovations in vehicle transmission technology. There is more likely to be process of gradual evolution. The main trends are system thinking embracing the factor:

Environment ↔ Traffic ↔ Vehicle ↔ Transmission

This defines the super ordinate development goals of vehicle transmission, their developments have to be fast and market –oriented. There has to be flexibility in adapting to consumer preference, legal requirement also have to be taken into account, such as the maximum permissible noise level.

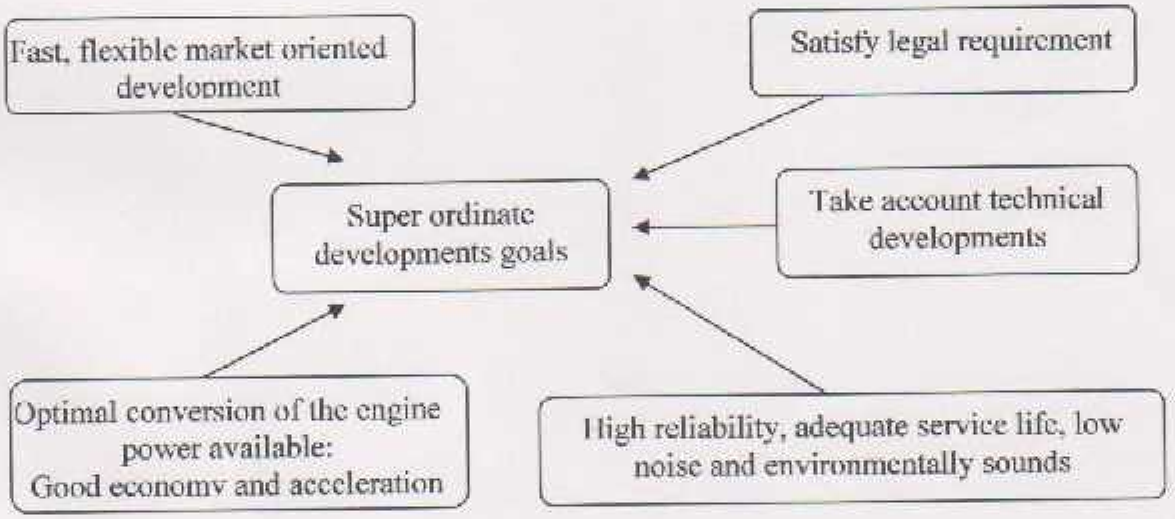


Figure 1.1 super ordinate development goals for vehicle transmission

1.4 Advanced transmissions and drivelines

What transmissions can learn from each other, a comparison of various transmission concepts following an analysis of this key strengths and weaknesses of the most important transmission types, attempts are being made to develop new, advantageous transmission design through the combination of various characteristics.

In each case, a conventional transmission is taken as a starting point and attempts are made to eliminate its weaknesses by drawing on ideas from other transmission designs. Relating to this concept a Subaru manual transmission is set in current project as a starting point. Since this type is a available in our workshop and its gradual development is so slowly if compared with the other modern types, figure 1.3 represents a five speed front wheel drive, transverse engine beside longitudinal transmission that Characterize this type.

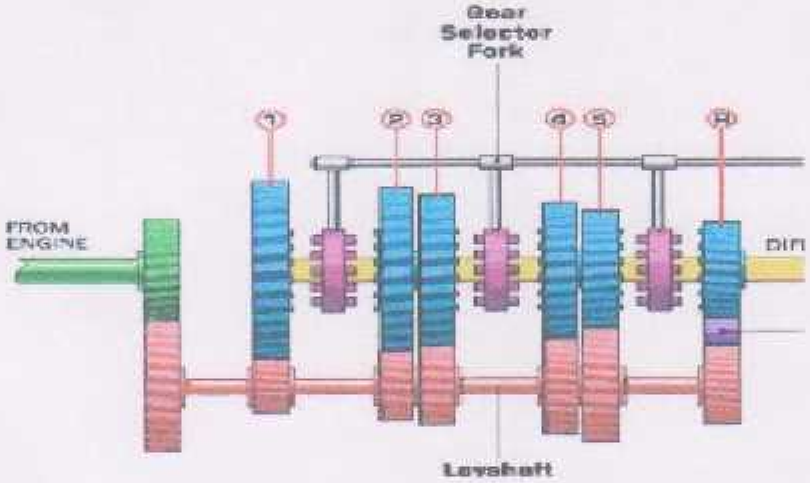


Figure 1.2 transmissions from engine through gears

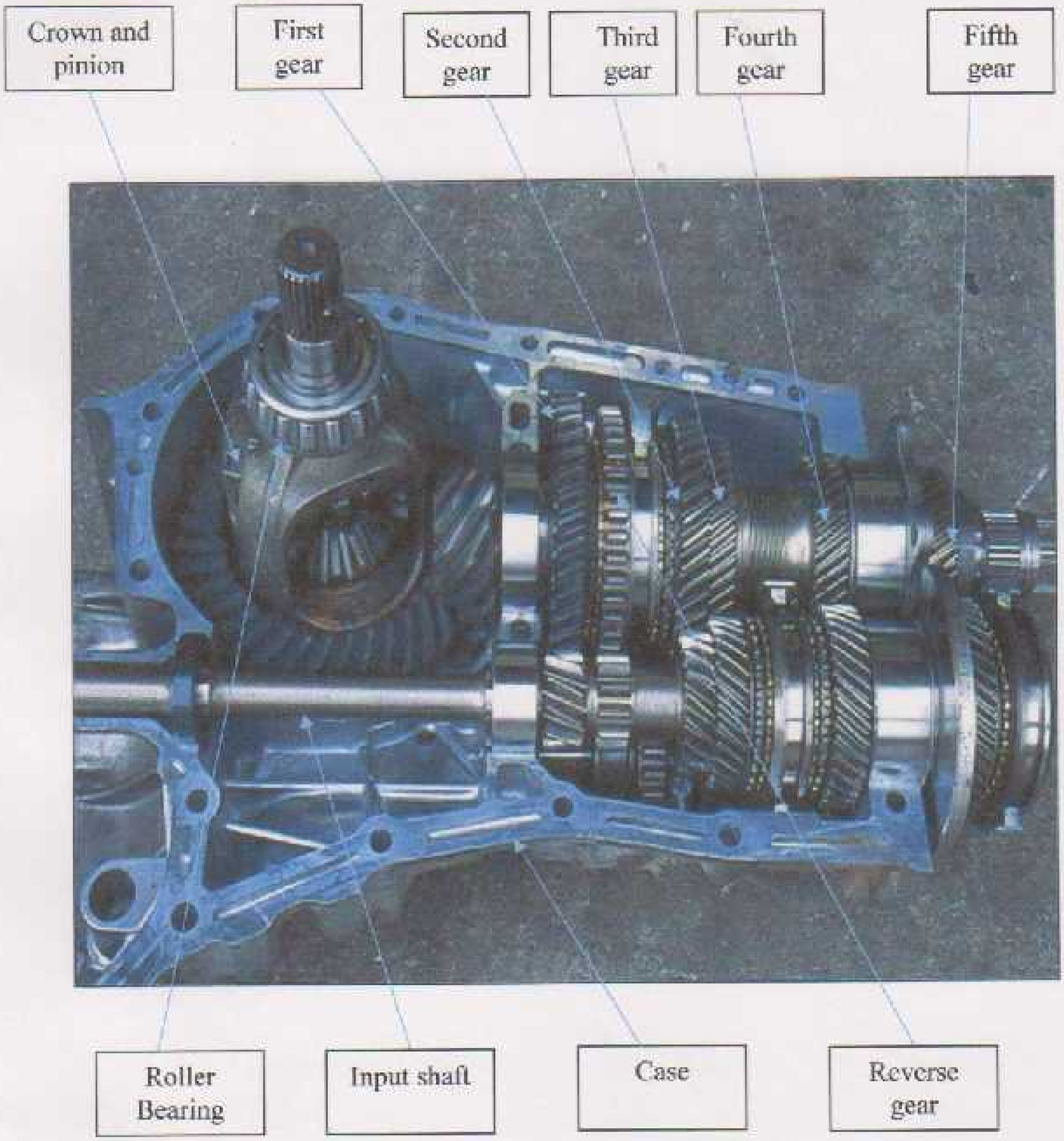


Figure 1.3 Subaru manual gear transmission

Chapter two: Gear transmission design

2.1 Terminology:

- Diametral pitch (d_p): The number of teeth per one inch of pitch circle diameter.
- Module. (m): The length, in mm, of the pitch circle diameter per tooth.
- Circular pitch (p): The distance between adjacent teeth measured along the at the pitch circle diameter.
- Addendum (h_a): The height of the tooth above the pitch circle diameter.
- Centre distance (a): The distance between the axes of two gears in mesh.
- Circular tooth thickness (ctt): The width of a tooth measured along the are at the pitch circle diameter.
- Dedendum (hf): The depth of the tooth below the pitch circle diameter.
- Outside diameter (D_o): The outside diameter of the gear.
- Base Circle diameter (D_b): The diameter on which the involutes teeth profile is based.
- Pitch circle diameter (p): The diameter of the pitch circle.
- Pitch point: The point at which the pitch circle diameters of two gears in mesh coincide.
- Pitch to back: The distance on a rack between the pitch circle diameter line and the rear face of the rack.
- Pressure angle: The angle between the tooth profile at the pitch circle diameter and a radial line passing through the same point.
- Whole depth: The total depth of the space between adjacent teeth.

2.2 Design Process:

To select gears from a stock gear catalogue or do a first approximation for a gear design select the gear material and obtain a safe working stress , e.g. Yield stress / Factor of Safety /Safe fatigue stress.

- Determine the input speed, output speed, ratio, torque to be transmitted

- Select materials for the gears (pinion is more highly loaded than gear)
- Determine safe working stresses (UTS /factor of safety or yield stress/factor of safety or Fatigue strength / Factor of safety)
- Determine Allowable endurance Stress Se
- Select a module value and determine the resulting geometry of the gear
- Use the Lewis formula and the endurance formula to establish the resulting face width
- If the gear proportions are reasonable then - proceed to more detailed evaluations
- If the resulting face width is excessive - change the module or material or both and start again

The gear face width should be selected in the range 9-15 x module or for straight spur gears-up to 60% of the pinion diameter.

The angular velocity ratio (speed ratio) is defined as:

$$MG = \left|\omega P/\omega g\right| = Ng/NP = dg/dp \tag{2.1}$$

The center distance is:

$$C.D = \left(dp + dg/2\right) = rp + rg \tag{2.2}$$

Increasing the center distance increase the pressure angle and also increase the pitch circle diameter.

2.3 Interference:

Interference will occur preventing rotation of bathe mating gears.

The smallest number of teeth on spur pinion which can drive a gear without interference is given by:

$$(Np)\min = \frac{2k}{(1+2m_G)\sin^2\phi}\left(m_G + \sqrt{m^2_G + (1+2m_G)\sin^2\phi}\right) \tag{2.3}$$

Where:

Ø: Pressure angle (in most cases Ø = 20 deg).

K = 1.0 for full depth teeth.

= 0.8 for stub teeth.

$$m_G = N_g / N_p \tag{2.4}$$

The largest spur gear with a specified pinion that is interference free is:

$$\left(N_g\right)_{max} = \frac{N^2{}_p \sin^2\phi - 4k^2}{4k - 2N_p \sin^2\phi} \tag{2.5}$$

For 13 tooth pinion with 20 degree pressure angle

$$\left(N_g\right)_{max} = \frac{(13)^2 \sin^2 20 - 4}{4 - 2(13)\sin^2 20} \tag{2.6}$$

$=16.45$

$= 16$ teeth

If the denominator of the above equation is zero

$$4k - 2N_p \sin^2\phi = 0 \tag{2.7}$$

Then:

$\left(N_g\right)_{max} = \infty$.

This means that the diameter of the gear is very large dg = ∞.

The smallest spur pinion that will operate with a rack without interference is given by

$$4k - 2N_p \sin^2\phi = 0 \rightarrow N_p = \frac{4k}{2\sin^2\phi} \tag{2.8}$$

For 20 deg, pressure angle full depth tooth, the smallest number of pinion teeth is:

$$\left(N_p\right)_{min} = \frac{4(1)}{2\sin^2 20} = 17.1 \quad = 18 \text{ teeth} \tag{2.9}$$

Table 2.1 Standard and commonly used tooth system for spur gear

Tooth system	Pressure angle (deg)	Addendum	Dedendum
Full depth	20	1/Pd or 1m	1.25 / Pd or 1 1.35 / Pd or 1
	$22.\frac{1}{2}$	1 / Pd or 1m	1.25 /Pd or 1 1.35 / Pd or 1
	25	1 / Pd or 1m	1.25 / Pd or 1 1.35 / Pd or 1
Sub	20	0.8 / Pd or 0.8 m	1 / Pd or 1

Table 2.2 Standard tooth proportion for helical gears

Quantity	Formula
Addendum	$\frac{1.00}{P_n}$
Dedendum	$\frac{1.25}{P_n}$
Pinion pitch diameter	$\frac{N_p}{P_n \cos\psi}$
Gear pitch diameter	$\frac{N_G}{P_n \cos\psi}$
Normal arc tooth thickness	$\frac{\pi}{P_n} - \frac{B_n}{2}$
Pinion base diameter	$d\cos\phi_t$
Gear base diameter	$D\cos\phi_t$
Base helix angle	$\tan^{-1}(\tan\psi an\psi c_t)$
External gear	
Standard center distance	$\frac{D+d}{2}$
Gear outside diameter	$D + 2d$
Pinion outside diameter	$d + 2a$
Gear root diameter	$D - 2b$
Pinion root diameter	$d - 2b$

2.4 Gear Tooth Failure Mechanisms:

The primary failure mechanisms for involute gear teeth are:

1) Excessive bending stresses at the base of the tooth.

2) Excessive bearing or contact stress at the point of contact.

The American Gear Manufacturers Association (AGMA) has developed standard methods for addressing both failure mechanisms.

2.5 AGMA Publications:

Standard 1010-95, Nomenclature of Gear Tooth Failure Modes, AGMA, Alexandria, VA, 1995.

Standard 6010-E88, Standard for Spur, Helical, Herringbone and Bevel Enclosed Drives, AGMA, Alexandria, VA, 1989.

Standard 2001-C95, Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth, AGMA, Alexandria, VA, 1994.

Standard 908-B89, Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth, AGMA, Alexandria, VA 1989.

2.6 Lewis Equation

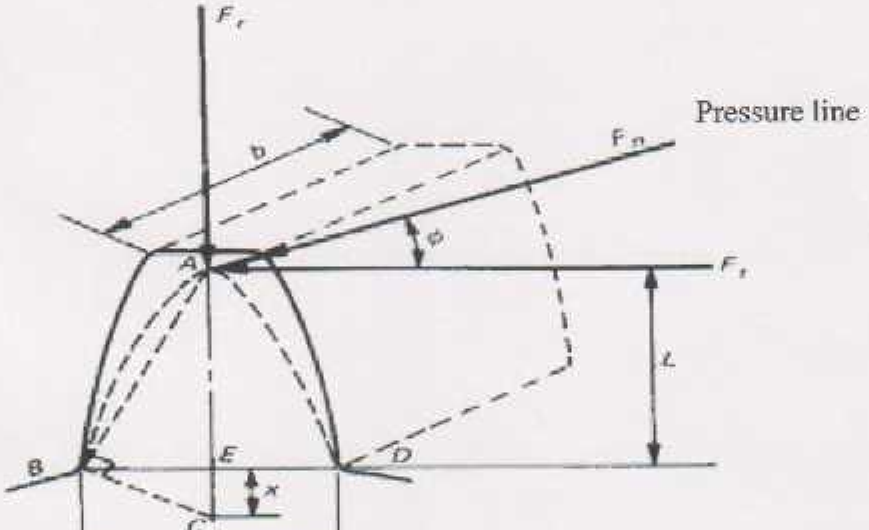


Figure 2.1 tooth profile.

$$\sigma = \frac{M}{I/c} \qquad (2.10)$$

$$M = W_t.L \qquad (2.11)$$

$$\frac{I}{c} = \frac{1}{12}bt^3 \qquad (2.12)$$

$$\frac{t}{2} = \frac{bt^2}{6} \qquad (2.13)$$

$$\sigma = \frac{6W_tL}{bt^2} \qquad (2.14)$$

$$\sigma = \frac{W_t}{b}\frac{1}{t^2/6L} = \left(\frac{W_t}{b}\right)\left(\frac{1}{t^2/4L}\right)\left(\frac{1}{4/6}\right) \qquad (2.15)$$

$$\frac{t/2}{x} = \frac{L}{t/2} \qquad (2.16)$$

$$x = \frac{t^2}{4L} \qquad (2.17)$$

$$\sigma = \left(\frac{W_t}{b}\right)\left(\frac{1}{x}\right)\left(\frac{1}{2/3}\right)\left(\frac{P}{P}\right) \qquad (2.18)$$

$$y = \frac{2x}{3P} \qquad \text{Lewis form factor} \qquad (2.19)$$

$$\sigma = \frac{W_t}{bpy} \qquad (2.20)$$

P= diametral pitch = π/p (2.21)

$Y=\pi y$ (2.22)

$$\sigma = \frac{W_tP}{FY} \qquad (2.23)$$

Table 2.3 values of the Lewis form factor Y:

Number of teeth	Y	Number of teeth	Y
12	0.245	28	0.353
13	0.261	30	0.359
14	0.277	34	0.371
15	0.290	38	0.384

16	0.296	43	0.397
17	0.303	50	0.409
18	0.309	60	0.422
19	0.314	75	0.435
20	0.322	100	0.447
21	0.328	150	0.460
22	0.331	300	0.472
24	0.337	400	0.480
26	0.346	Rack	0.485

Table 2.3 for the values of the Lewis form factor (this value for normal pressure angle of 20 degree, full depth teeth).

2.7 Dynamic effect:

When a pair of gears is driven at moderate or high speed and noise is generated it's certain that dynamic effect is present.

One of the earliest efforts to account for an increase in the load due to velocity employed a number of gears of the same size, material, and strength.

Several of these gears were tested to destruction by meshing and loading them at zero velocity.

Barth equation:

$$K_v = \frac{600+V}{600} \quad \text{(Cast iron, cast profile)} \tag{2.24}$$

$$K_v = \frac{1200+V}{1200} \quad \text{(Cut or milled profile)} \tag{2.25}$$

V: is the pitch line velocity in feet per minute

$$K_V = \frac{50+\sqrt{V}}{50} \tag{2.26}$$

$$K_V = \sqrt{\frac{78+\sqrt{V}}{78}} \tag{2.27}$$

In SI unit:

$$K_v = \frac{3.05 + V}{3.05} \quad \text{(Cast iron, cast profile)} \quad (2.28)$$

$$K_v = \frac{6.1 + V}{6.1} \quad \text{(Cut or milled profile)} \quad (2.29)$$

$$K_v = \frac{3.56 + \sqrt{V}}{3.56} \quad \text{(Hobbed or shaped profile)} \quad (2.30)$$

$$K_v = \sqrt{\frac{5.56 + \sqrt{V}}{5.56}} \quad \text{(Shaved or ground profile)} \quad (2.31)$$

Where V in (m/s)

$$\sigma = \frac{W_t P}{bY} \quad (2.32)$$

The metric version of this equation is :

$$\sigma = \frac{K_v W^t}{bmY} \quad (2.33)$$

Where the face width b and the module m are both in mm, expressing the tangential component of load in Newton's, then results in stress units of mega Pascal (Mpa).

As general rule, spur gears should have a face width b from 3 to 5 times the circular pitch.

2.8 Surface durability:

$$P_{max} = \frac{2F}{\pi bl} \quad (2.34)$$

Where:

P_{max} = largest surface pressure.

F= force pressing the two cylinder together.

l= length of cylinder.

b= face width, and we obtained from:

$$b = \left\{ \frac{2F}{\pi l} \frac{\left[\left(1 - v_1^2\right)/E_1\right] + \left[\left(1 - v_2^2\right)/E_2\right]}{\left(1/d_1\right) + \left(1/d_2\right)} \right\}^{1/2} \quad (2.35)$$

Where:

v1, v2, E1, and E2 are the elastic constant.

d1, d2 are the diameters of the pinion and gear.

The surface compressive stress is found from equation:

$$\sigma_c^{\,2} = \frac{W^t}{\pi F\cos\phi}\,\frac{(1/r_1)+(1/r_2)}{\left[\left(1-v_1^{\,2}\right)/E_1\right]+\left[\left(1-v_2^{\,2}\right)/E_2\right]} \tag{2.36}$$

Where:

r1, r2 are the instantaneous values of the radios of curvature on the pinion and gear tooth. Profile respectively at the point of contact and find as :

$$r_1 = \frac{d_p\sin\phi}{2} \quad , \quad r_2 = \frac{d_G\sin\phi}{2} \tag{2.37}$$

Where φ is the pressure angle and dp and d_G are the pitch diameters of the pinion and gear, respectively.

The elastic coefficient Cp:

$$C_p = \left[\frac{1}{\pi\left(\dfrac{1-v_p^{\,2}}{E_p}+\dfrac{1-v_G^{\,2}}{E_G}\right)}\right]^{1/2} \tag{2.38}$$

With this simplification and the addition of velocity factor Kv can be written

$$\sigma_c = -C_p\left[\frac{K_v W^t}{F\cos\phi}\left(\frac{1}{r_1}+\frac{1}{r_2}\right)\right]^{1/2} \tag{2.39}$$

2.9 The AGMA equations:

$$\sigma = \begin{cases} W^t K_v K_O K_s \dfrac{P_d}{F}\dfrac{K_m K_B}{J} \\ W^t K_o K_v K_s \dfrac{1}{bm_t}\dfrac{K_H K_B}{Y_J} \end{cases} \tag{2.40}$$

F : face width (b).

K_O : is the over load factor.

K_s : Size factor.

K_m: Load distribution factor.

K_v: Dynamic factor.

K_B : is the rim thickness factor.

J : Geometry factor for bending strength.

P_d : transverse Diametral Pitch : N /d.

d : Pitch Diameter.

W_t : Tangential transmitted Load.

mt: is the transverse metric module.

The fundamental equation for pitting resistance (contact stress) is:

$$\sigma_c = \begin{cases} C_P \sqrt{W^t K_o K_v K_s \dfrac{K_m}{d_p F} \dfrac{C_f}{I}} \\ Z_E \sqrt{W^t K_o K_v K_s \dfrac{K_H}{d_{w1} b} \dfrac{Z_R}{Z_I}} \end{cases} \text{(u. s customary units \& SI unit).} \qquad (2.41)$$

W_t : tangential transmitted load.

F : face width (b).

K_o : is the over load factor.

K_s : Size factor.

K_m : Load distribution factor.

K_v : Dynamic factor.

Cp (ZE): is an elastic coefficient $\sqrt{N/mm^2}$ $\sqrt{lbf/in^2}$.

C_f(ZR):is the surface condition factor.

d_p (dw1): is the pitch diameter of the pinion (mm).

I (ZI):is the geometry factor for pitting resistance.

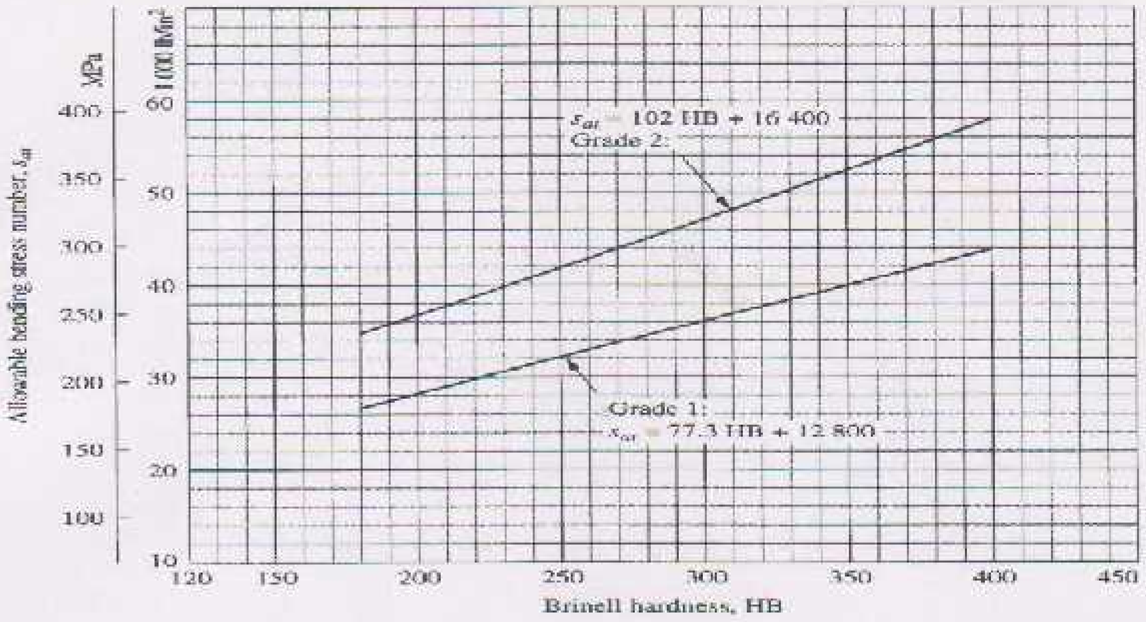


Figure 2.2 Allowable bending stress numbers for through hardened steels.

Grade 1: is the basic or standard material classification.

Grade 2: requires better than normal micro structure control.

2.9.1 Geometry Factor I and J:

The Lewis equation factor y is used to introduce the effect of tooth form into he stress equation.

The determination of the AGMA factors I and J depend upon the face contact ratio mF , this is defined as :

$$m_F = \frac{F}{P_X} \qquad (2.42)$$

Where:

P_x is the pitch and F is the face width.

(For spur gear mF = 0 & helical gear mF > 1).

2.9.2 Bending strength geometry factor J:

The AGMA factor J employs a modified value of the Lewis factor.

The fatigue stress concentration factor K_f, and tooth load sharing ratio m_N resulting equation for J is:

$$J = \frac{Y}{K_f m_N} \tag{2.43}$$

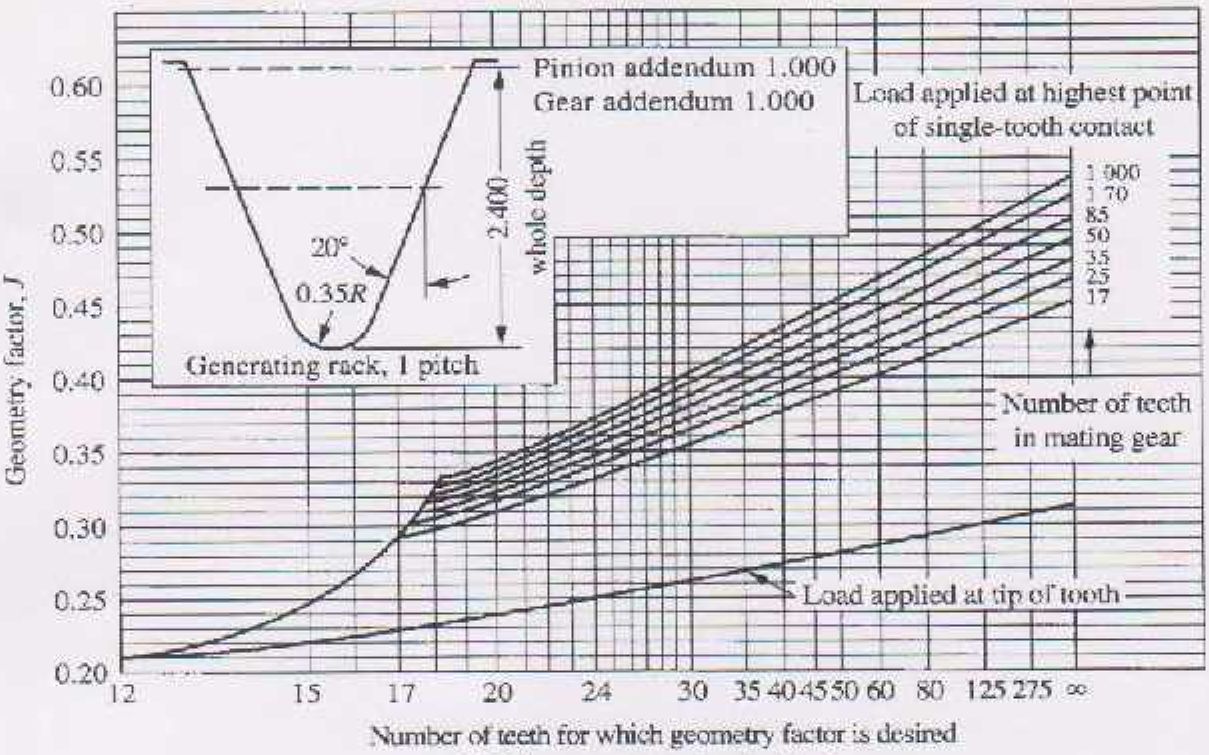
The factor of Y is not Lewis factor, the value of y obtained from generated layout of the tooth profile and is based on the highest point of single tooth contact.

The factor K_f is called the stress correction factor by AGMA its based on the formula deduced from photo elastic investigation of stress concentration in gear teeth over 50 years ago .

The load sharing ratio m_N is equal to the face width divided by the minimum total length of the lines of contact, this factor depend on:

- The transverse contact ratio mp.
- The face contact ratio m_F.
- The effect of any profile modification.
- The tooth deflection for spur gear $m_N = 1$.

The figure below used to obtain the geometry factor J for spur gears having a 20 degree pressure angle and full depth teeth.



(a) 20° spur gear: standard addendum

Figure 2.3 the geometry factor J.

2.9.3 Surface strength geometry factor I:

Is also called the pitting resistance geometry factor by AGMA

$$I = \begin{cases} \dfrac{\cos\phi_t \sin\phi_t}{2m_N} \dfrac{m_G}{m_G + 1} \leftrightarrow \text{external gear} \\ \dfrac{\cos\phi_t \sin\phi_t}{2m_N} \dfrac{m_G}{m_G - 1} \leftrightarrow \text{internal gear} \end{cases}$$

(2.44)

Where m_N=1 for spur gears.

$$d_P = \frac{N_P}{P_d} \quad (2.45)$$

Where:

d: is the pitch diameter.

N: is the number of teeth.

P: is the diametral pitch.

$$V = \frac{\pi d n}{12} \tag{2.46}$$

Where:

V: Pitch line velocity.

n: number of revolutions.

$$\sigma = \left\{ W^{t} K_{v} K_{O} K_{S} \frac{P_{d}}{F} \frac{K_{m} K_{B}}{J} \right\} \tag{2.47}$$

Where:

W^{t}: Tangential transmitted Load and found by:

$$W^{t} = \frac{33000H}{V} \tag{2.48}$$

2.9.4 Dynamic factor K_V:

$$K_{V} = \left(\frac{A + \sqrt{200V}}{A} \right)^{B} \tag{2.49}$$

$$A = 50 + 56(1 - B) \tag{2.50}$$

$$B = 0.25(12 - Q_{v})^{2/3} \tag{2.51}$$

Where Qv is the end point of the Qv curve.

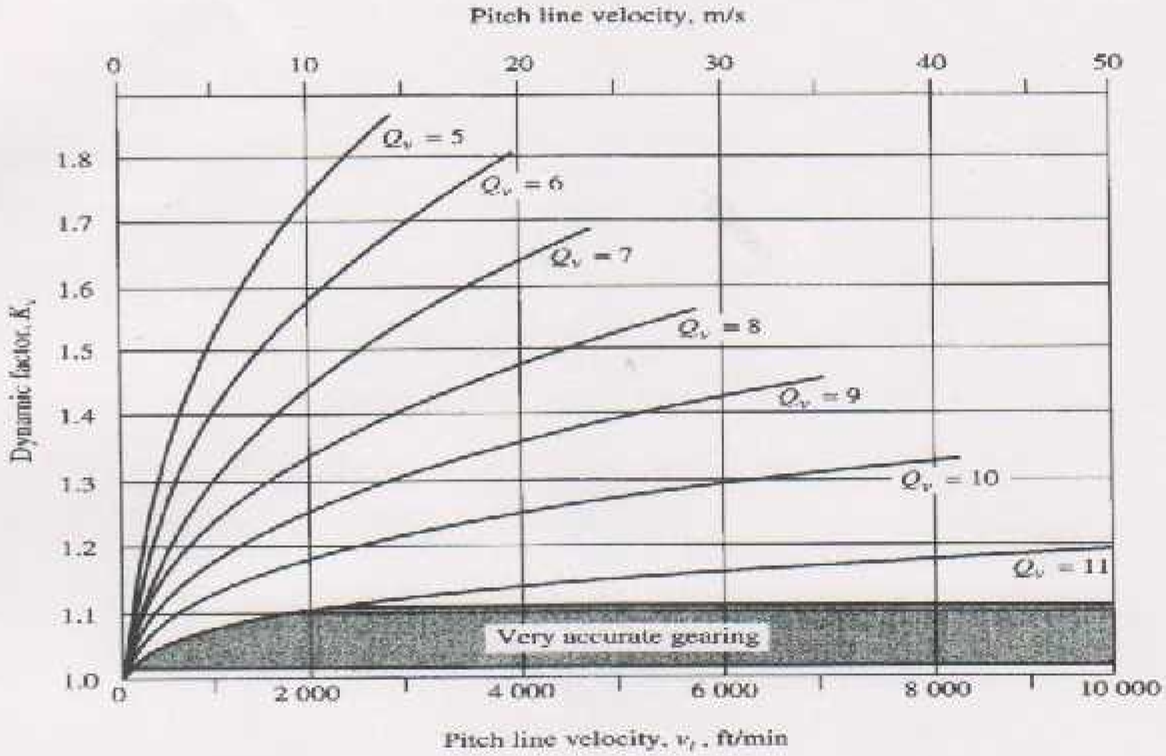


Figure 2.4 Q_v curve.

2.9.5 Over load factor Ko:

Table 2.4 Load factor value:

	Driven Machine		
Power source	Uniform	Moderate shock	Heavy shock
Uniform	1.00	1.25	1.75
Light shock	1.25	1.50	2.00
Medium shock	1.50	1.75	2.25

2.9.6 Size factor K_s:

Reflects non uniformity of material properties and equal (1).

It depends on:

- Tooth size.
- Diameter of part.
- Ratio of tooth size to diameter of part.
- Face width.
- Area of stress pattern.
- Ratio of case depth to tooth size.
- Harden ability and heat treatment.

2.9.7 Load distribution factor K_m:

$$Km = 1 + C_{mc}\left(C_{pf}C_{pm} + C_{ma}C_e\right) \tag{2.52}$$

Where:

$$C_{mc} = \begin{cases} 1 & \text{for uncrowned teeth} \\ 0.8 & \text{for crowned teeth} \end{cases} \tag{2.53}$$

$$C_{Pf} = \begin{cases} \dfrac{F}{10d} - 0.025 & F \le 1\text{ in} \\ \dfrac{F}{10d} - 0.0375 + 0.0125F & 1 \le F \le 17\text{ in} \\ \dfrac{F}{10d} - 0.1109 + 0.0207F - 0.000228F^2 & 17 \le F \le 40\text{ in} \end{cases} \tag{2.54}$$

$$C_{Pm} = \begin{cases} 1 & \text{for straddle mounted pinion with } \dfrac{S_1}{S_2} \le 0.175 \\ 1.1 & \text{for straddle mounted pinion with } \dfrac{S_1}{S_2} \ge 0.175 \end{cases} \tag{2.55}$$

$$C_{ma} = A + BF + CF^2 \tag{2.56}$$

Table 2.5 values of A, B and C can found from table below:

Condition	A	B	C
Open gearing	0.247	0.0167	$-0.765(10^{-4})$
Commercial, enclosed unit	0.127	0.0158	$-0.930(10^{-4})$
Precision ,enclosed unit	0.0675	0.0128	$-0.926(10^{-4})$
Extra precision enclosed gear ur	0.00360	0.0102	$-0.822(10^{-4})$

$$C_e = \begin{cases} 0.8 & \textit{for gearing adjusted at assembly or compatibility} \\ 1 & \textit{for all condition} \end{cases} \quad (2.57)$$

KB = is the rim thickness factor and found from:

$$K_B = \begin{cases} 1.6 \ln \dfrac{2.242}{m_B} & m_B \le 1.2 \\ 1 & m_B \ge 1.2 \end{cases} \quad (2.58)$$

2.9.8 AGMA bending endurance strength:

$$\sigma_{all} = \frac{S_t}{S_F} \frac{Y_N}{K_T K_R} \quad (2.59)$$

Where:

S_t : is the allowable bending stress (N/mm^2).

Y_N : is the stress cycle factor for bending stress.

K_T : is the temperature factor.

K_R : is the reliability factor.

S_F : is the AGMA factor of safety.

2.9.9 Bending factor of safety:

$$S_F = \frac{S_t Y_N / (K_T K_R)}{\sigma} \quad (2.60)$$

2.10 Bevel gear:

Fundamental contact stress equation:

$$\sigma_H = Z_E \left(\frac{1000 W^t}{b d Z_I} K_A K_V K_{H\beta} Z_x Z_{xc} \right)^{1/2} \quad (2.61)$$

We will use σ_H for contact stress to remain consistent with our notation.

Permissible contact stress number (strength) equation:

$$\sigma_{HP} = \frac{\sigma_{H\,time} Z_{NT} Z_W}{S_H K_\beta Zz} \quad (2.60)$$

2.11 Bending stress:

$$\sigma_F = \frac{1000W^t}{b} \frac{K_A K_v}{m_{et}} \frac{Y_x K_{H\beta}}{Y_\beta Y_J} \quad (2.61)$$

Permissible bending stress equation:

$$\sigma_{FP} = \frac{\sigma_{F\,time} Y_{NT}}{S_F k_0 Y_z} \quad (2.62)$$

2.12 AGMA equation factors:

2.12.1 Overload factor K_o (K_A):

The overload factors makes allowance for any externally applied loads in excess of the nominal transmitted load, the appendix gives the overload.

Table 2.6 overloads factors:

	Character of load on driven machine			
Character of prim mover	Uniform	Light shock	Medium shock	Heavy shock
Uniform	1.00	1.25	1.50	1.75 or higher
Light shock	1.10	1.35	1.60	1.85 or higher
Medium shock	1.25	1.50	1.75	2.00 or higher
Heavy shock	1.50	1.75	2.00	2.25 or higher

2.12.2 Dynamic factor K_v:

The dynamic factor makes allowance for the effect of gear-tooth quality related to speed load.

$$K_V = \left(\frac{A + \sqrt{200 v_{et}}}{A}\right)^B \quad (2.63)$$

$$A = 50 + 56(1 - B) \quad (2.64)$$

$$B = 0.25(12 - Q_U)^{2/3} \quad (2.65)$$

v_{et} : is the pitch line velocity at outside pitch diameter.

$$v_{et} = 5.236(10^{-5}) d_1 n_1 \quad (2.66)$$

The maximum pitch line velocity is associated from curve in figure 2.4

$$v_{te\max} = \frac{[A + (Q_v - 3)]^2}{200} \quad (2.67)$$

2.12.3 Size factor for pitting resistance $C_S(Z_X)$

$$Z_X = \begin{cases} 0.5 & b < 12.7\,\text{mm} \\ 0.00492\,b + 0.4375 & 12.7 \le b \le 114.3\,\text{mm} \\ 1 & b > 114.3\,\text{mm} \end{cases} \quad (2.68)$$

2.12.4 Size factor for bending Y_X

$$Y_X = \begin{cases} 0.5 & m_{et} < 1.6\,\text{mm} \\ 0.4867 + 0.008339\,m_{et} & 1.6 \le m_{et} \le 50\,\text{mm} \end{cases} \quad (2.69)$$

2.12.5 Load distribution factor $K_{H\beta}$

$$K_{H\beta} = K_{mb} + 5.6(10^{-6})b^2 \tag{2.70}$$

Where:

$$K_{mb} = \begin{cases} 1.00 & \text{both member straddle - mounted} \\ 1.10 & \text{one member straddle - mounted} \\ 1.25 & \text{niether member straddle - mounted} \end{cases} \tag{2.71}$$

2.12.6 Crowning factor for pitting C_{XC}

The teeth of most bevel gears are crowned in the lengthwise direction during manufacture to accommodate to the deflection of the mountings.

$$C_{XC} = \begin{cases} 1.5 & \text{properly crowned teeth} \\ 2.0 & \text{or larger uncrowned teeth} \end{cases} \tag{2.72}$$

2.12.7 The lengthwise curvature factor for bending strength $K_X = 1$

$$K_x = Y_\beta = 1 \tag{2.73}$$

2.12.8 Stress cycle factor for pitting resistance Z_{NT}

$$Z_{NT} = \begin{cases} 2 & 10^3 \le n_L < 10^4 \\ 3.4822\, n_L^{-0.0602} & 10^4 \le n_L < 10^{10} \end{cases} \tag{2.74}$$

2.12.9 Stress cycle factor for bending strength Y_{NT}

$$Y_{NT} = \begin{cases} 2.7 & 10^2 \le n_L \le 10^3 & \\ 6.1514 n_L^{-0.1182} & 10^3 \le n_L \le 3(10^6) & \\ 1.6831 n_L^{-0.0323} & 3(10^6) \le n_L \le 10^{10} & \textit{general} \\ 1.3558 n_L^{-0.0323} & 3(10^6) \le n_L \le 10^{10} & \textit{critical} \end{cases} \tag{2.75}$$

2.12.10 Hardness ratio factor C_H

$$Z_W = 1 + B_1(z_2 / z_2 - 1) \quad , \quad B_1 = 0.00898(H_{B1} / H_{B2}) - 0.00829 \tag{2.76}$$

The C_H factor varies with pinion surface rougher f_P and the mating gear hardness:

$$Z_W = 1 + B_2(450 - H_{B2}) \quad , \quad B_2 = 0.00075\exp(-0.0122 f_P \tag{2.77}$$

Where:

f_P = pinion surface hardness µin.

H_{B2} = minimum Brinell hardness.

2.12.11 Temperature factor K_θ

$$K_\theta = \begin{cases} 1 & 0°C \le \theta < 120°C \\ (273 + \theta)/393 & \theta > 120°C \end{cases} \tag{2.78}$$

2.12.12 Reliability factor C_R and K_R

$$K_R = \begin{cases} 0.50 - 0.25\log(1 - R) & 0.99 \le R < 0.999 \\ 0.70 - 0.15\log(1 - R) & 0.90 \le R < 0.99 \end{cases} \tag{2.79}$$

And the reliability of stress (fatigue) number allowable can be obtained from the table below.

Table 2.7 Reliability factors

Requirements of application	Reliability factors for steel	
	C_R	K_R
Fewer than failure in 10000	1.22	1.50
Fewer than failure in 1000	1.12	1.25
Fewer than failure in 100	1.00	1.00
Fewer than failure in 10	0.2	0.85
Fewer than failure in 2	0.84	0.70

Fewer than failure in 100	1.00	1.00
Fewer than failure in 10	0.2	0.85
Fewer than failure in 2	0.84	0.70

2.12.13 Elastic coefficient for pitting resistance Z_E

$$Z_E = \sqrt{\frac{1}{\pi\left[(1-\nu_1^2)/E_1 + (1-\nu_2^2)/E_2\right]}} \tag{2.80}$$

Where:

Z_E =elastic coefficient, $190\sqrt{N/mm^2}$ for steel.

E_1 and E_2 = young's modulus for pinion and gear respectively, N/mm^2.

2.13 Rolling Contact Bearings

Rolling contact bearings are used to minimize the friction associated with relative motion performed under load.

Bearing Nomenclature:

2.14 Bearing Life

When the ball or roller of rolling-contact bearings rolls, contact stresses occur on the inner ring, the rolling element, and on the outer ring.

If a bearing is clean and properly lubricated, is mounted and sealed against the entrance of dust and dirt, is maintained in this condition, and is operated at reasonable temperatures, then metal fatigue will be the only cause of failure.

Under ideal conditions, the fatigue failure consists of spalling of the load-carrying surfaces.

The ABMA (American Bearing Manufactures Association) standard states that the failure criterion is the first evidence of fatigue.

Bearings of the same type, size, and material will exhibit wide variations in life.

Life: Number of revolutions (or hours of operation at design speed) of the inner ring (outer ring is stationary) that a certain percentage of the bearings will survive at a known load.

L_{10} Life: Number of revolutions (or hours at constant speed) that 10% of the bearings tested fail. (i.e., 90% will survive). This corresponds to 90% reliability

Median Life: Number of revolutions (or hours at constant speed) that 50% of the bearings tested fail. (i.e., 50% will survive). This corresponds to 50% reliability.

2.15 Statistical Nature of Life (Load/Life relationship)

Testing identical bearings at different radial loads:

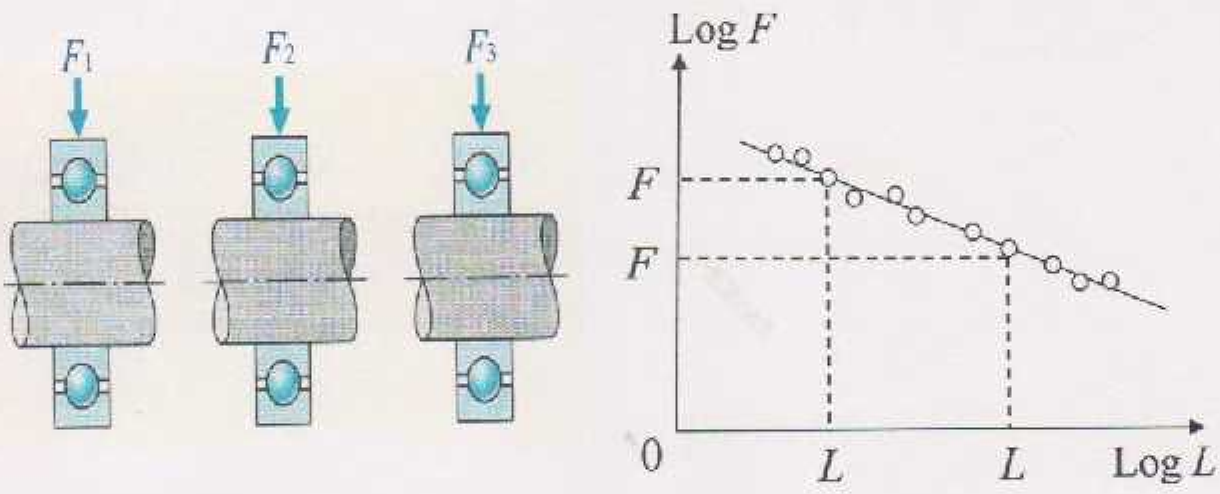


Figure 2.6 Typical bearing load-life log-log curves

$$a = \begin{cases} 3 \text{ for ball bearing} \\ 3.33 \text{ for roller bearing} \end{cases} \tag{2.81}$$

$$\left[\frac{L_2}{L_1}\right] = \left[\frac{F_1}{F_2}\right]^a \tag{2.82}$$

2.16 Rated Load/Life Relationship

From the equation:

$$\left[\frac{L_{10}}{L_D}\right] = \left[\frac{F_D}{C_{10}}\right]^a \tag{2.83}$$

$$C_{10} = \left[\frac{L_D}{L_{10}}\right]^{1/a} \times F_D \tag{2.84}$$

F_D = Desired radial load (lbf or KN).

C_{10} = Catalog rating; to be calculated from equation (2.79).

L_D = Desired Life (revolutions).

L_{10}= 106 revolutions (based on 90% reliability).

Loads are often nonsteady, so that the desired load is multiplied by an application factor a_f. The steady load af F_D does the same damage as the variable load F_D does to the rolling surfaces. Therefore, replace F_D by af F_D when calculating the bearing rating using equation (2.79) this is necessary for safety.

Table 2.8 load application factors.

Type of application	Load factor
Precision gearing	1.0 – 1.1
Commercial gearing	1.1 – 1.3
Applications with poor bearing seals	1.2
Machinery with no impact	1.0 – 1.2
Machinery with light impact	1.2 – 1.5
Machinery with moderate impact	1.5 – 3.0

2.17 Bearing Selection procedure:

For ball or roller bearings subjected to radial load only with 90% reliability:

- Find the radial load on the bearing (F_D)
- Assume the desired life (L_D). This is our decision.
- Calculate the catalog rating C_{10} from equation (2.79)
- Check the bearing catalog and select the suitable bearing according to the dimension requirement and the required rating C_{10} calculated in the previous step.
- Also if the radial load and the bearing rating are known, then we can predict the life of the bearing using equation (2.79) which can be rewritten as:

$$L_D = \left[\frac{C_{10}}{F_D}\right]^a \times L_{10} \qquad (2.85)$$

Life measure may be in revolutions or in hours such that:

$$L_{10} = L_R \times N_R \times 60 \tag{2.86}$$

$$L_D = L_{Dh} \times N_D \times 60 \tag{2.87}$$

Where:

L_{10} : Rating life (revolutions).

L_R : Rating life (hours).

n_R : Rating speed (rev/min).

L_D : Desired life (revolutions).

L_{Dh} : Desired life (hours).

n_D : Desired speed (rev/min).

the equation 2.79 can be rewritten as :

$$C_{10} = \left(\frac{L_D n_D 60}{L_R n_R 60}\right)^{\frac{1}{a}} \times F_D \tag{2.88}$$

Shafts generally have two bearings (A and B)

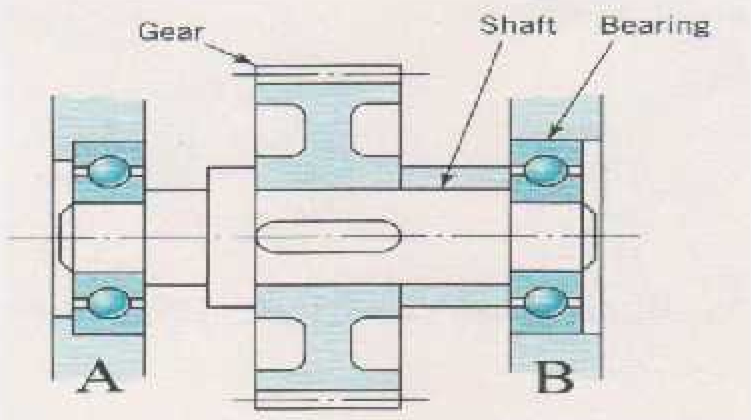


Figure 2.7 Reliability of the bearing pair on the shaft

The reliability of the bearing pair on the shaft *R* is:

$R=R_A R_B$

(2.89)

In sizing bearings, one can begin by making:

$$R_A = R_B \rightarrow R_A = R_B^2 \qquad (2.90)$$

Here R is given or assumed. Now R_A can be inserted in equation (2.81) to compute the catalog rating of the required bearing

$$C_{10} = F_D\left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}}\right]^{1/a} \qquad (2.91)$$

Where:

RD : Desired Reliability.

x0, θ, b are Weibull parameters:

x0 : minimum value of the variate (use x0=0.02).

θ : Characteristic parameter corresponding to 63.2% value of the variate (use θ =4.459).

b : shape parameters (use b=1.483).

Where the life ratio:

$$x_D = \frac{L_D}{L_{10}} \qquad (2.92)$$

2.18 General Selection Procedure of Ball and Cylindrical Roller Bearings:

Case1: No thrust loading

1. Compute *Fx* and *Fy* by applying static equilibrium equations to the shaft supported by the bearing.

2. Find the resultant radial load.

$$F_r = \sqrt{F_x^2 + F_y^2} \tag{2.93}$$

$$F_D = a_f F_r \tag{2.94}$$

3. Assume the desired life (L_D) and Reliability (R_D)

$$x_D = \frac{L_D}{L_{10}} = \frac{L_D}{10^6} \tag{2.95}$$

4. Calculate the required catalog rating:

$$C_{10} = F_D\left[\frac{x_D}{x_D + (\theta - x_0)(1 - R_D)^{1/b}}\right]^{1/a} \tag{2.96}$$

5. Check the catalog and select a suitable bearing.

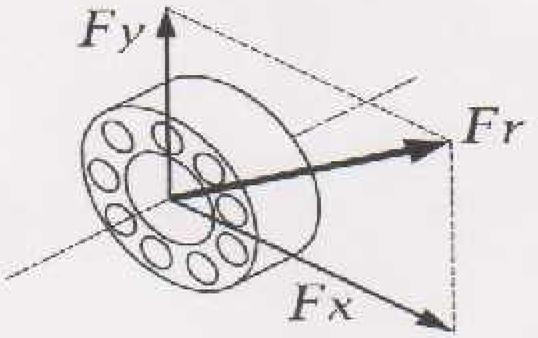


Figure 2.7 Radial and thrust load

Case2: Radial and thrust loading

1. Compute F_x and F_y and F_a by applying static equilibrium equations to the shaft supported by the bearing. And calculate:

$F_a/VF\gamma$ (2.97)

2. Find the resultant radial load.

$$F_r = \sqrt{F_x^2 + F_y^2} \tag{2.98}$$

3. Assume the desired life (L_D) and Reliability (R_D)

$$x_D = \frac{L_D}{L_{10}} = \frac{L_D}{10^6} \tag{2.99}$$

4. Start with assumed Fe (set the initial trial: $Fe = Fr$).

5. Compute $C10$ using..

$$C_{10} = F_e \left[\frac{x_D}{x_O + (\theta - x_O)(\ln 1/R_D)^{1/b}} \right]^{1/a} \tag{2.100}$$

6. From table below, select a standard $C10$ and $C0$ according to the result of Step 5. (Name them C_{10}^* and C_0^*).

Bore (mm)	OD (mm)	Width (mm)	Radius (mm)	Diameter(mm)		Deep groove		Angular contact	
				d_S	d_H	C_{10}	C_0	C_{10}	C_0
10	30	9	0.6	12.5	27	5.07	2.24	4.94	2.12
12	32	10	0.6	14.5	28	6.8	3.10	7.02	3.05
15	35	11	0.6	17.5	31	7.80	3.55	8.06	3.65
17	40	12	0.6	19.5	34	9.56	4.50	9.96	4.75
20	47	14	1.0	25	41	12.7	6.20	13.3	6.55
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0
35	72	17	1.0	41	65	25.5	13.7	27.0	15.0
40	80	18	1.0	46	72	30.7	16.6	31.9	18.6
45	85	19	1.0	52	77	33.2	18.6	35.9	21.2
50	90	20	1.0	56	82	35.1	19.6	37.7	22.8
55	100	21	1.5	63	90	43.6	25.0	46.2	28.5
60	110	22	1.5	70	99	47.5	28.0	55.9	35.5
65	120	23	1.5	74	109	55.9	34.0	63.7	41.5
70	125	24	1.5	79	114	61.8	37.5	68.9	45.5
75	130	25	1.5	86	119	66.3	40.5	71.5	49.0

80	140	26	2.0	93	127	70.2	45.0	80.6	55.0
85	150	28	2.0	99	136	83.2	53.0	90.4	63.0
90	160	30	2.0	104	146	95.6	62.0	106	73.5

7. Check your selection: Find *Fa/C0** then, from table, read *e* and read *X2*, *Y2* $(\text{if } F_a/VF_r \le e)$

or read X1, Y1 $(\text{if } F_a/VF_r > e)$

8. Compute *Fe* using equation (2.)

$$F_e = \begin{cases} X_1 VF_r + Y_1 F_a & \text{for } \dfrac{F_a}{VF_r} \le e \\ X_2 VF_r + Y_2 F_a & \text{for } \dfrac{F_a}{VF_r} > e \end{cases} \qquad (2.101)$$

9. Recalculate C_{10} (as expressed in step 5) based on the new value of *Fe* obtained in step 8.

10. If $C_{10} > C_{10}^*$, go to step 6; select higher C_{10} and *C0* and continue…

If $C1_0 \le C_{10}^*$ (such that C_{10} is close to C_{10}^*), stop and print the values of C_{10} and C_0.

Chapter three: designs and analysis

3.1 Introduction:

In this chapter the first principal model of each part of the transmission will be simulated using ANSYS program to ensure that each part with stand circumstances and load applied in each process also stresses diagram will be plotted to more than path for every part to show regions of risks and stresses intensities.

The criteria of analysis are different for each part with respect to the load applied and the conditions of operating for it. The major criterion in the analysis that will be done for each part is Von Misses criterion. Von Misses is used to estimate yield criteria of ductile materials it's calculated by combining stresses in two or three dimensions. With the result compared to the tensile strength of the material loaded in one dimension. Von Misses stresses is also useful for calculating the fatigue strength. Von Misses criterion states that the failure occur when the energy of distortion reach the same energy for yield/failure in the uniaxial tension.

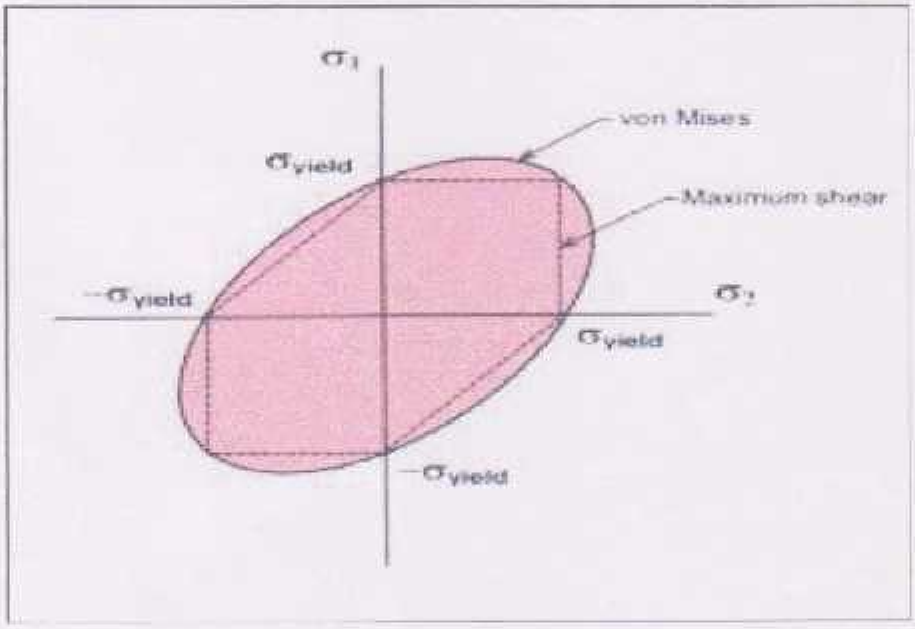


Figure 3.1 Von Misses stresses

Mathematically this is expressed as:

$$0.5[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]\leq\sigma_y^2 \qquad (3.1)$$

Where σ_1, σ_2, σ_3 are the principal stresses, σ_y is the yield strength.
Notice that which had been used in the analysis are mm for length, second for time, Newton for force, N/mm^2,(Mpa) for pressure, Celsius for temperature. Also in ANSYS figures the red color refers to tension and the blue refers to compression.

3.2 First principle model of each part :

the first principal model of each part which had been designed by CATIA and SolidWorks programs is as the following :
this figure below shows the manual gear transmission

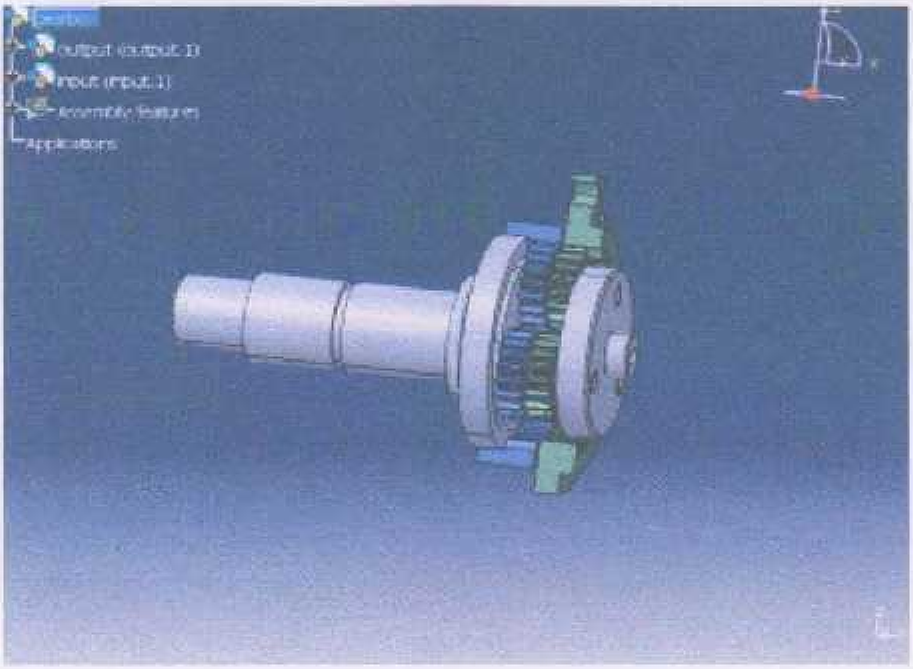


Figure 3.2 gear assembly

This designed gear consists of five forward gears and one reverse , each of them appears below:

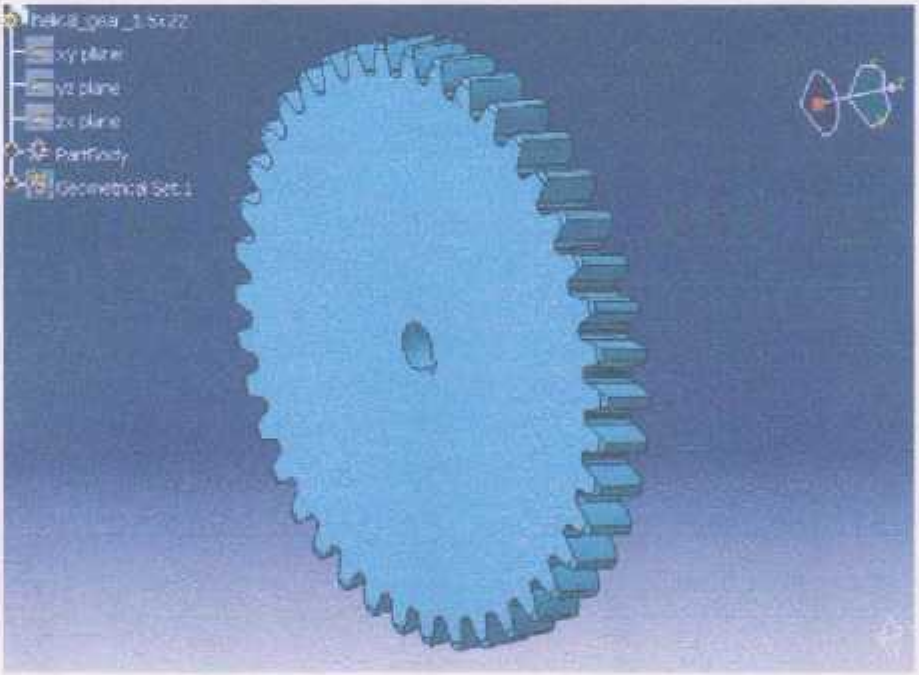


Figure 3.3 first gear

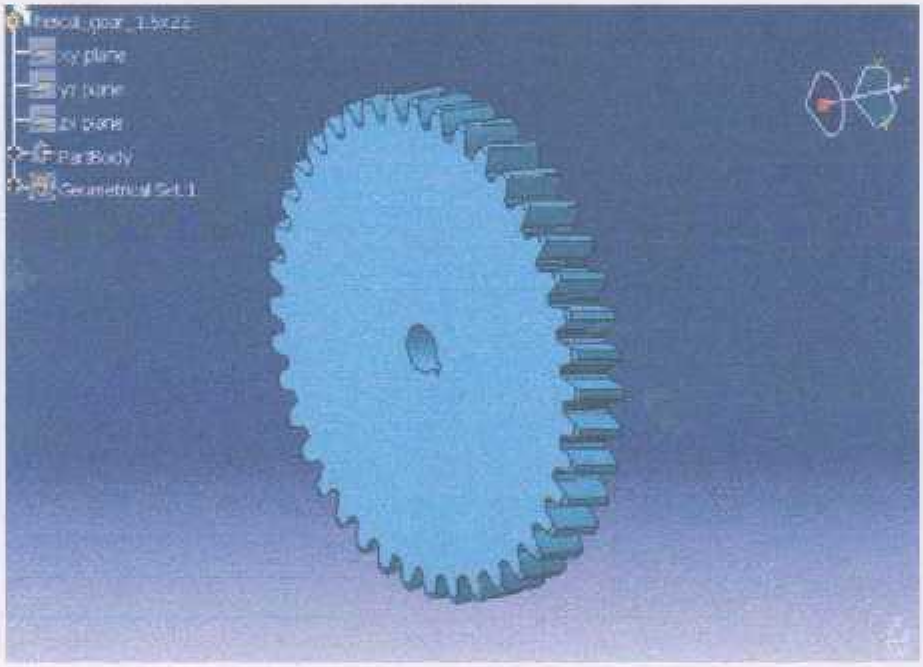


Figure 3.4 second gear

Figure 3.5 third gear

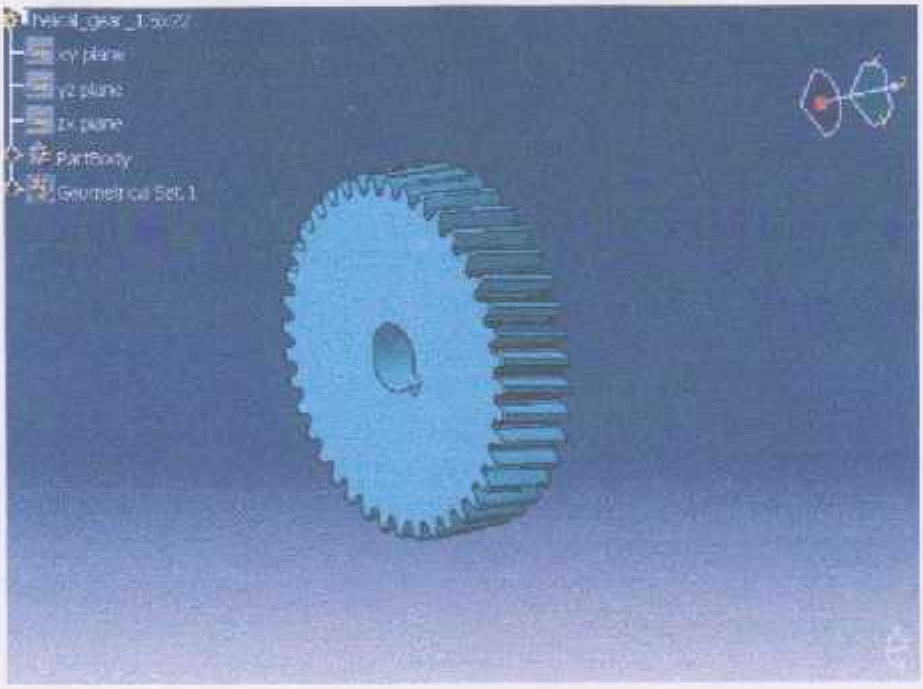


Figure 3.6 fourth gear

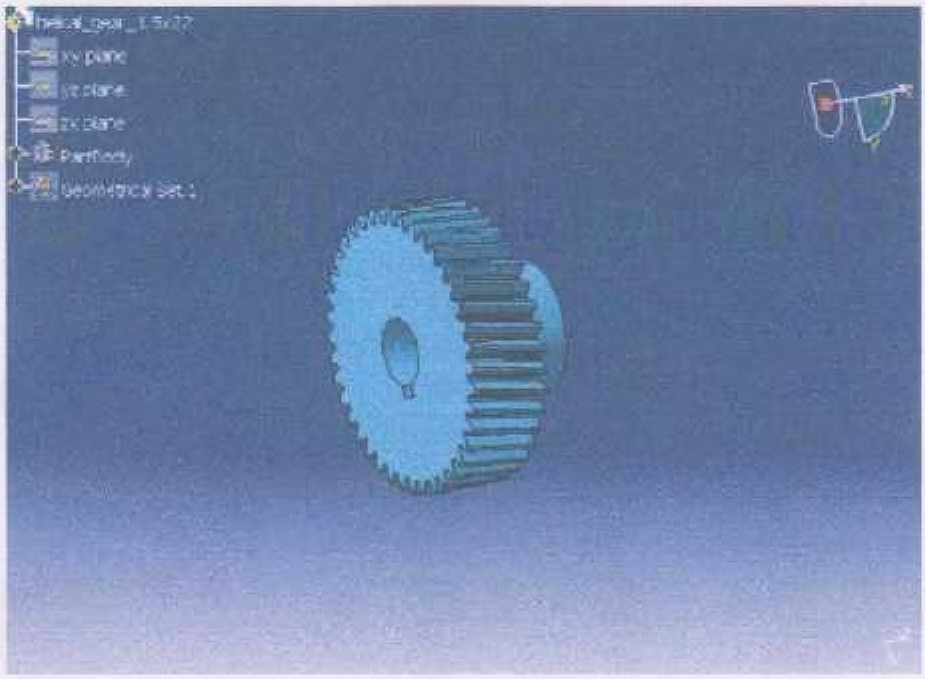


Figure 3.7 fifth gear

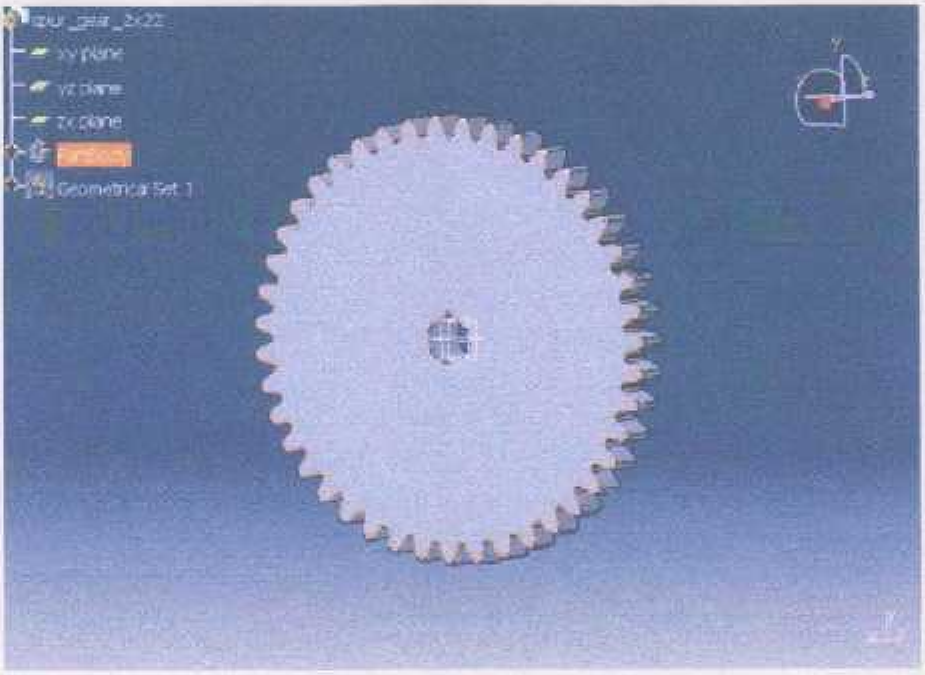


Figure 3.8 reverse gear

And here in the figures below bevel type gear for pinion and crown gears which had been designed by Solid Works.

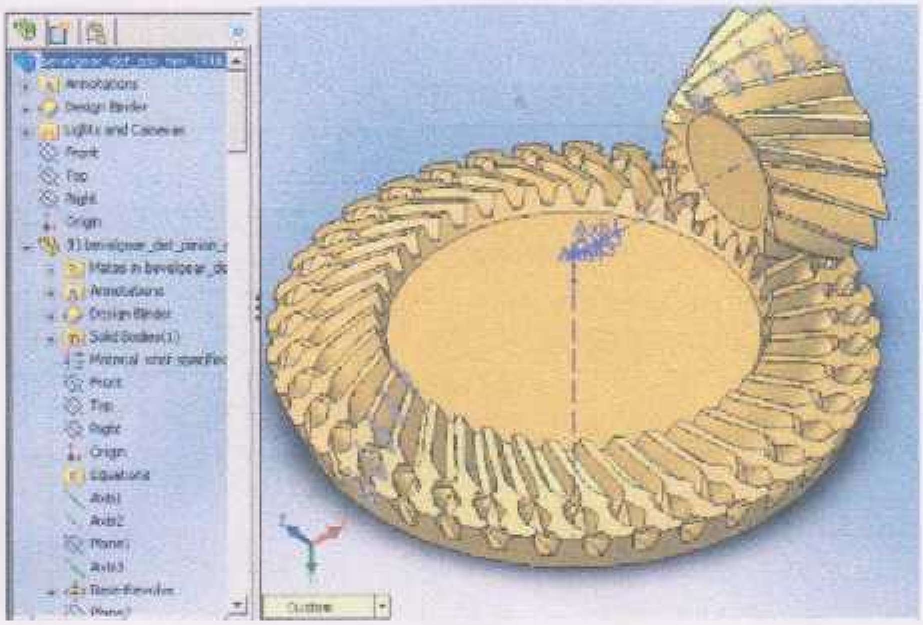


Figure 3.9.a pinion and crown

The second figure here shows when sense command is used to determine the type of the material used .

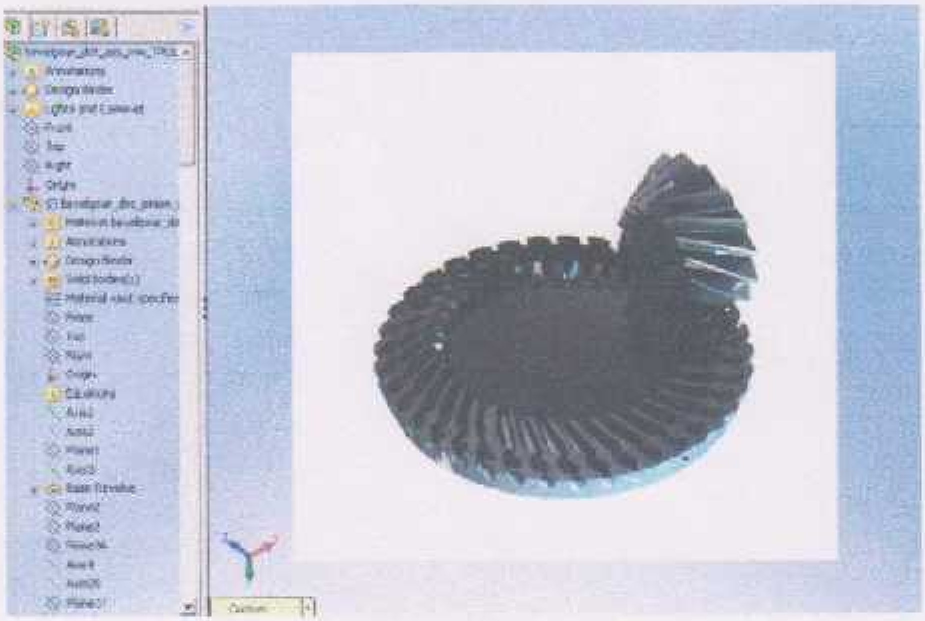


Figure 3.9.b pinion and crown

And the rolling bearing type appears in the figure below:

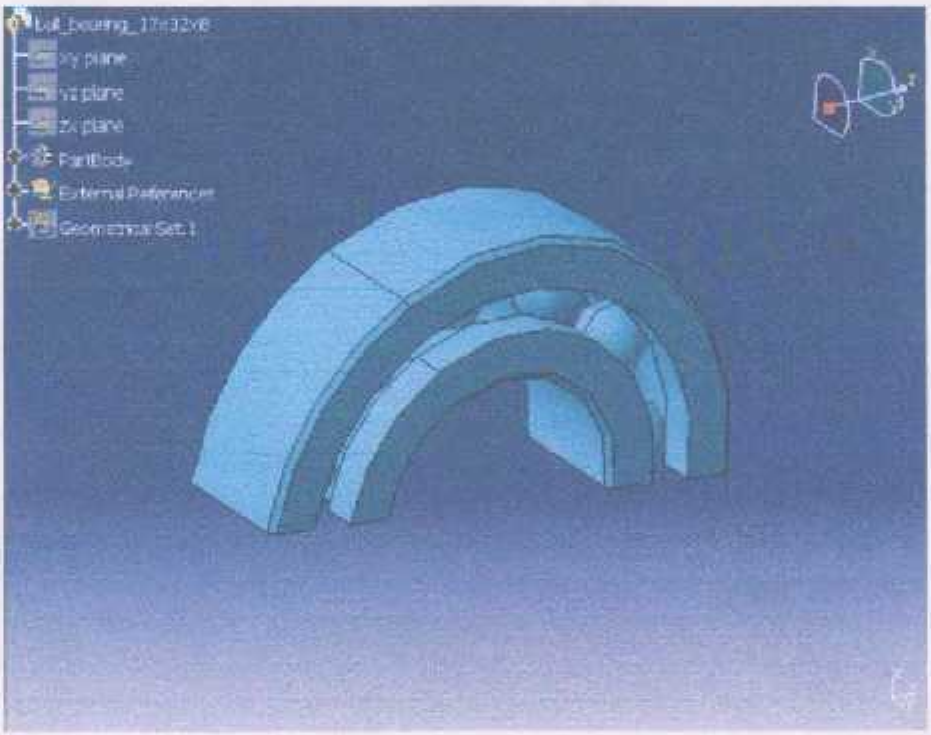


Figure 3.10 rolling bearing

3.3 Analysis

The properties of the alloy structural steel which is used for this design is as follows:

Density=7870 Kg/m^3.

σ_Y=1350MPa.

σ_T=1570 MPa.

Passions ratio=0.3.

Young modulus of elasticity=206 Gpa.

3.3.1 Stress analysis first part

The analysis include: Von-Misses stress, X- component, Y- component, Z-component, stress intensity, XY shear, XZ shear and YZ shear. After the analyses of the first models of the helical gear on ANSYS program the following results had been got.

- **Von-Misses stress**

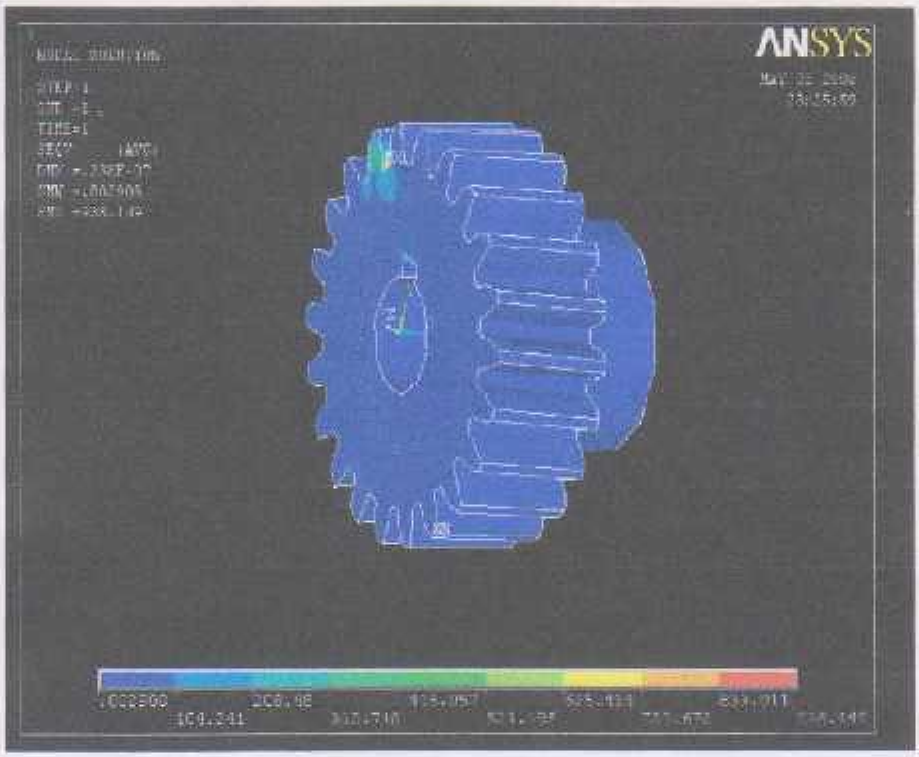


Figure 3.11 Von-Misses stress helical gear

As the previous result shows; it has been noticed that the Von-misses stress is 9٣٨.١٤٩ MPa and it is lower than the yield strength of alloy structural steel which equals 1350 MPa. Further more the maximum deflection in the gear is 0.2٨٣(10^{-7}) mm; which means that the gear can withstand this load safely.

- **X-component.**

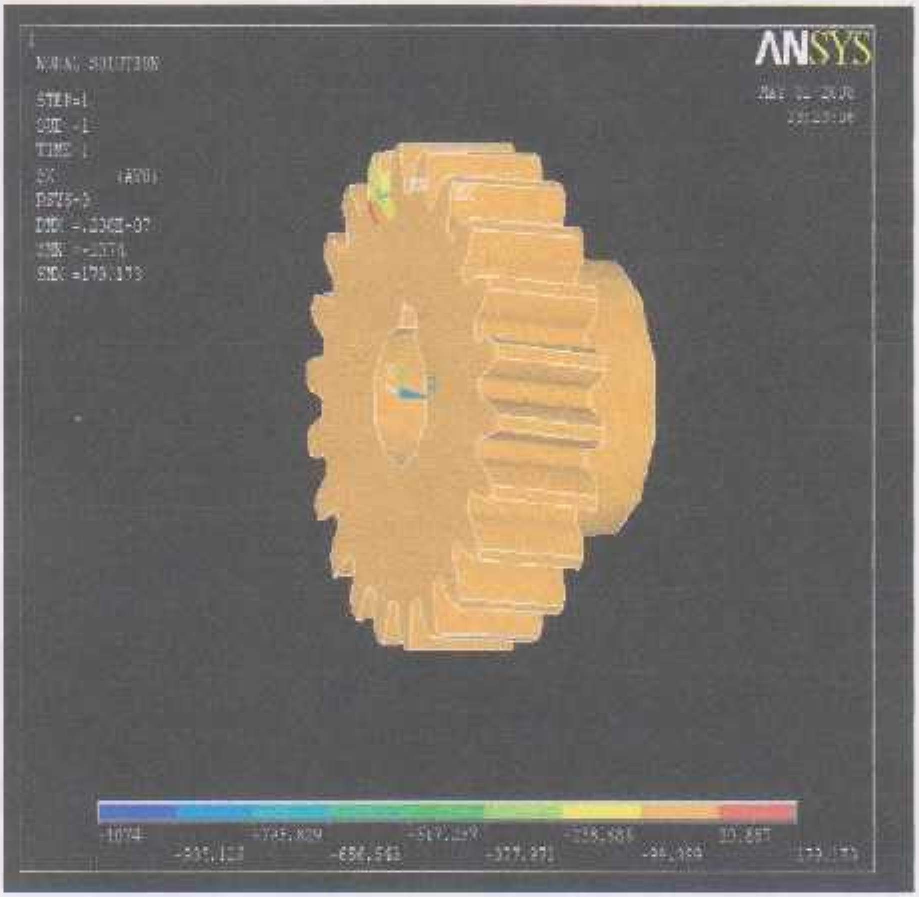


Figure 3.12 X-component of stress of the helical gear

- **Y-component**

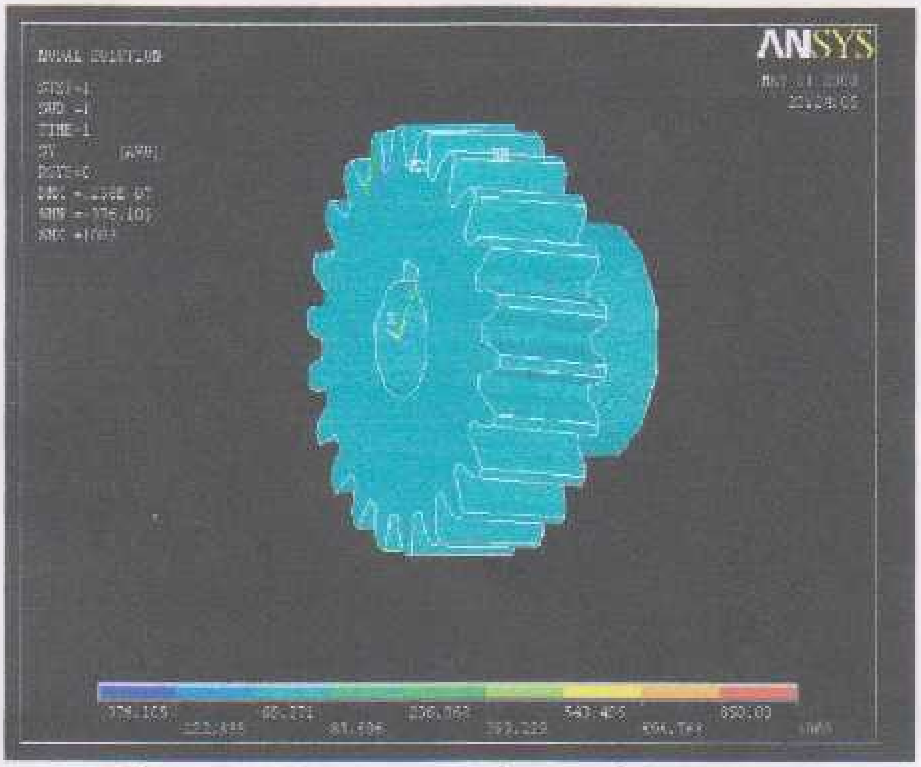


Figure 3.13 Y-component of stress of the helical gear

- **Z-component**

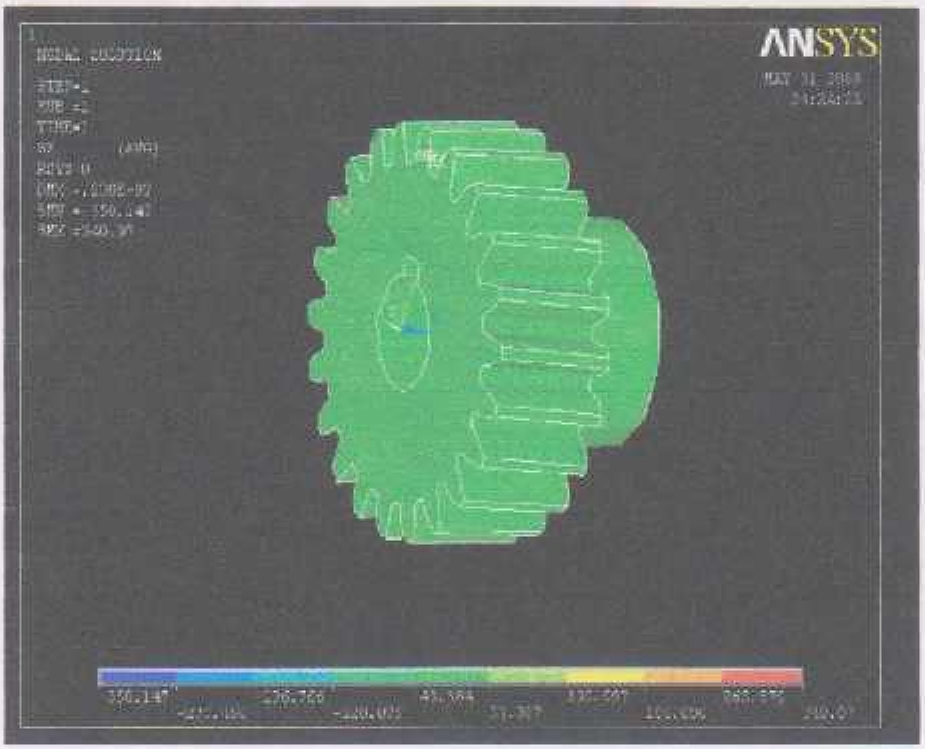


Figure 3.14 Z-component of stress of the helical gear

The previous three figures show the distribution of stress in X, Y, and Z-axis; it shows that the variations of stress in Y, Z axis are more tan X-axis.

- **Stress intensity**

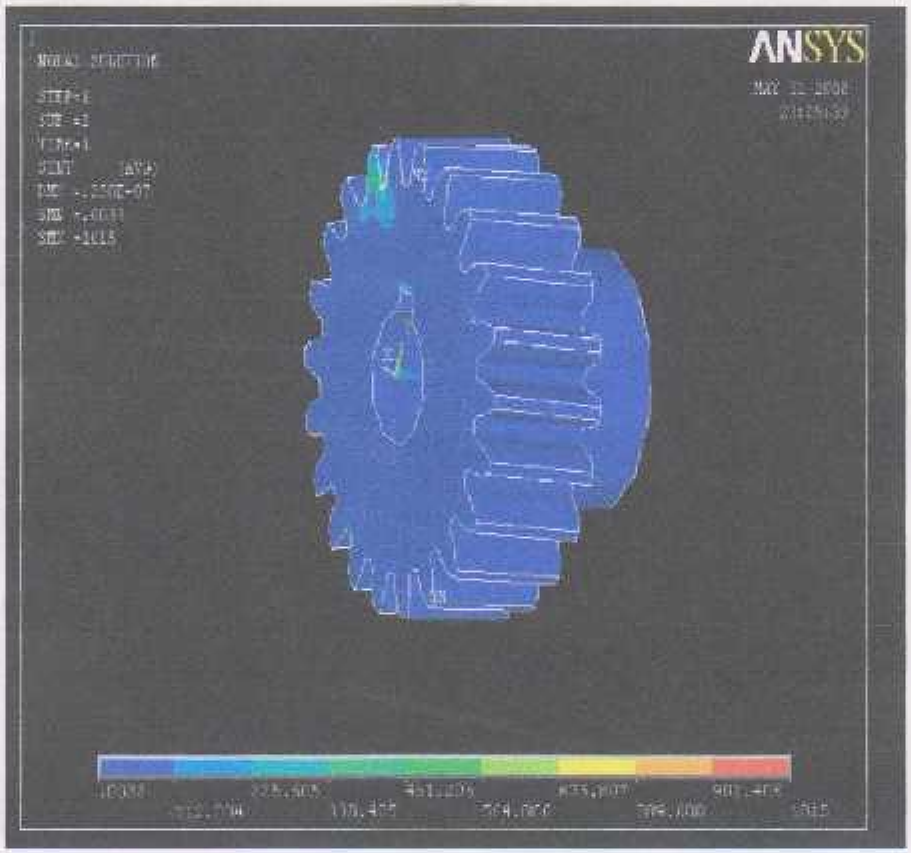


Figure 3.15 stress intensity of the helical gear

• **XY shear**:

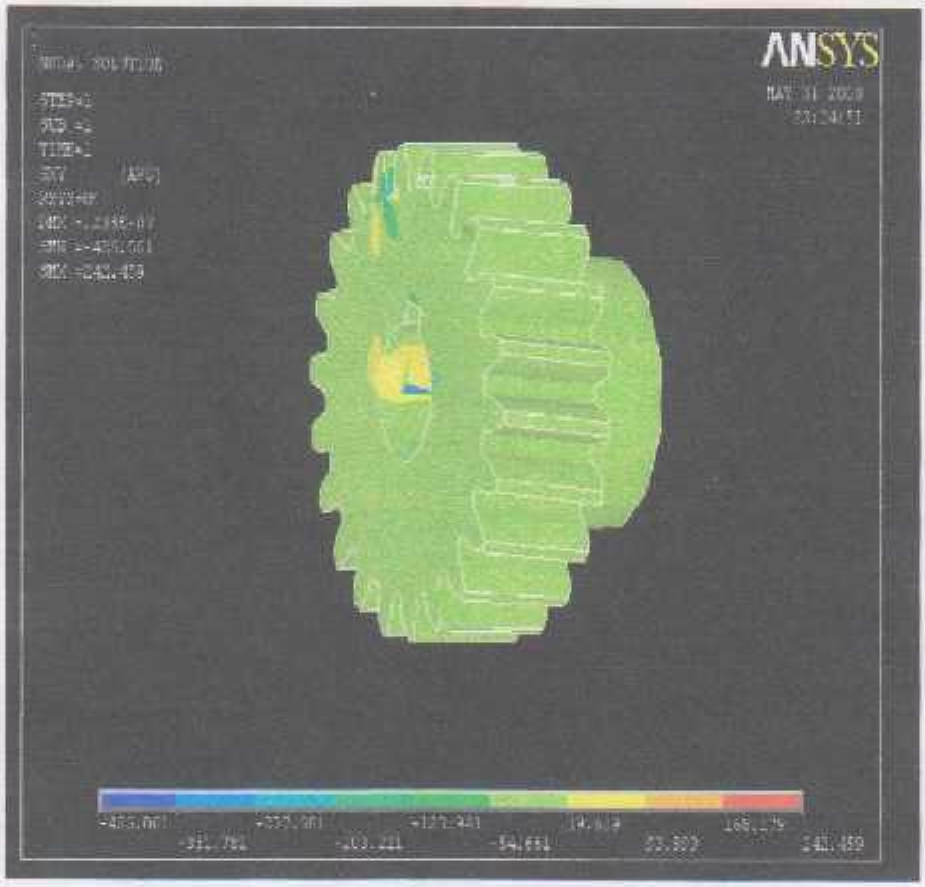


Figure 3.16 XY shear of the helical gear

- **XZ - shear**

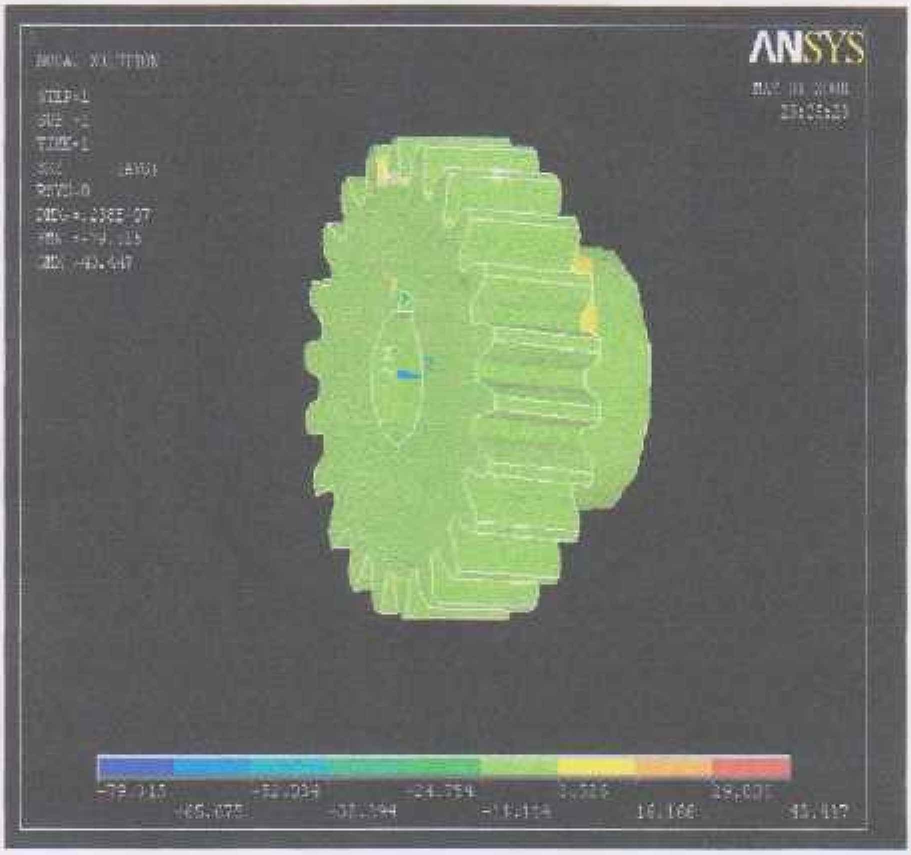


Figure 3.17 XZ shear of the helical gear

- **YZ - shear**

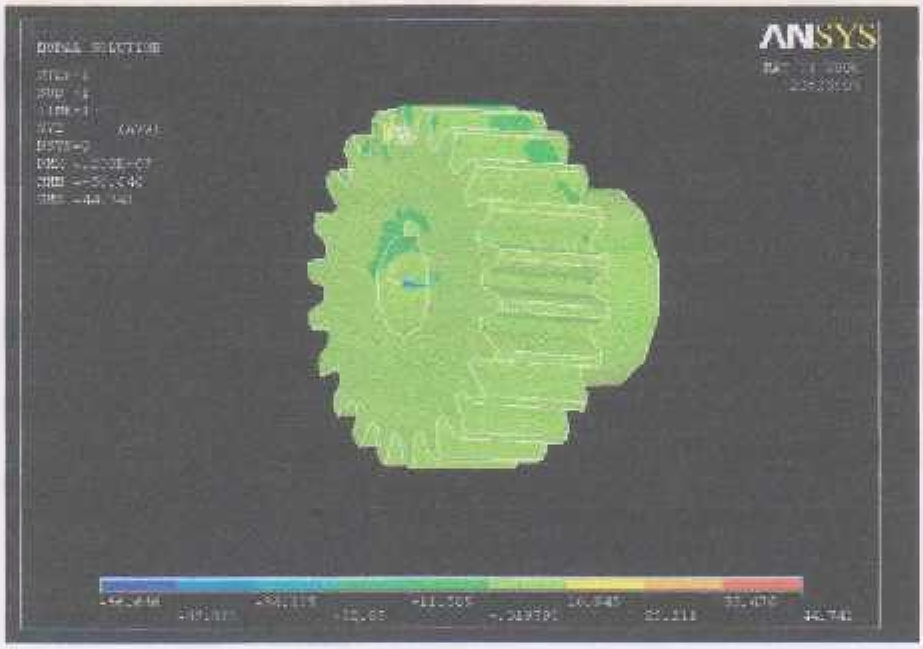


Figure 3.18 YZ shear of the helical gear

From the previous figures of the shear stress it can be concluded that the shear is concentrated in XY plane, and in the other two planes has less values and less concentration.

3.3.2 Mechanical and thermal analysis

The analysis include: Von-misses strain, X-component, Y-component, Z-component, XY shear of total strain, XZ shear of total strain, YZ shear of total strain, and strain intensity.

- **Von-misses**

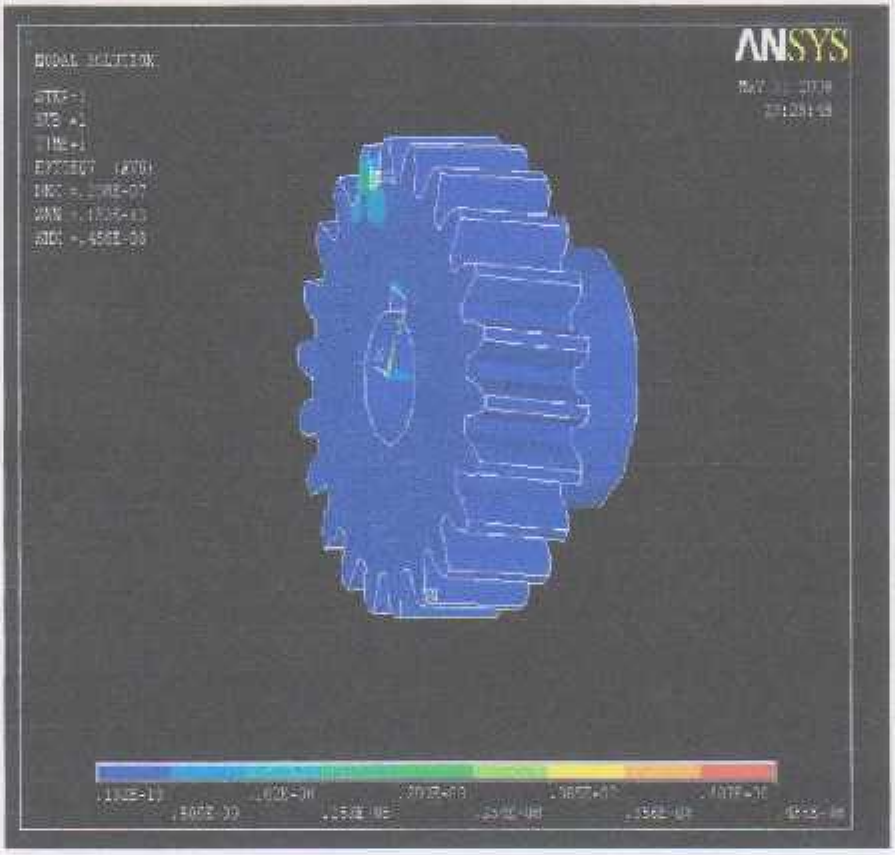


Figure 3.19 Von misses total strain of helical gear

From this figure the maximum strain is $0.472(10^{-8})$ and as it had been introduced in appendix A the strain is 0.000624; which mean that this strain within the safe range

- **X -component**

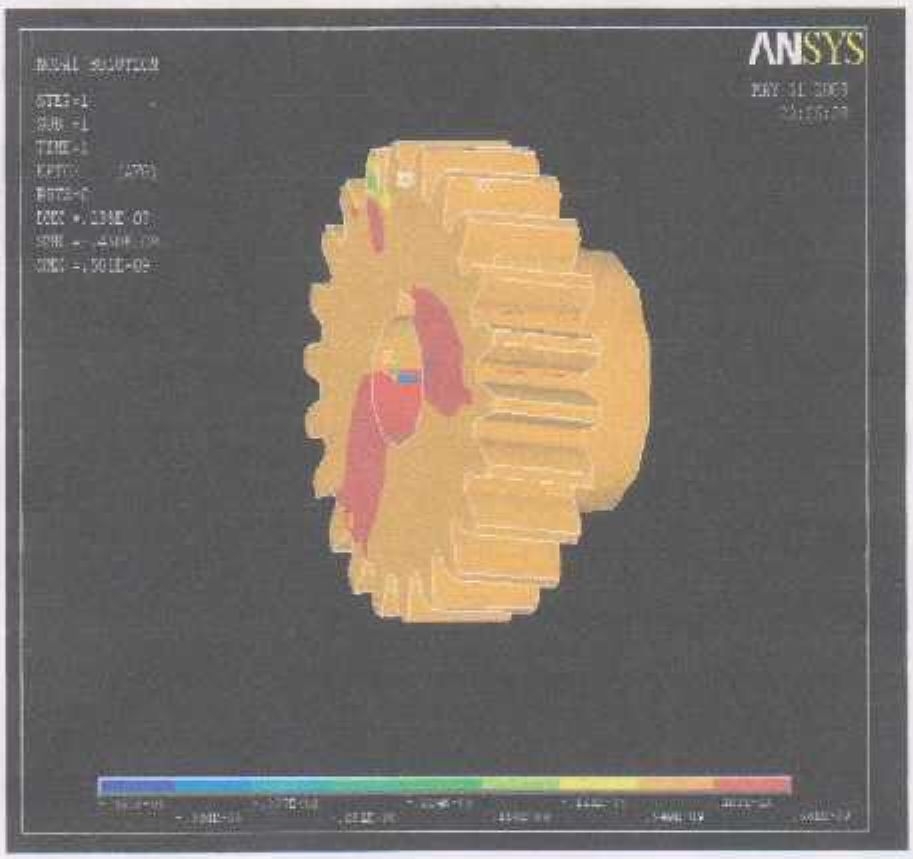


Figure 3.20 X-component of strain of the helical gear

- **Y -component**

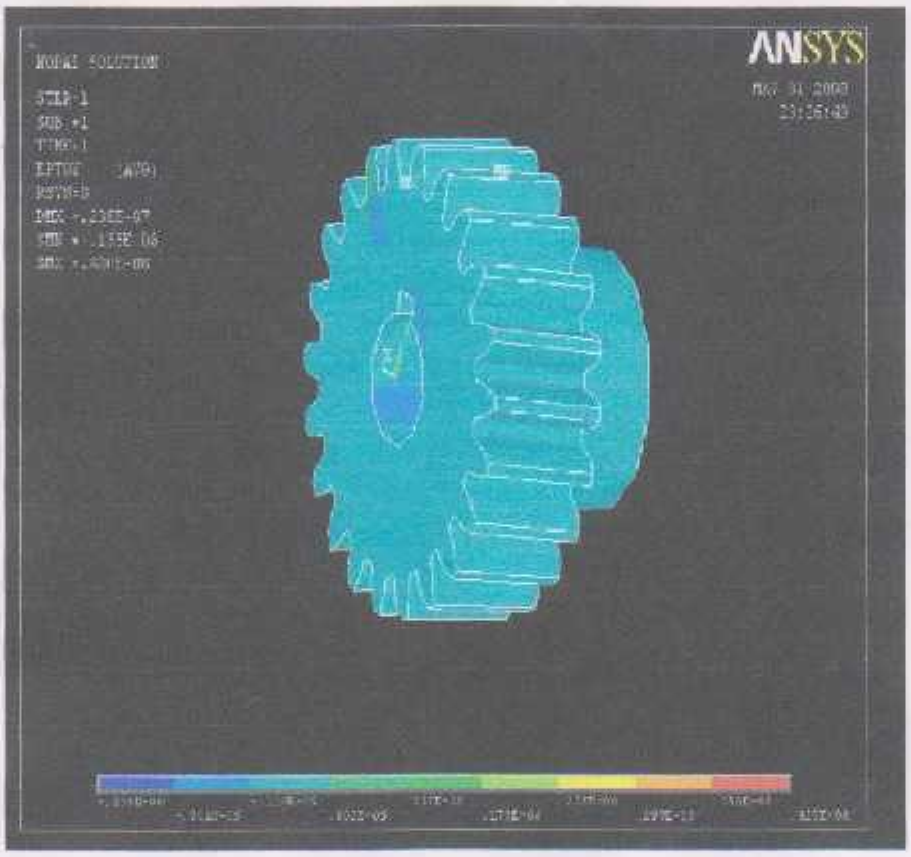


Figure 3.21 Y- component of strain of the helical gear

- **Z component**

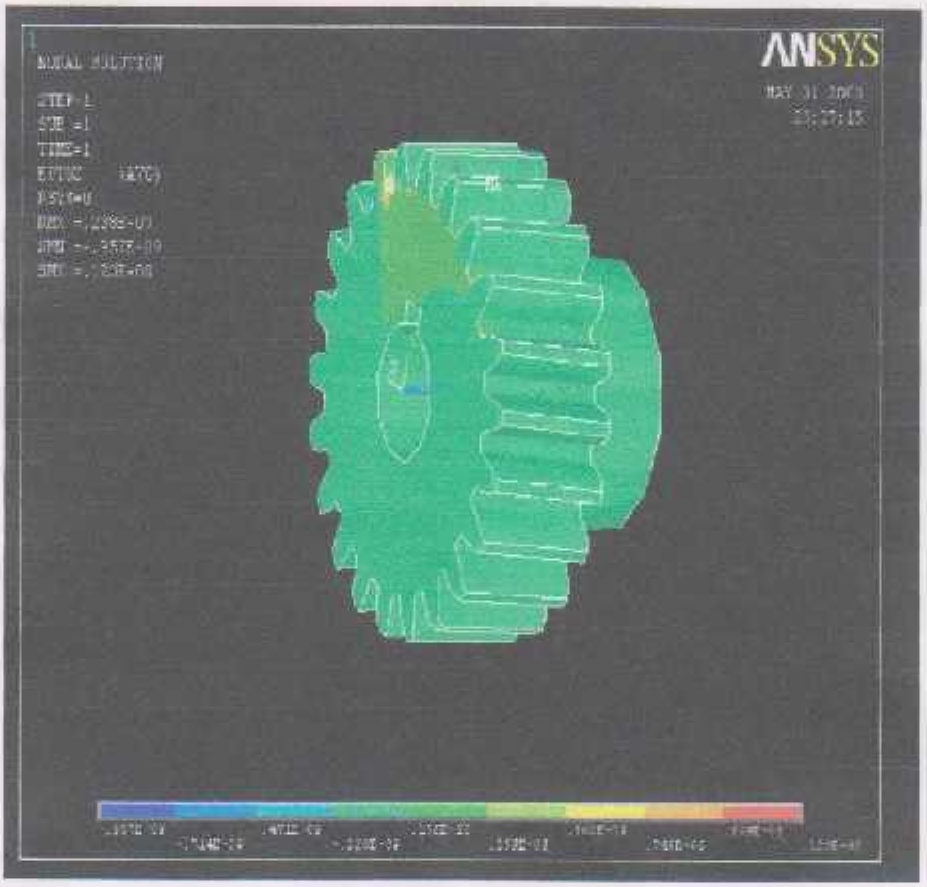


Figure 3.22 Z-component of strain of the helical gear

The previous three figures show the distribution of strain in X, Y and Z-axis; it shows that the variations of strain in Y, Z- axis are more than X- axis.

- **XY -shear of total strain**

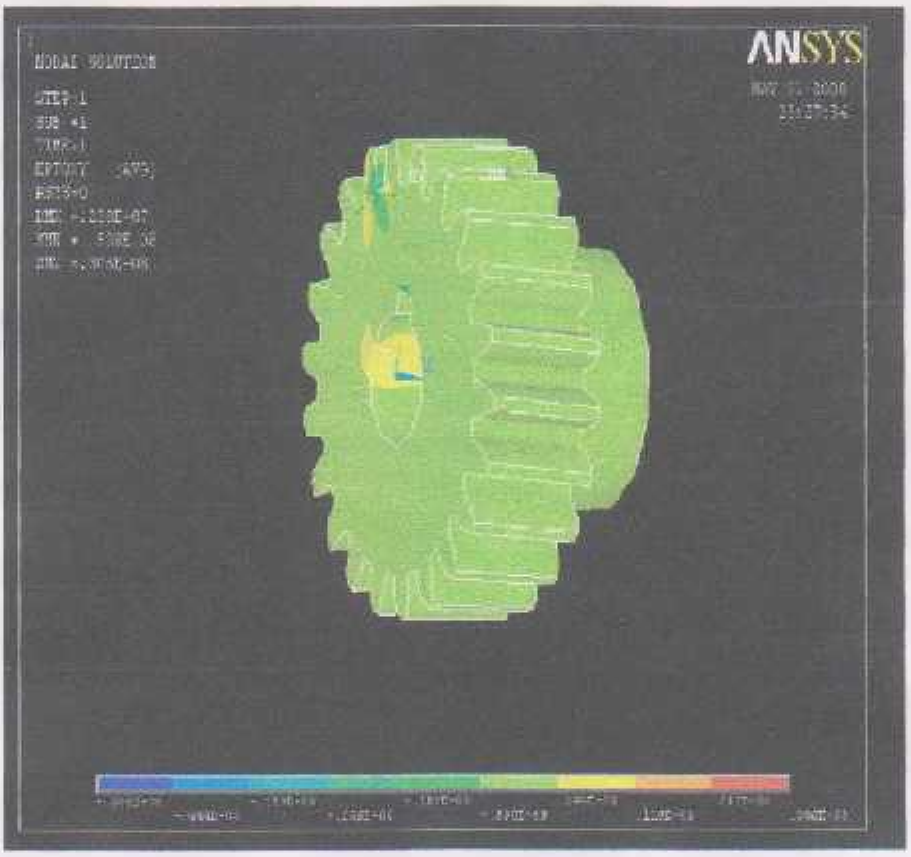


Figure 3.23 XY shear of total strain of the helical gear

- **XZ -shear of total strain**

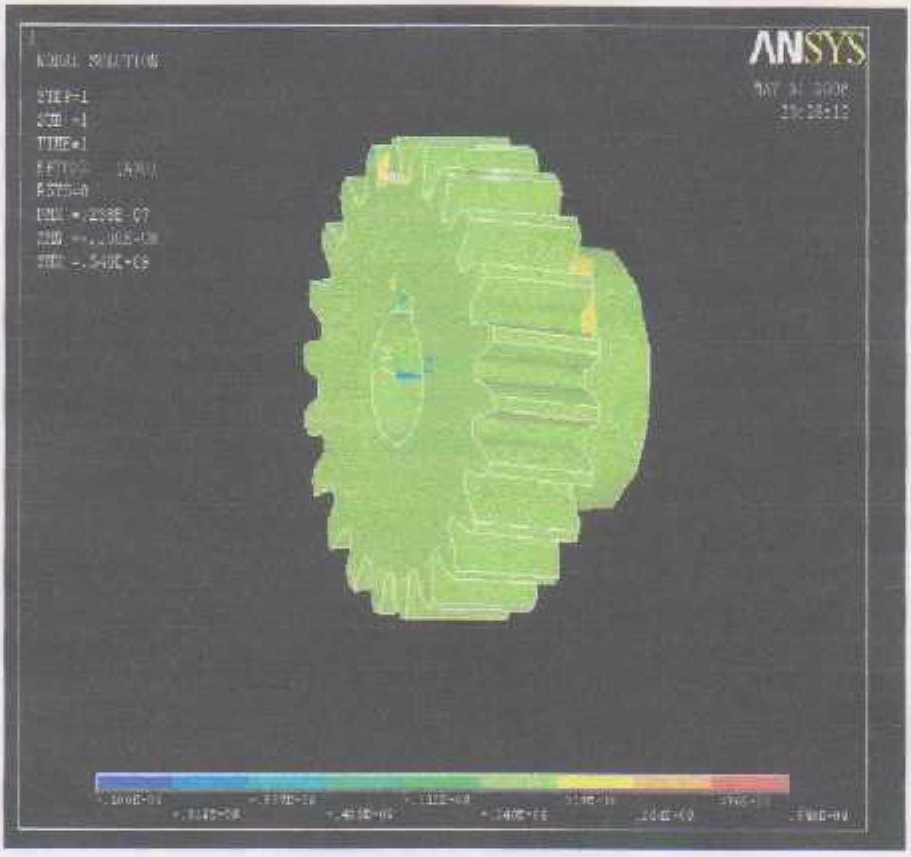


Figure 3.24 XZ shear of total strain of the helical gear

- **YZ -shear of total strain**

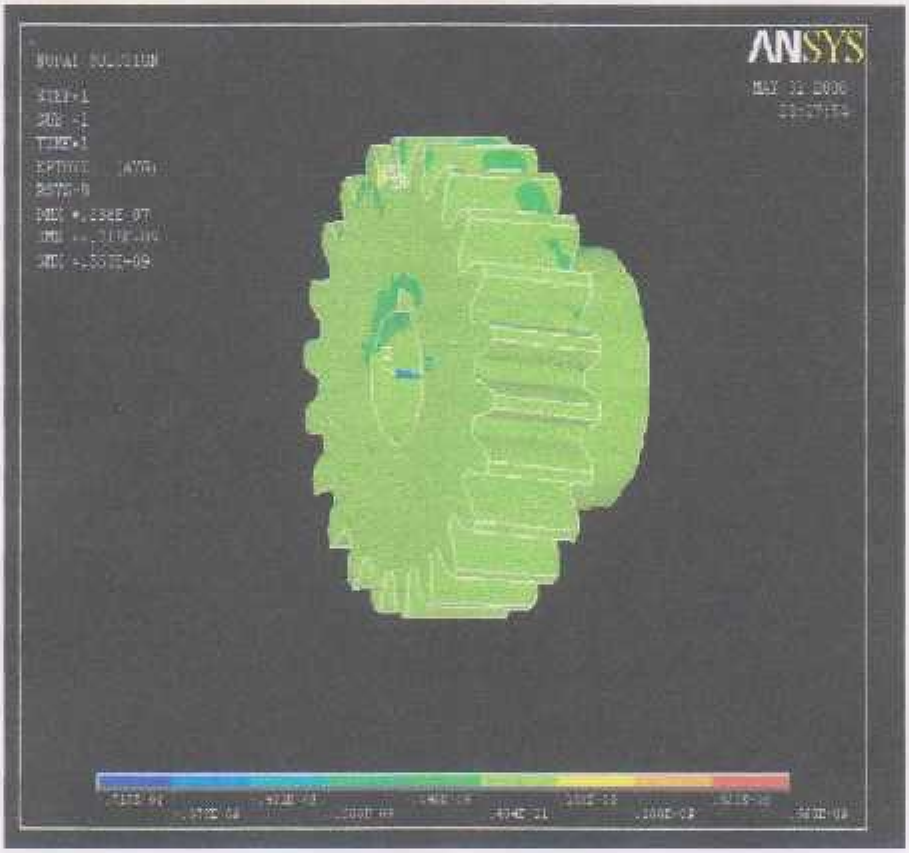


figure 3.25 YZ shear of total strain of helical gear

From the previous figures of the shear strain it can be conclude that the shear is concentrated in XY plane, and in the other two planes has less values and less concentration.

- **Strain intensity**

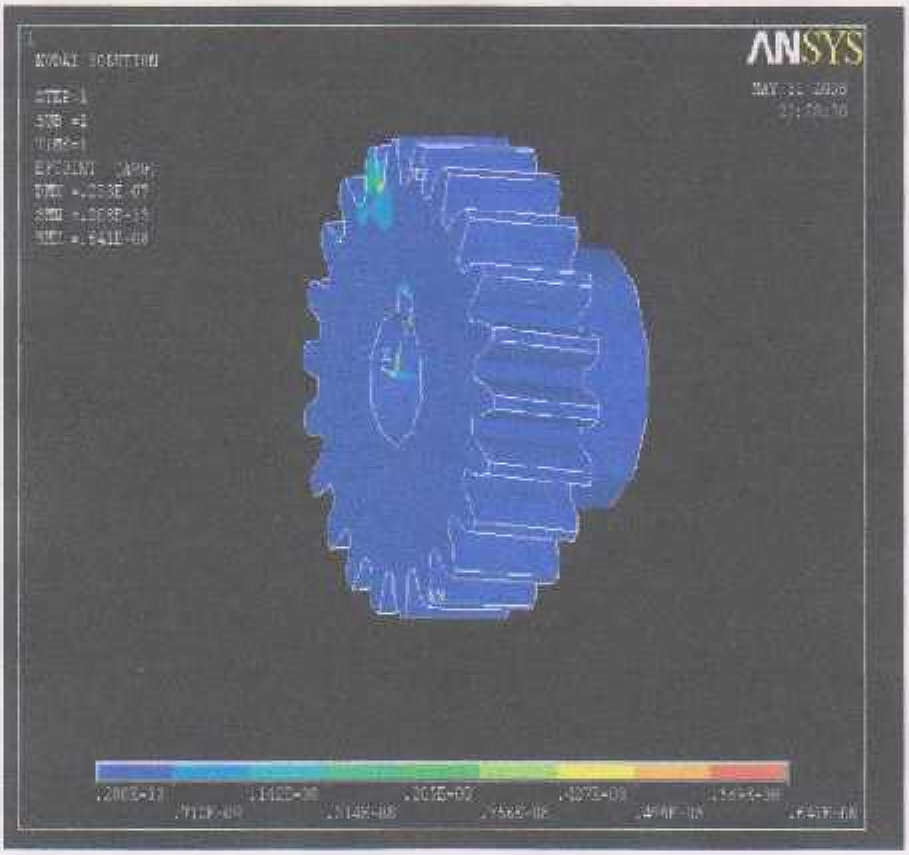


Figure 3.26 strain intensity of the helical gear

3.3.3 Stress analysis second part:

The analysis include: Von-misses stress, X-component, Y-component, Z-component, Stress intensity, XY shear, XZ shear, and YZ shear. After the analysis of the first model of the spur gear on ANSYS program the following results had been got.

- **X-component**

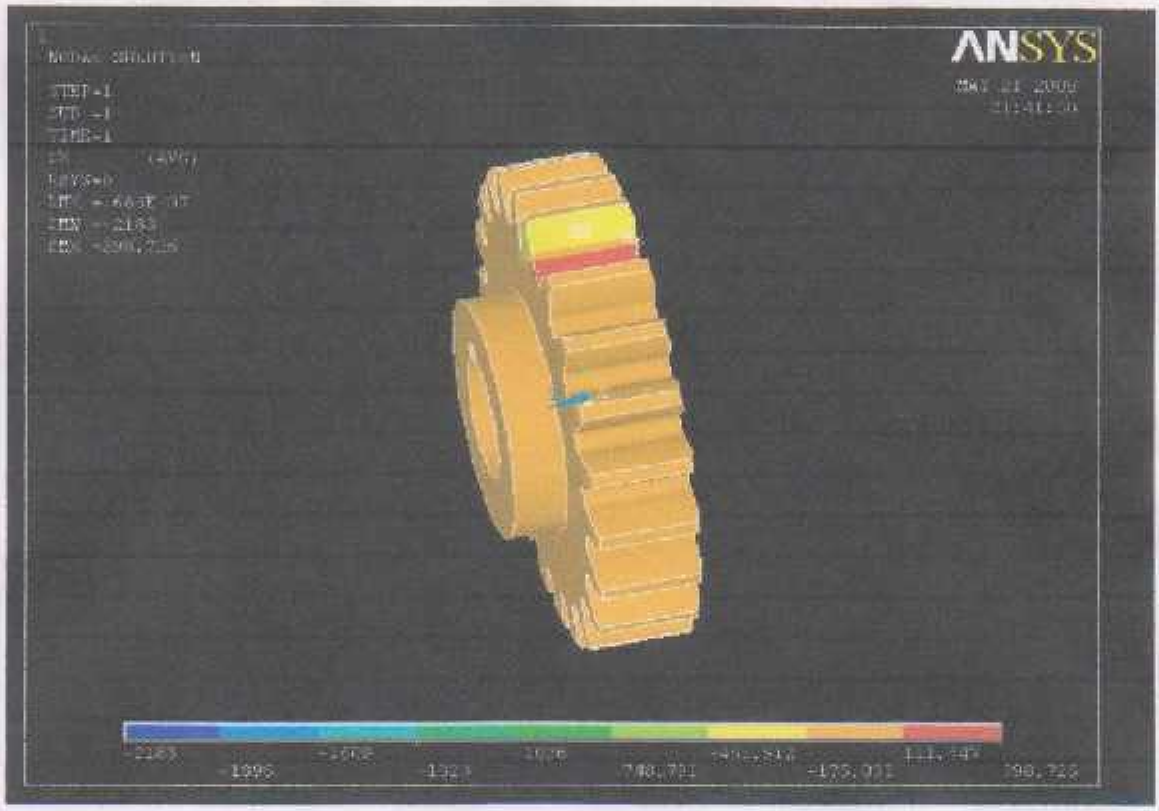


Figure 3.27 X-component of stress of spur gear

- **Z-component**

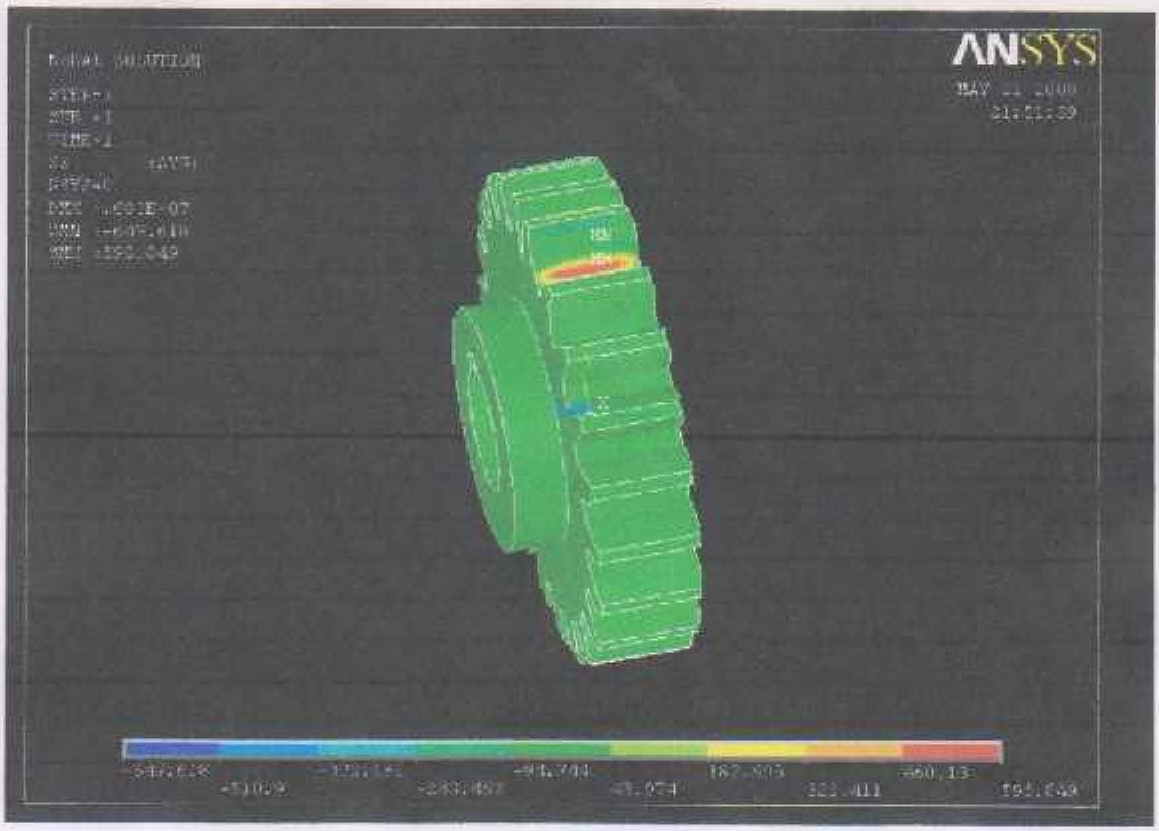


Figure 3.28 Z-component of stress of the spur gear

The previous three figures show the distribution of stress in X, Y, and Z-axis; it shows that the variations of stress in X, Z-axis are more than X-axis.

- **XY shear:**

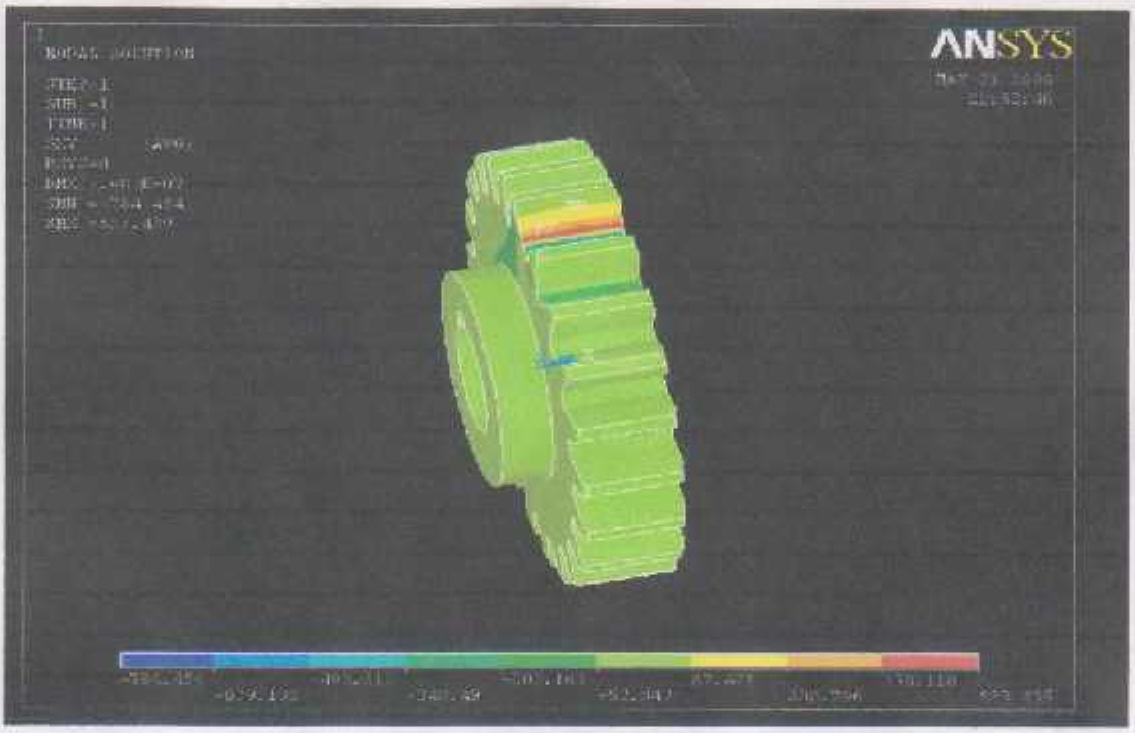


Figure 3.29: XY shear of the spur gear

- **XZ shear**

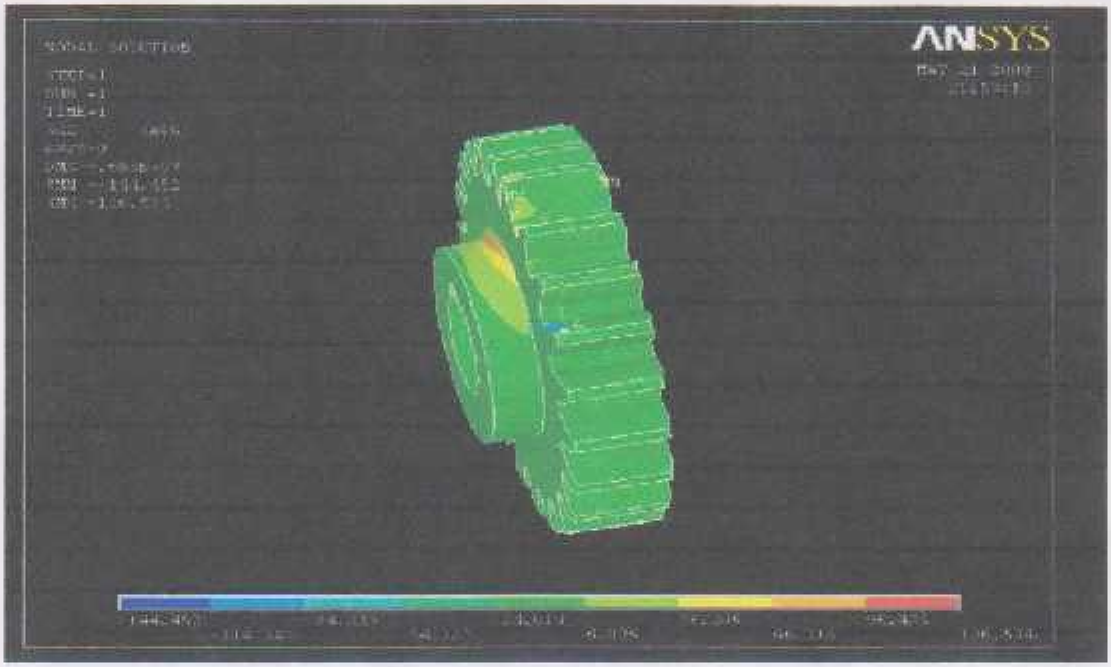


Figure 3.30 XZ shear of the spur gear

- **YZ shear**

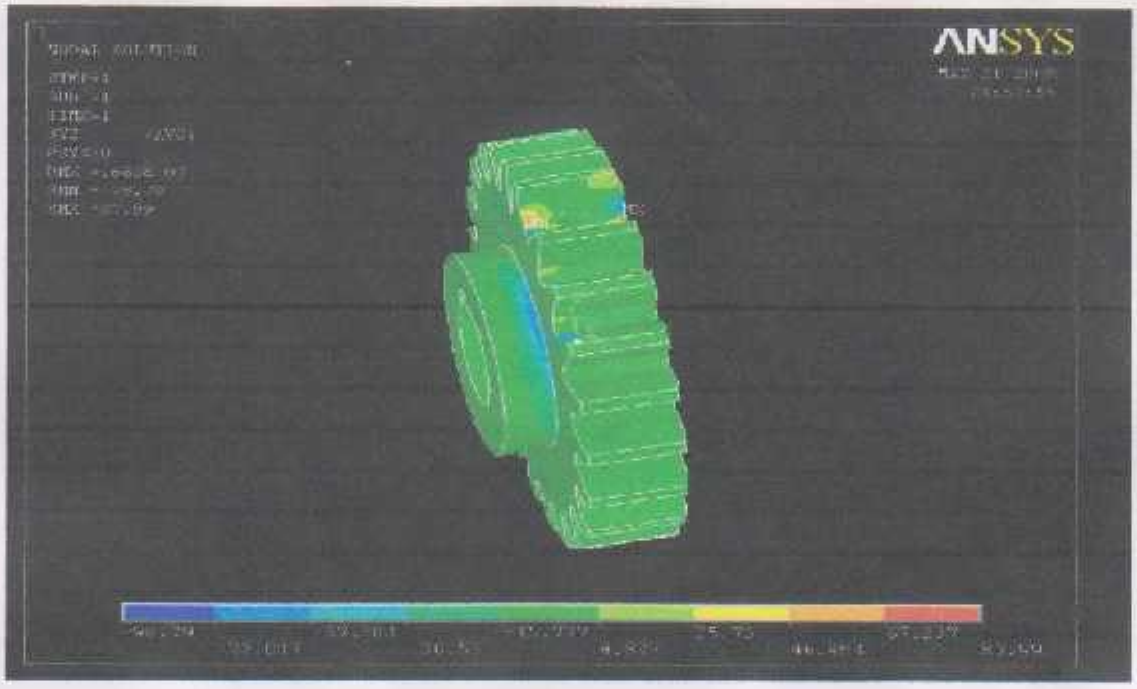


Figure 3.31 YZ shear of the spur gear

From the previous figures of the shear stress it can be concluded that the shear is concentrated in XY plane, and the other two planes has less values and less concentration.

3.3.4 Mechanical and thermal analysis:

The analysis include: Von-misses Strain, X-component, Y-component, Z-component, XY shear of total strain, XZ shear of total strain, YZ shear of total strain, and strain intensity.

- **Von-misses strain:**

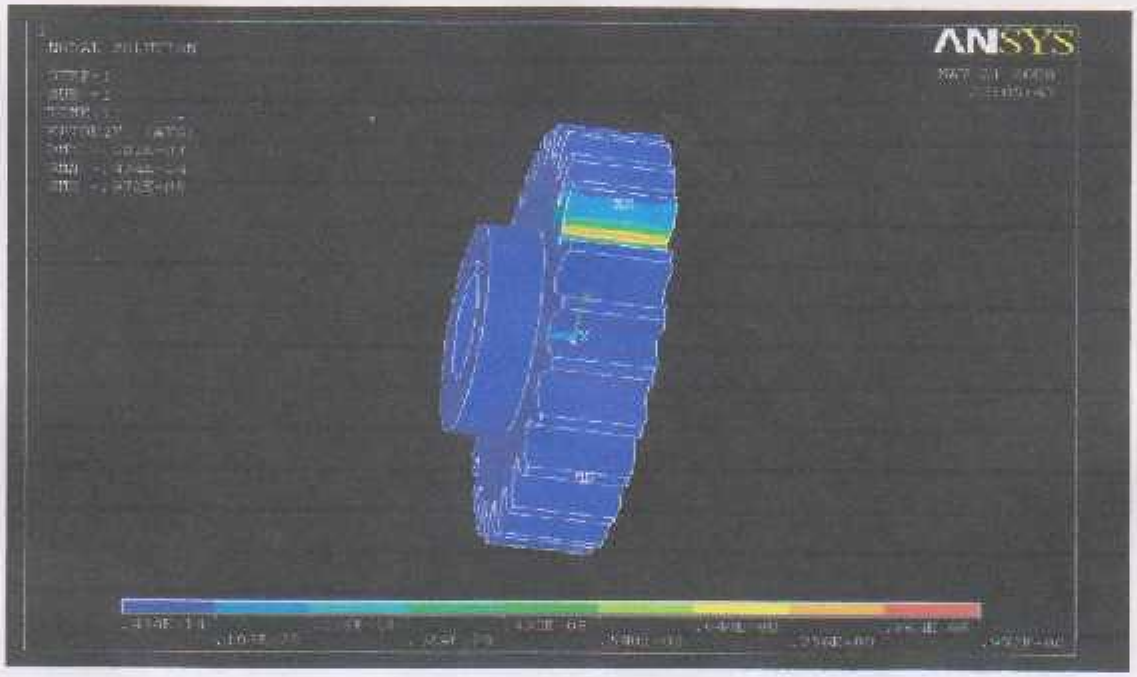


Figure 3.32 Von misses strain of the spur gear

From the figure the maximum strain is $0.972(10^{-8})$ and as it had been introduced in appendix A the strain is $0.624(10^{-3})$; which means that this strain within the safe range.

- **X-component :**

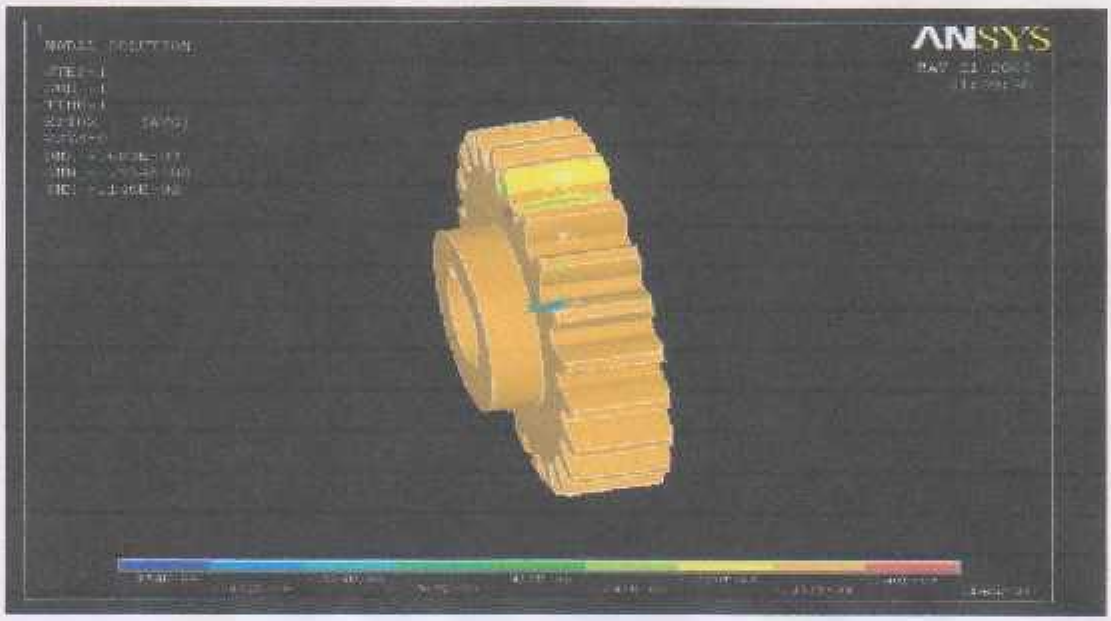


Figure 3.33 X-component of strain of the spur gear

• **Y-component**

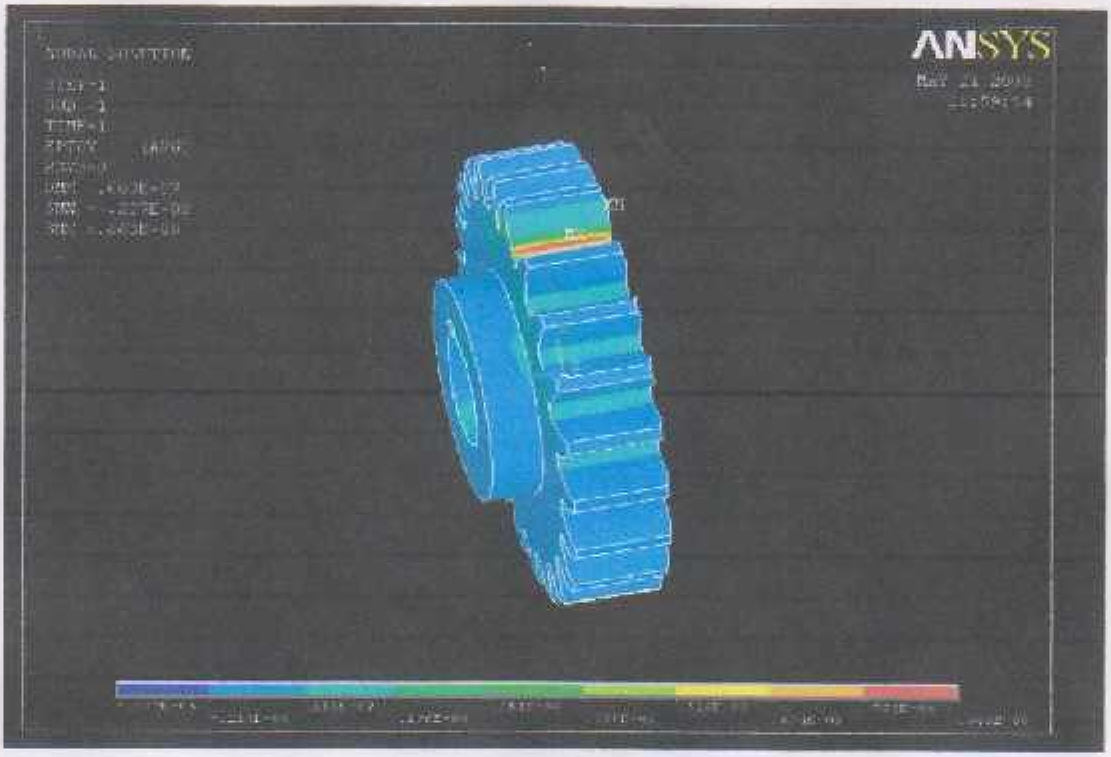


Figure 3.34 Y-component of strain of the spur gear

• **z-component:**

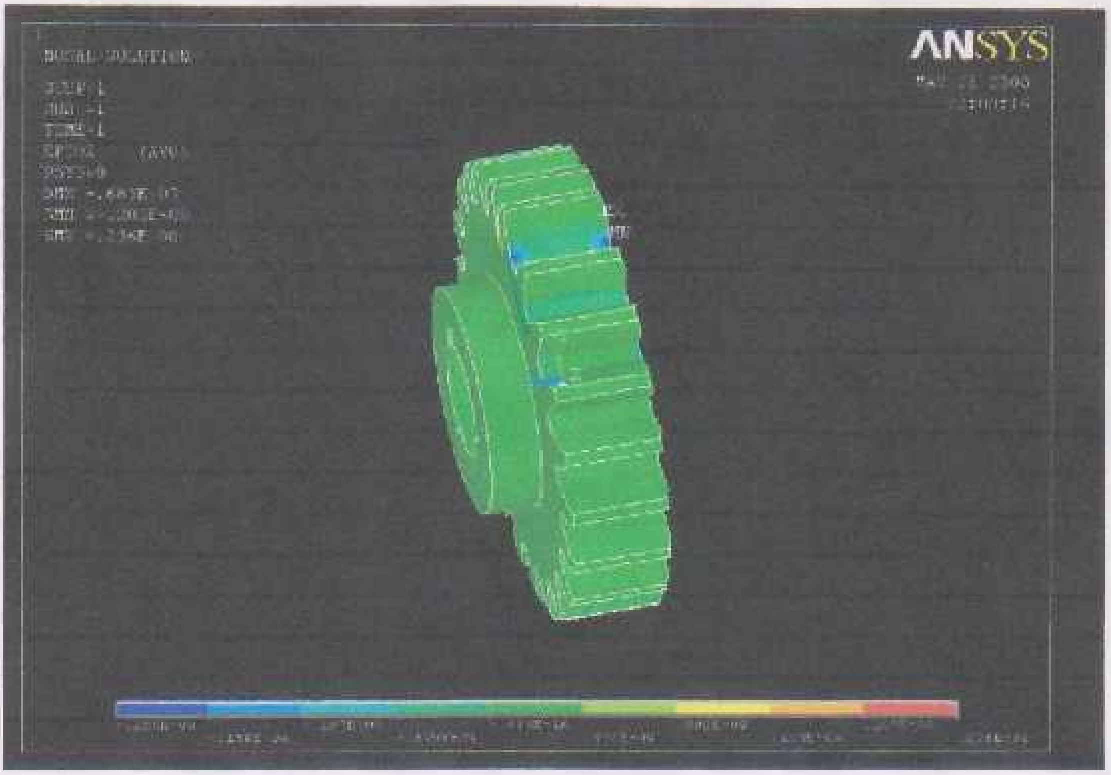


Figure 3.35 Z-component of strain of the spur gear

The previous three figures show the distribution of strain in X, Y, and Z axis; It shows that the variations of strain in Y, Z-axis are more than X-axis.

• **XY shear of total strain** :

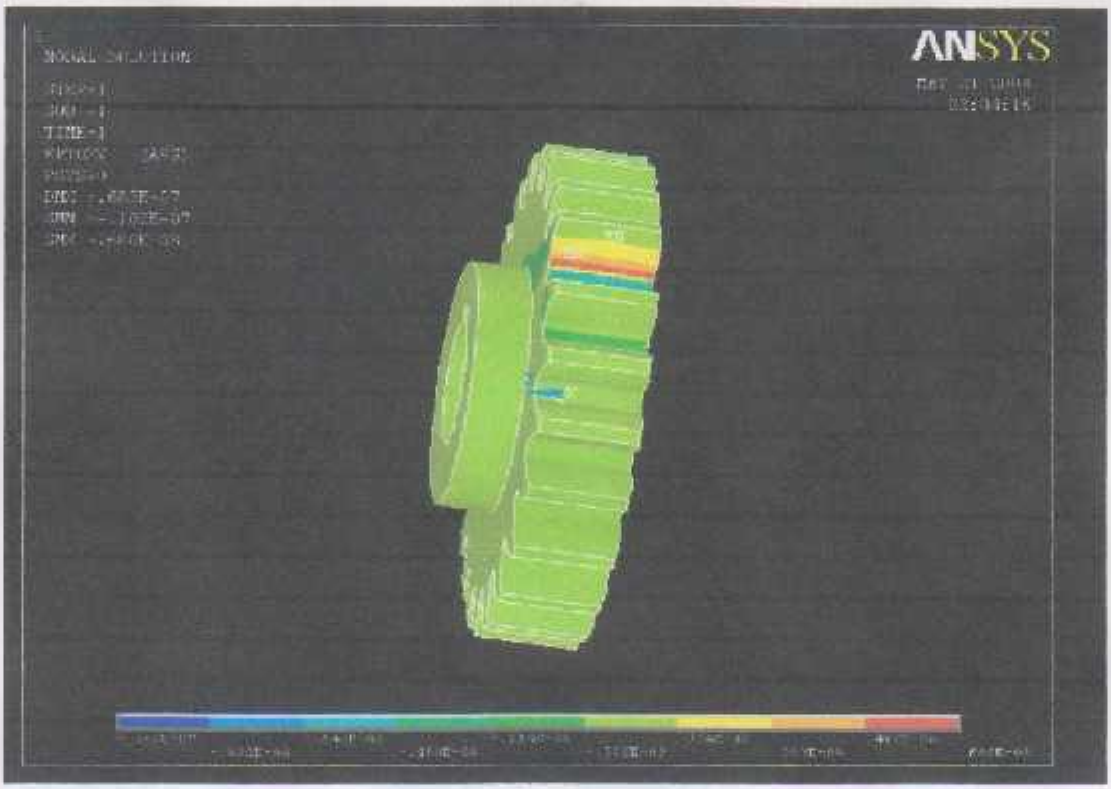


Figure 3.36 XY shear of total strain

- **XZ shear of total strain:**

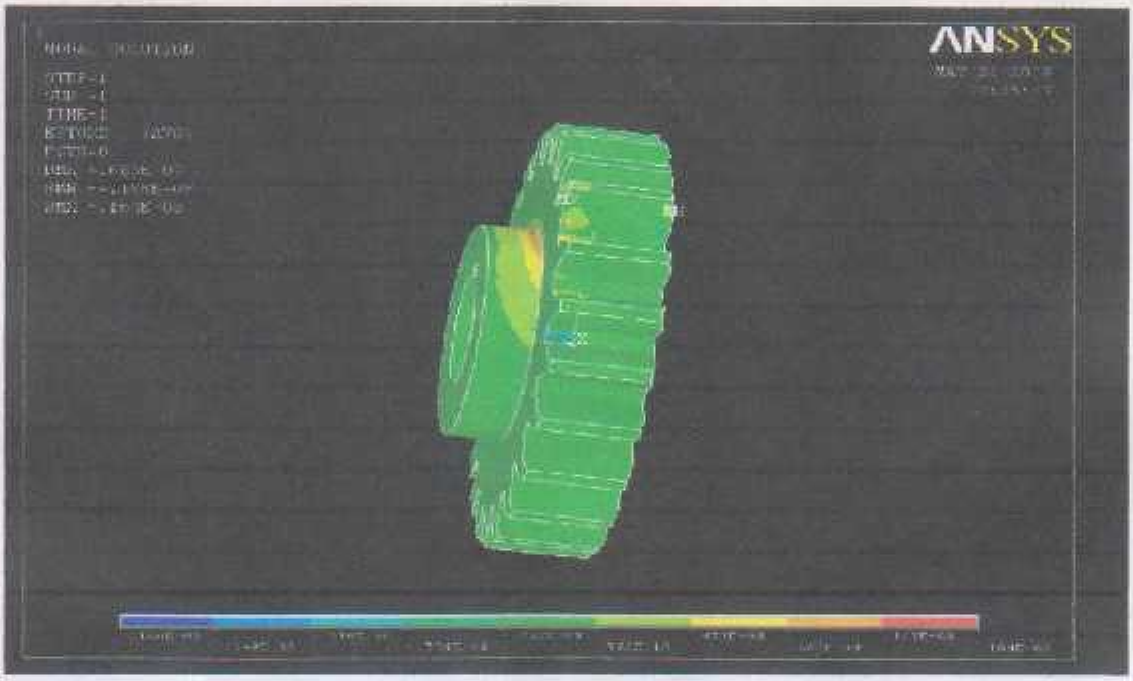


Figure 3.37 XZ shear of total strain of the spur gear.

- **YZ shear of total strain:**

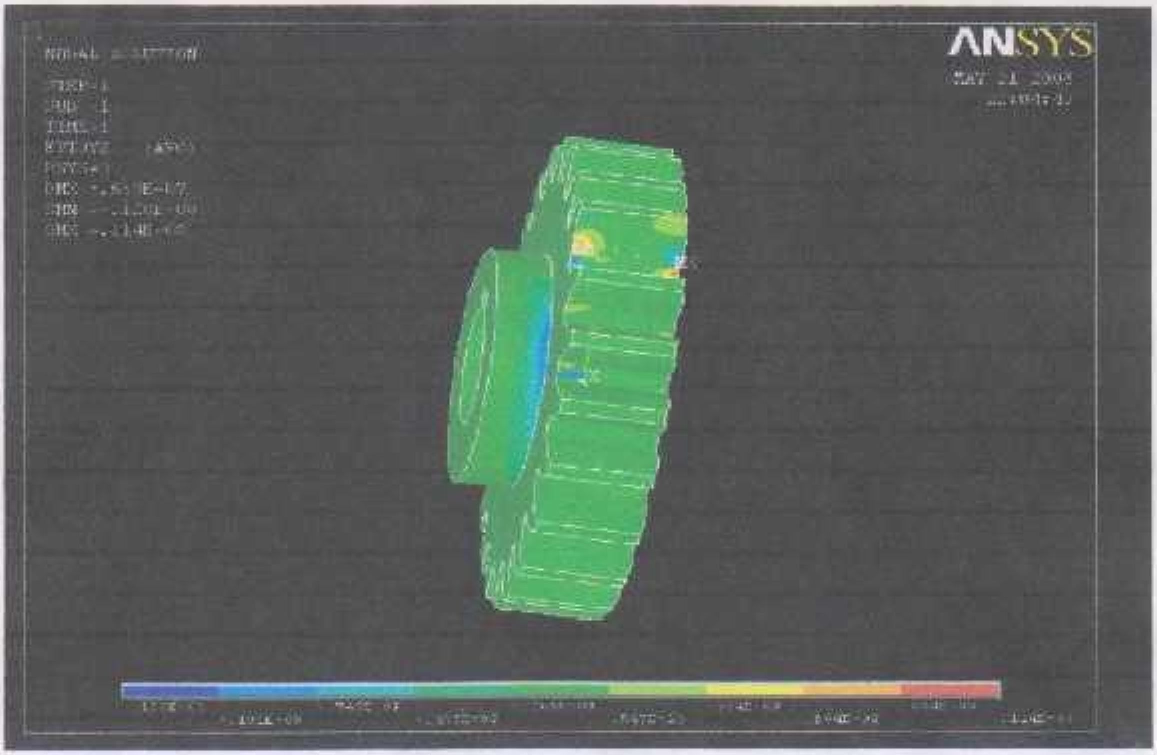


Figure 3.38 YZ shear of total strain of the spur gear.

From the previous figures of the shear strain it can be concluded that the shear is concentrated in XY plane, and in the other two planes has less values and less concentration.

• **Strain intensity**

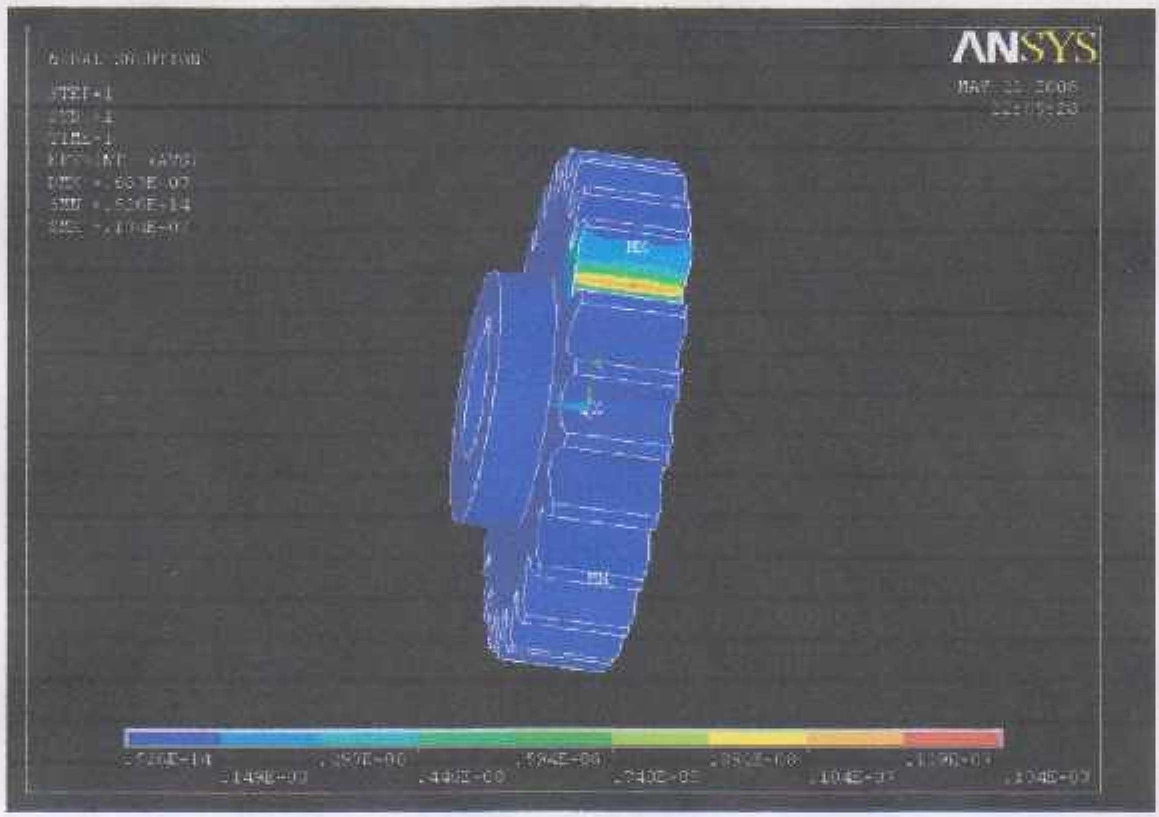


Figure 3.39 strain intensity of the spur gear

3.3.5 Stress analyses third part

The analysis include: Von-Misses stress, X- component, Y- component, Z-component, stress intensity, XY shear, XZ shear and YZ shear. After the analyses of the third models of the bevel gear on ANSYS program the following results had been got.

- **Von-Misses stress**

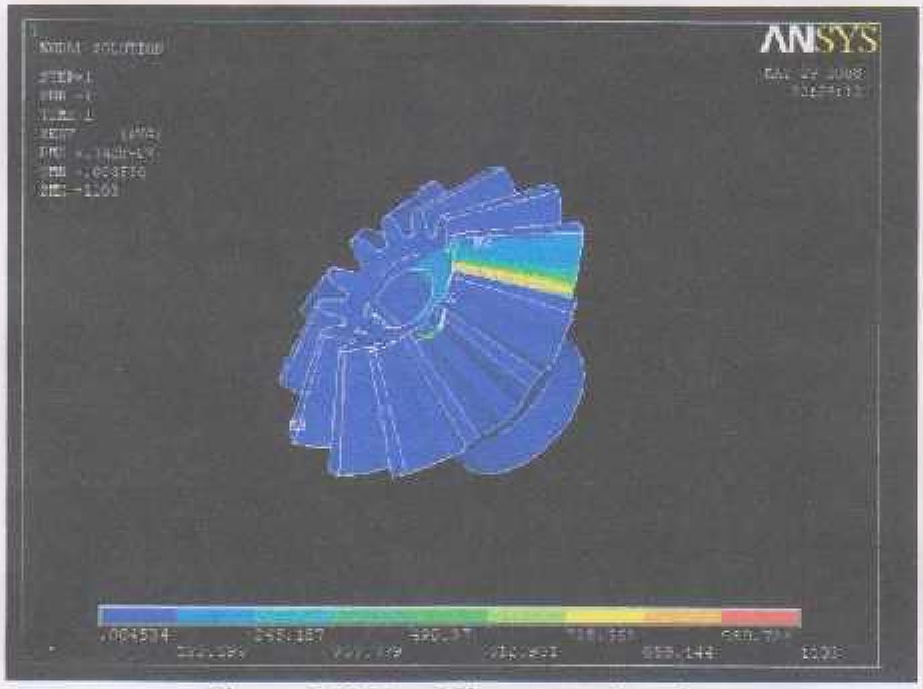


Figure 3.40 Von-Misses stress bevel gear

As the previous result shows; it has been noticed that the Von-misses stress is 1103 MPa and it is lower than the yield strength of alloy structural steel which equals 1350 MPa. Further more the maximum deflection in the gear is $0.342(10^{-7})$ mm; which means that the gear can withstand this load safely.

* **X-component.**

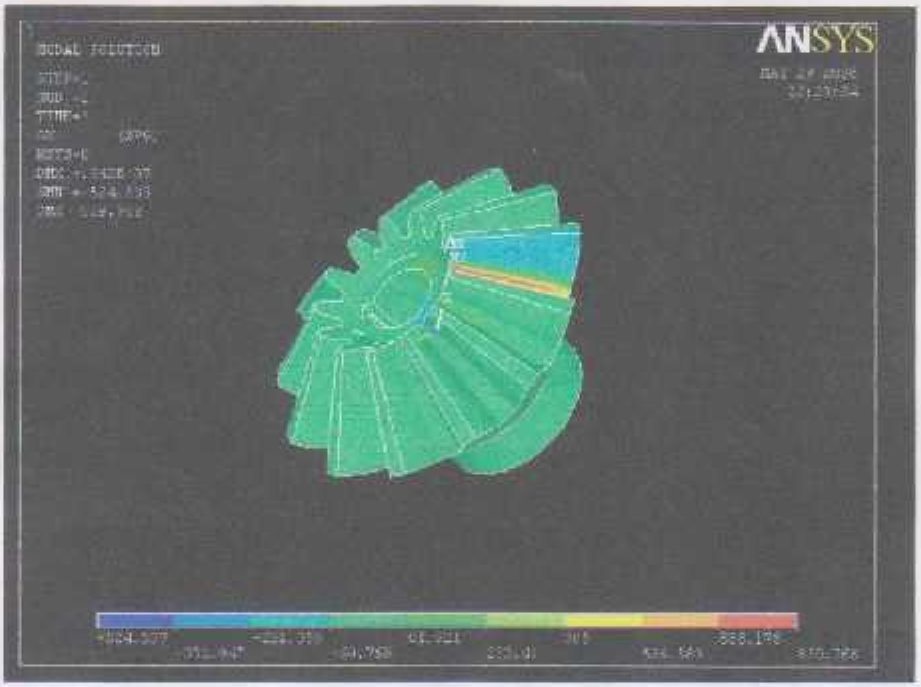


Figure 3.41 X-component of stress of the bevel gear

* **Y-component**

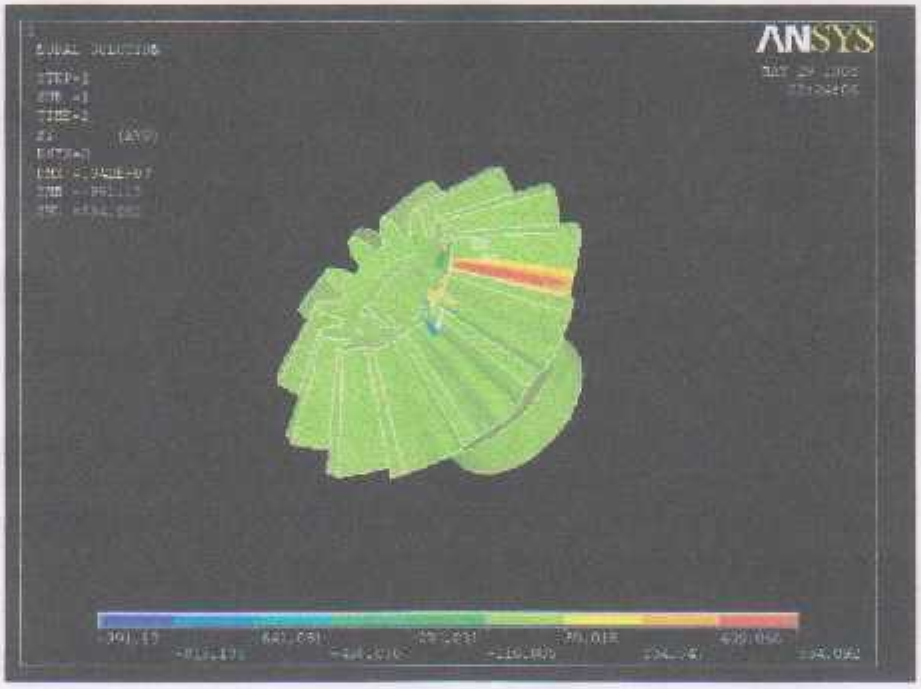


Figure 3.42 Y-component of stress of the bevel gear

- **Z-component**

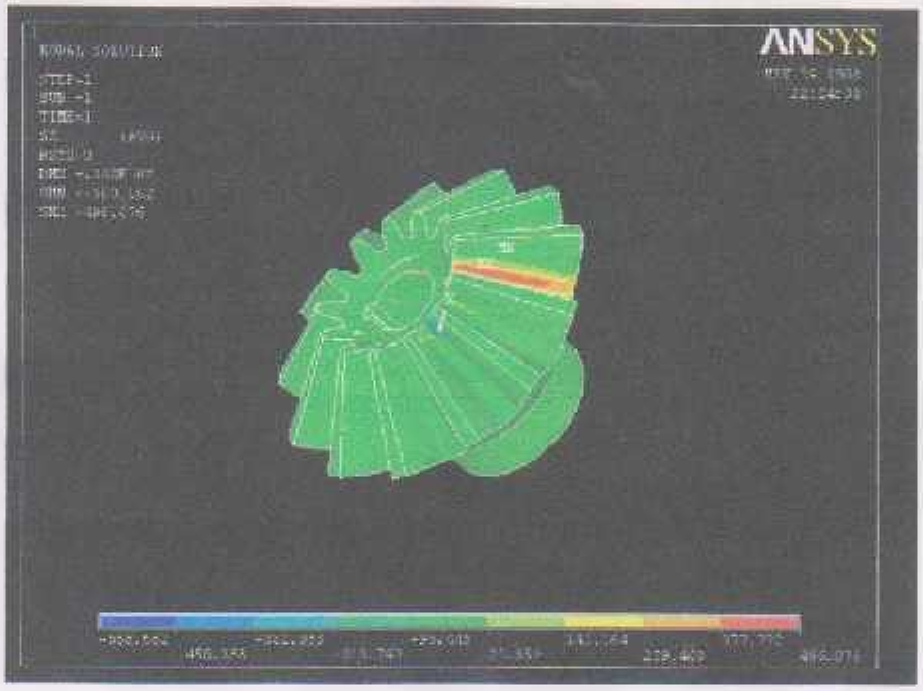


Figure 3.43 Z-component of stress of the bevel gear

The previous three figures show the distribution of stress in X, Y, and Z-axis, it shows that the variations of stress in X, Y axis are more tan Z-axis.

- **Stress intensity**

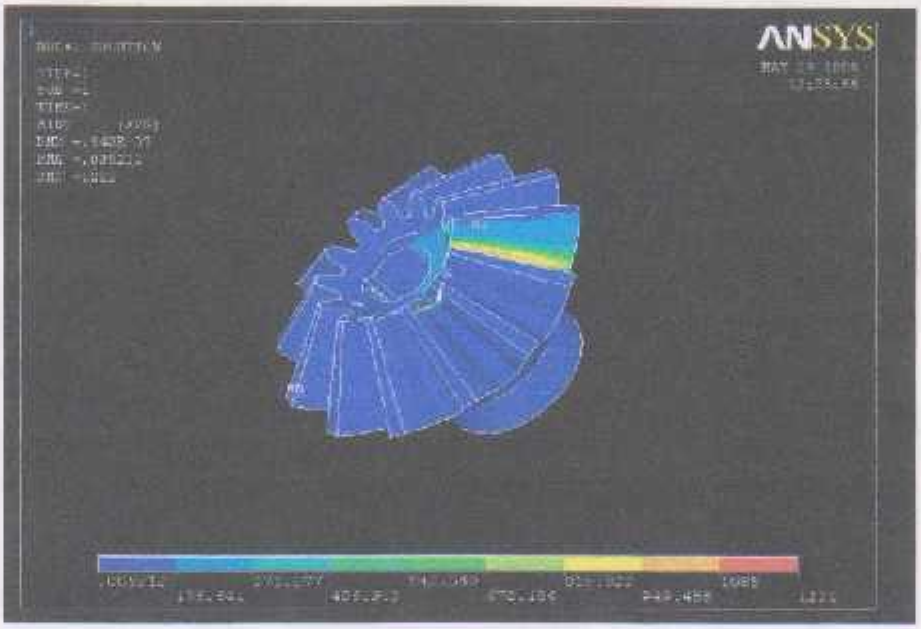


Figure 3.43 Z-component of stress of the bevel gear

- **XY shear:**

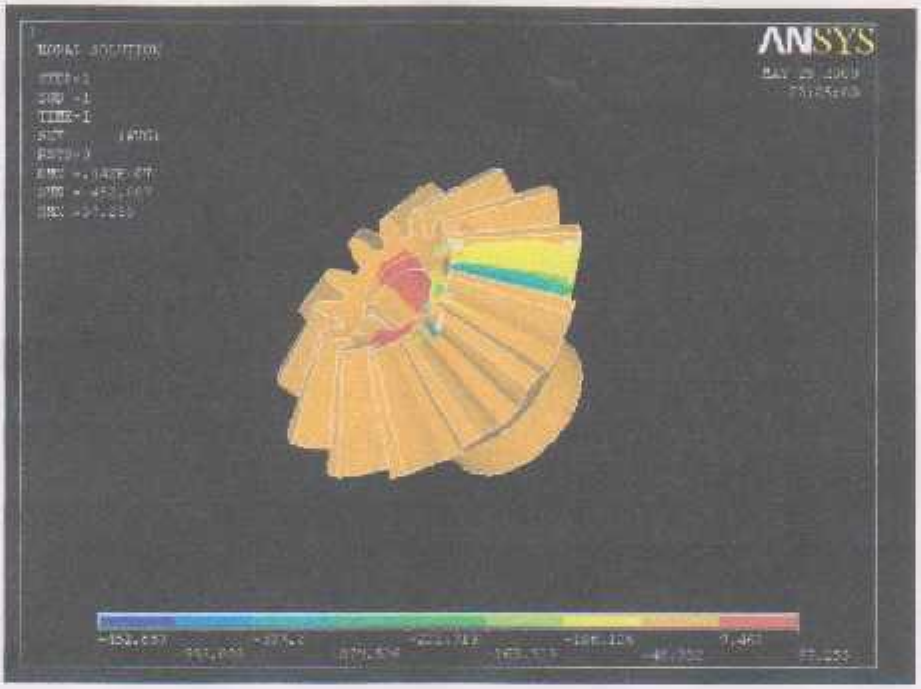


Figure 3.45 XY shear of the bevel gear

- **XZ - shear:**

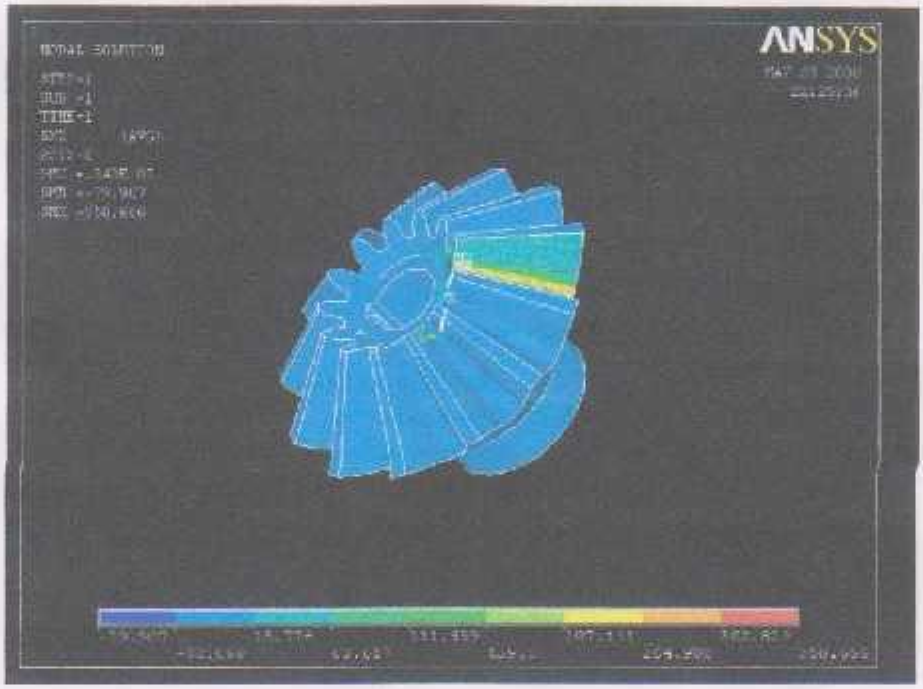


Figure 3.46 XZ shear of the bevel gear

- **YZ - shear**

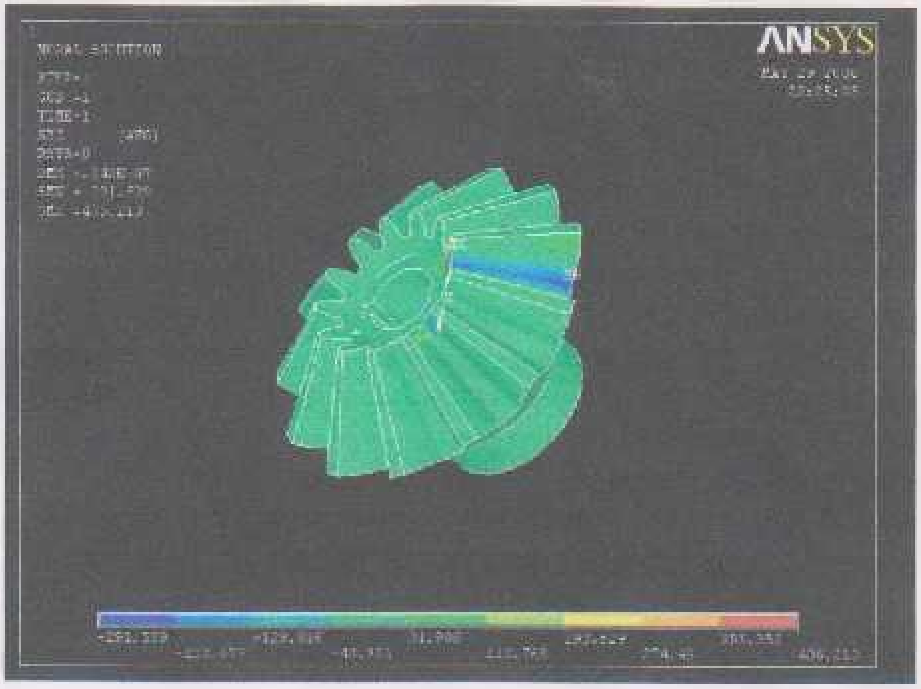


Figure 3.47 YZ shear of the bevel gear

From the previous figures of the shear stress it can be concluded that the shear is concentrated in YZ plane, and in the other two planes has less values and less concentration.

3.3.6 Mechanical and thermal analysis

The analysis include: Von-misses strain, X-component, Y-component, Z-component, XY shear of total strain, XZ shear of total strain, YZ shear of total strain, and strain intensity.

- **Von-misses**

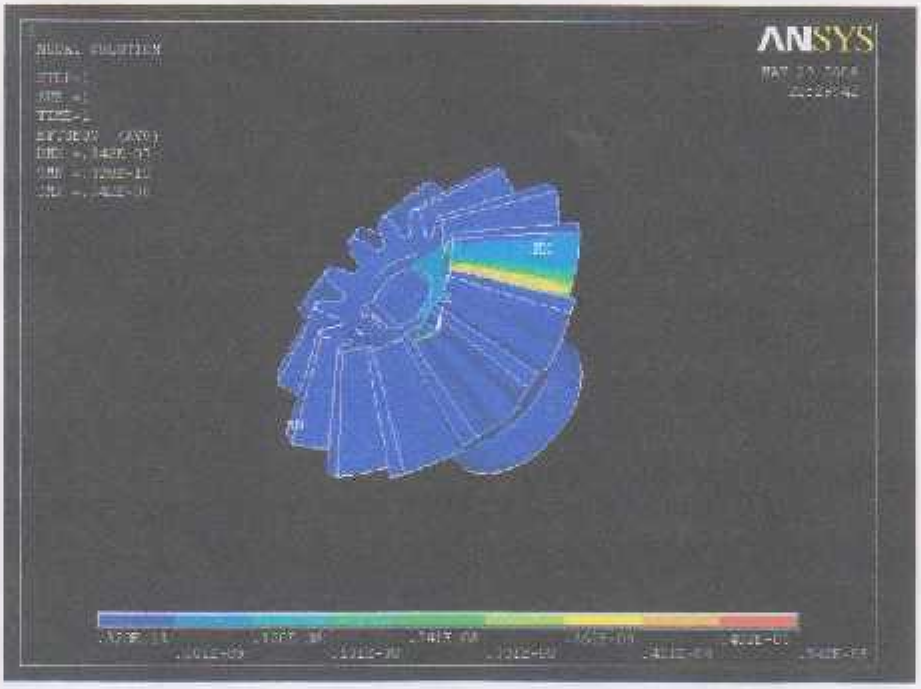


Figure 3.48 Von misses total strain of bevel gear

From this figure the maximum strain is $0.472(10^{-8})$ and as it had been introduced in appendix A the strain is $0.624(10^{-3})$; which mean that this strain within the safe range.

- **X -component**

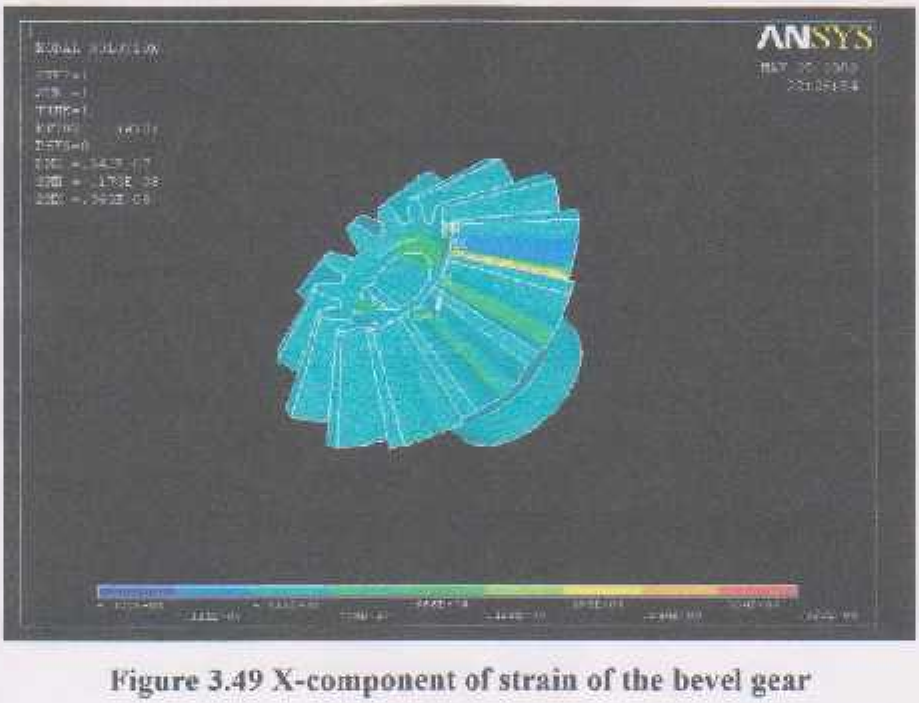


Figure 3.49 X-component of strain of the bevel gear

- **Y -component**

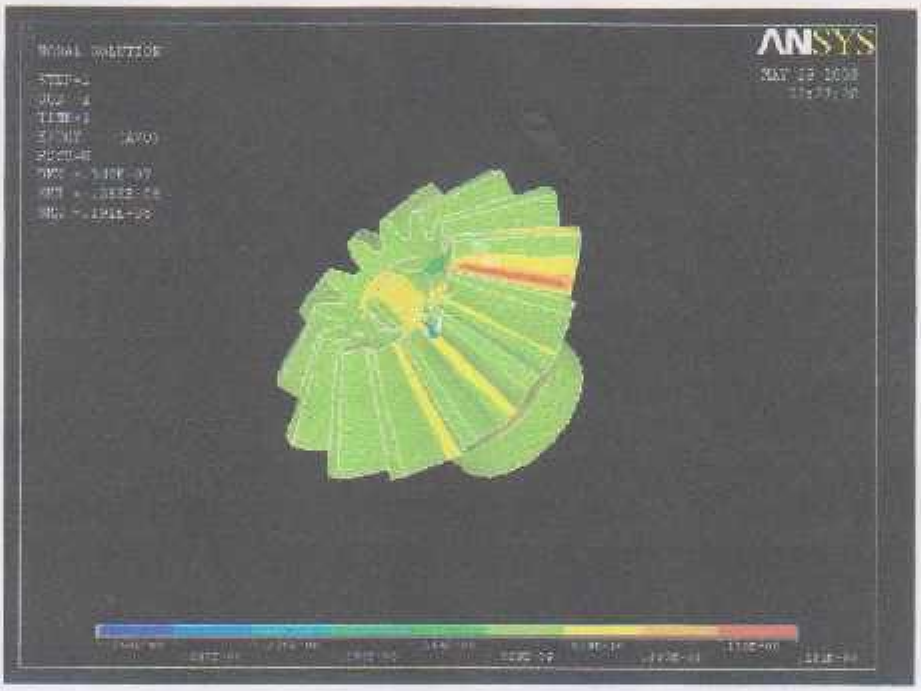


Figure 3.50 Y- component of strain of the bevel gear

- **Z component**

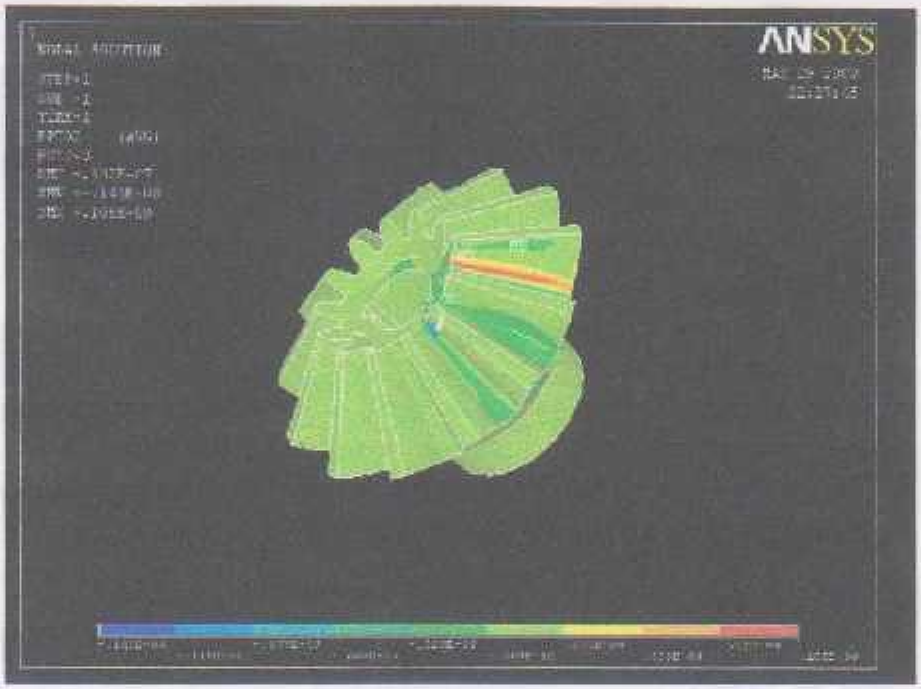


Figure 3.51 Z-component of strain of the bevel gear

The previous three figures show the distribution of strain in X, Y and Z-axis, it shows that the variations of strain in X, Y- axis are more than Z- axis.

- **XY -shear of total strain**

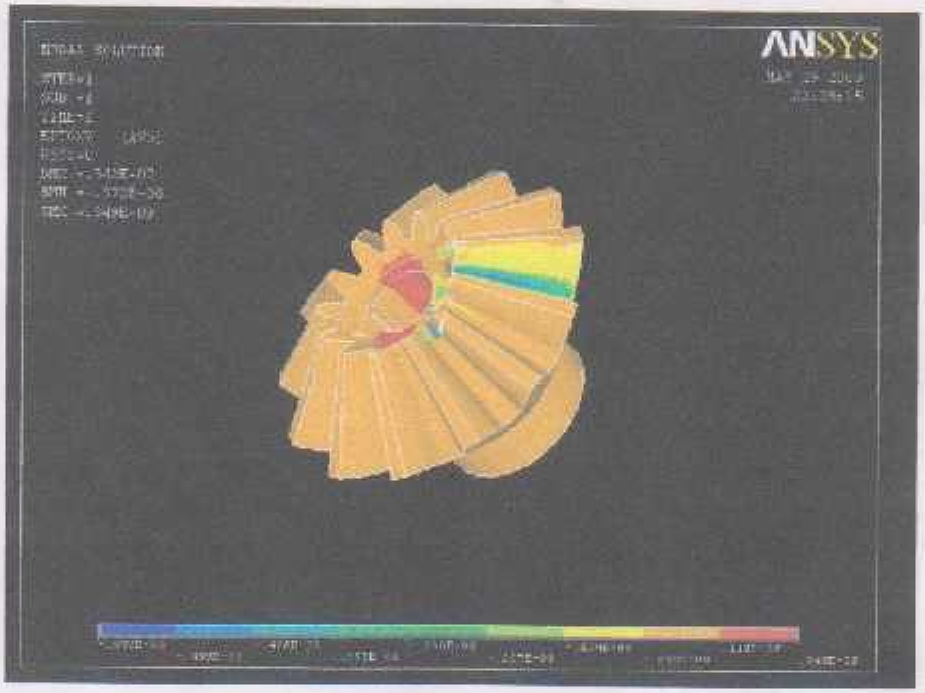


Figure 3.52 XY shear of total strain of the bevel gear

- **XZ -shear of total strain**

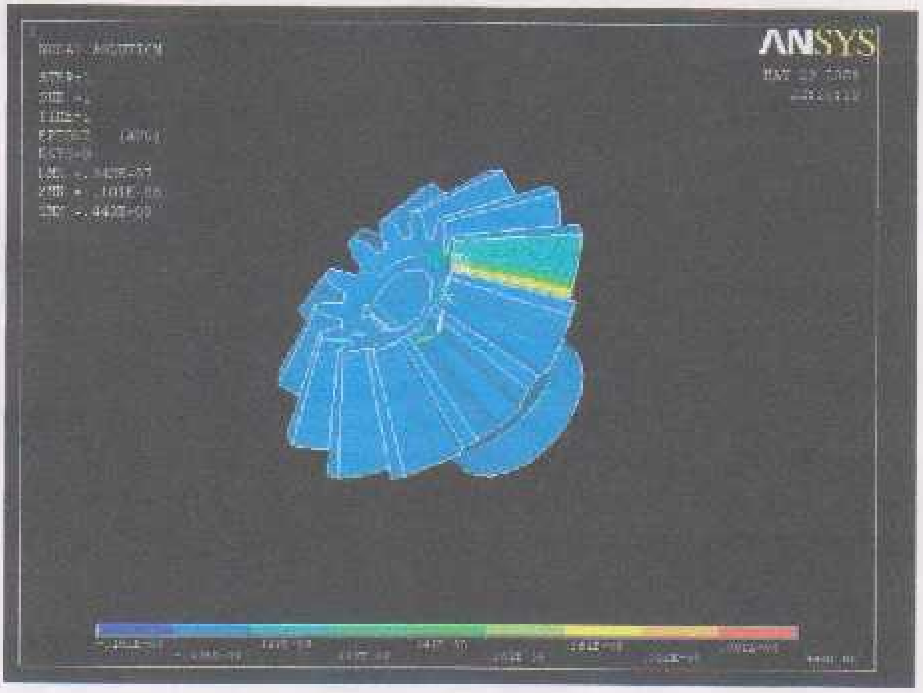


Figure 3.53 XZ shear of total strain of the bevel gear

* **YZ -shear of total strain**

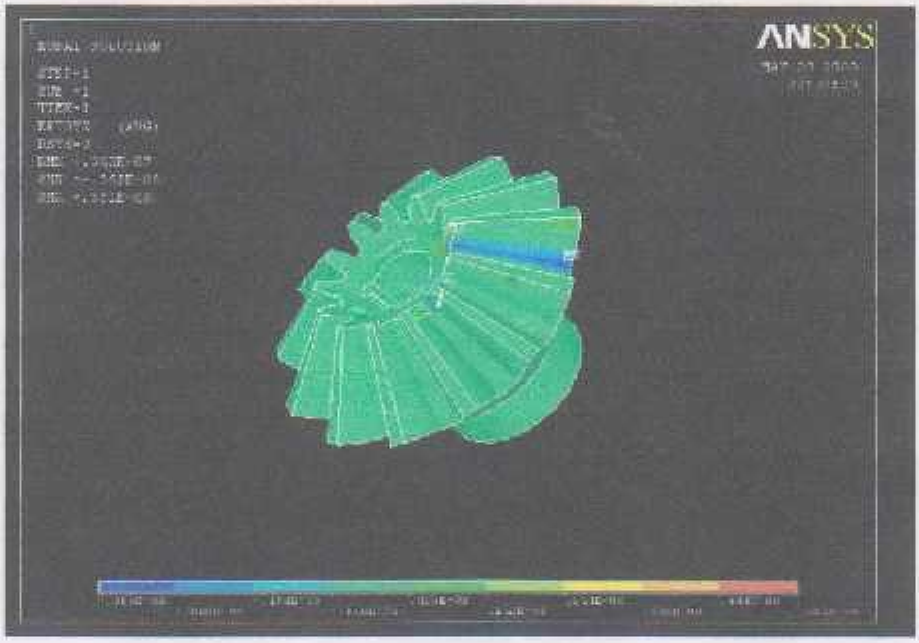


figure 3.54 YZ shear of total strain of bevel gear

From the previous figures of the shear strain it can be conclude that the shear is concentrated in YZ plane, and in the other two planes has less values and less concentration.

* **Strain intensity**

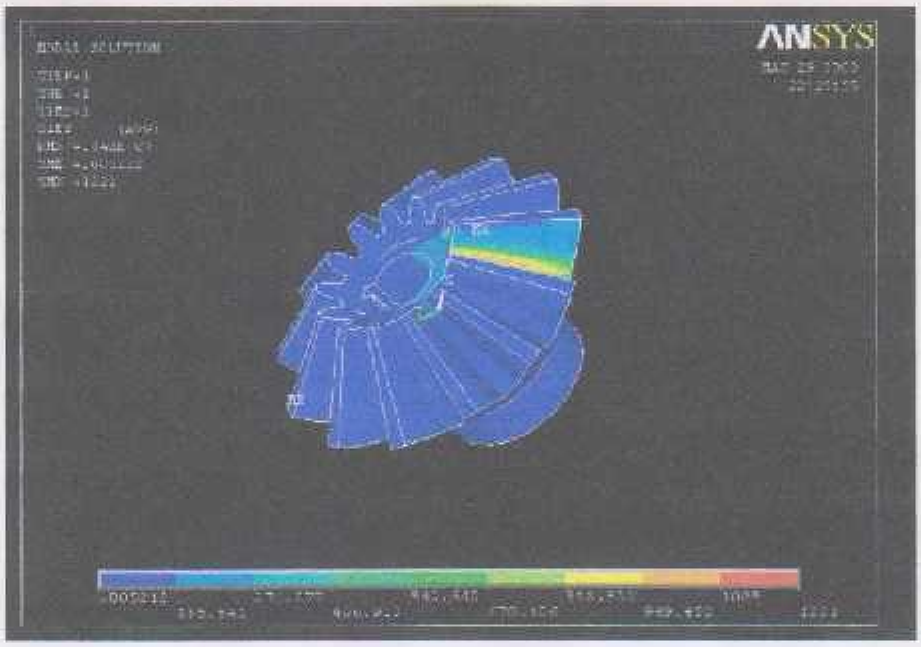


Figure 3.55 strain intensity of the bevel gear

Chapter four: Conclusions and Recommendations

4.1 conclusions

- A good base in the mechanical design calculations.
- A good knowledge in design considerations and constraints.
- A good base in CATIA, ANSYS, and SOLIDWORKS; the design begins using CATIA and SOLIDWORKS and after that this model is exported to ANSYS for the analysis.
- Many designs were made until the most optimized model was achieved.
- More than one criterion was used for the design such as von misses, shear stress in the planes.

4.2 Recommendations

- We strongly recommend providing a workstation in the university labs for the design calculations because these software need computers with high performance capacities to achieve correct and fast calculations.
- We strongly recommend to replace the AutoCAD course with CATIA and SOLIDWORKS for CAD and to insert the ANSYS as a university course.
- We also recommend providing independent budget for scientific researches aims to avoid the fund's problems occurred in the university.

4.3 Software to be used

4.3.1 CATIA

Why the CATIA program has been chosen for designing the manual gear transmission?
The decision was based on the high resolution of the 3D parts produced and the ease to move from the 2D to the 3D region.
It works in the way you think it should; you buy a block and start cutting, as opposed to making 2 blocks and subtracting them (Boolean),(AutoCAD).
It can be used in mechanical design because it uses the finite element method, also the software gives you the ability to assign material properties (metal like steel, aluminum, etc. or other types of material such as wood, stone, etc.), you can assign property values to the materials used such as the young modulus, poisons ratio, density, thermal expansion and yield strength.

When compared with AutoCAD you will find a big difference in the resolution. In addition AutoCAD does not support mechanical analysis on product, on the order hand CATIA affords a high flexibility in 3D operations which are not enhanced in AutoCAD; where AutoCAD is essentially based on Boolean rules such as subtracting one object from another, CAIA uses the idea of material removal such as pocketing.

Another feature in CATIA that has a huge effect on the design process is the ability to adjust the 3D parts without much effort in redrawing the parts from the beginning.

Another important thing when comparing the two software is that despite the high difference in resolution between CATIA and AutoCAD the size of the AutoCAD files is larger than the CATIA files.

4.3.2 ANSYS 9.0

ANSYS is a software package which used in finite element analysis. Its field of use is large including structural work, electromagnetic, fluid dynamics, thermal analysis, etc. ANSYS software is produced by ANSYS. Inc

The ANSYS 9.0 will be used to make the analysis of the parts of the manual gear transmission, so that the material and geometry of each component will be selected optimally.

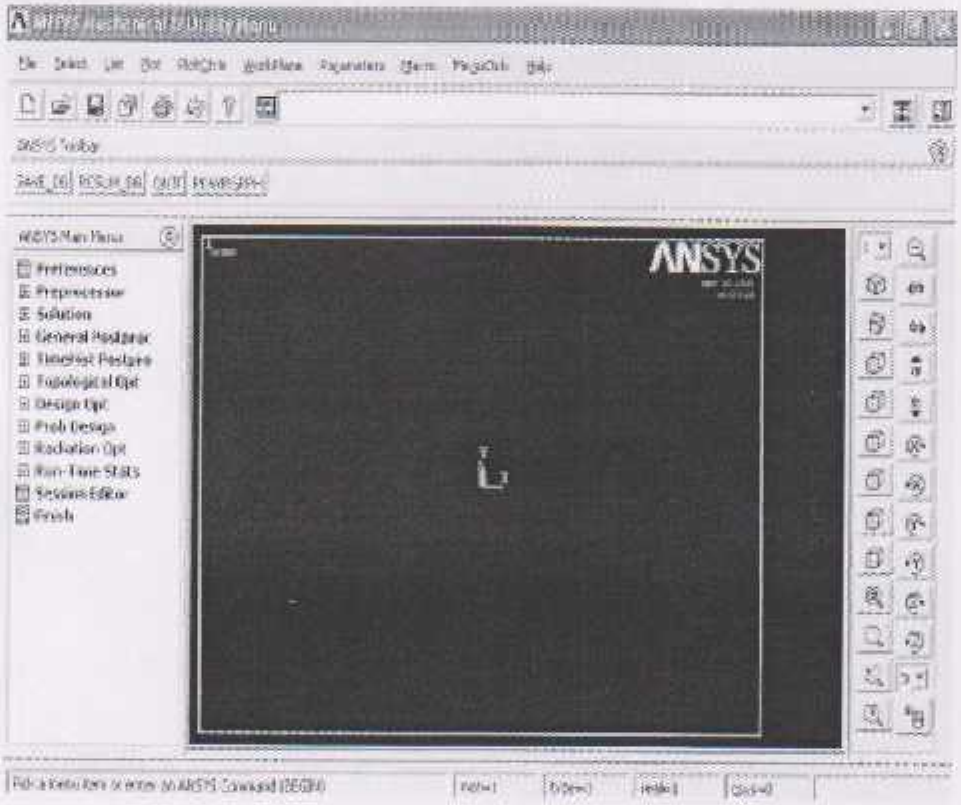


Figure 4.1 ANSYS Interface

The ANSYS 9.0 program has a comprehensive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation, and reference material.

ANSYS finite element analysis software enables engineers to perform the following tasks:

- Build computer models or transfer CAD models of structures, products, component, or systems.
- Apply operating loads or other design performance conditions.
- Study physical responses, such as stress levels, temperature distributions, or electromagnetic fields.
- Optimize a design early in the development process to reduce production costs.

4.3.3 SOLIDWORKS 3D CAD

SolidWorks is a 3D mechanical CAD used by product designers and mechanical engineers worldwide, its utilize a parametric feature-based approach to creating models and assemblies, allowing create accurate 3D models that automate a full range of design development process, reduce costs, and improve product quality.

SolidWorks software allows testing and revises product designs easily, so design work done 20-30% faster. SolidWorks easy to learn and use, it offers unmatched compatibility with AutoCAD software.
SolidWorks software allow preserving the value of the DWG data with the best available tools for converting data from 2D to 3D, accommodating reusable 2D geometry, and enabling a smooth transition, including extensive Help documentation for AutoCAD users.

4.3.4 MITCaLc

Due to the presence of several correction factors applied to Lewis stress equations and the correction factors required for correcting strengths, gear design can become quite unwieldy with out a computer, so MITCaLc is a system designed on Microsoft Excel being used to do all the calculations. It is based on AGMA stress and strength equations that are explained in details in chapter two.

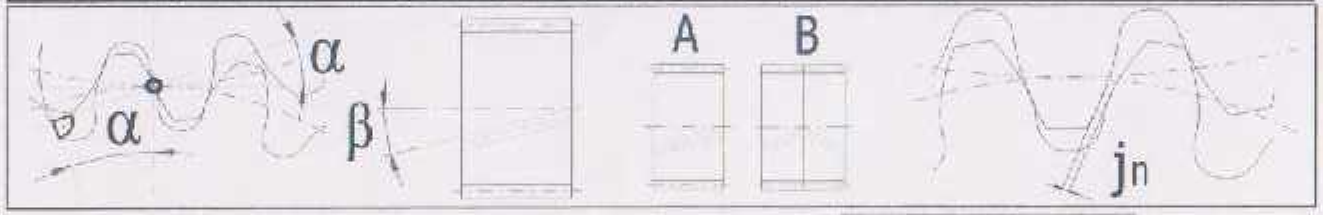
Appendix

Calculation of the conventional design

First gear

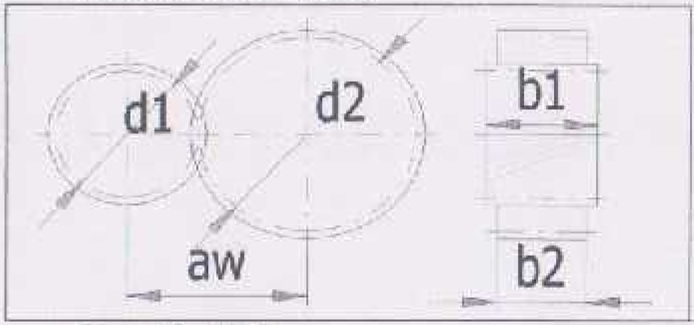
Spur gearing, Helical gearing [mm/ISO]

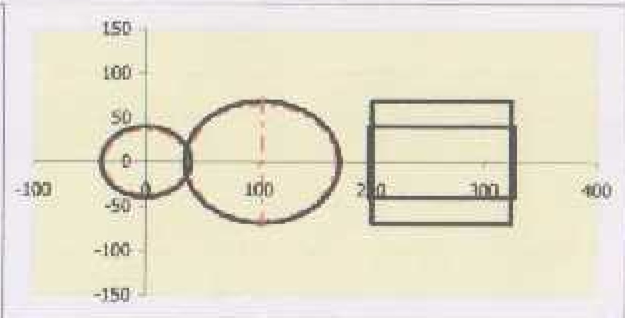
		Pinion	Gear	
Check lines:3.11;.;.;.;				
☐ Project information				
Input section				
☑ **Options of basic input parameters**				
Transferred power		70.000	68.544	[kW]
Speed (Pinion / Gear)		1000.0	558.1	[/min]
Torsional moment (Pinion / Gear)		668.50	1172.81	[Nm]
Transmission ratio / from table		1.80		
Actual transmission ratio / deviation		1.79	-0.47%	
☑ **Options of material, loading conditions, operational and production parameters**				
Material of the pinion :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.			
Material of the gear :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.			
Loading of the gearbox, driving machine - examples		A...Continuous		
Loading of gearbox, driven machine - examples		A...Continuous		
Type of gearing mounting		Overhung gearing - type 1		
Accuracy grade - ISO1328 |Ra max|v max		10....(Ra max.= 12.5 / v max.= 3)		
Coefficient of one-off overloading	KAS	2.00		
Desired service life	Lh	80000		[h]
Coefficient of safety (contact/bend)	SH / SF	1.10	1.30	
Automatic design ☐				
☑ **Design of a module and geometry of toothing**				



	Pinion	Gear	
Number of teeth Pinion / Gear	24	43	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

The ratio of the pinion width to its diameter	0.6	< 0.6	
Module / Standardized value	3		[mm]
Reference diameter Pinion / Gear	73.61	131.88	[mm]
Recommended width of gearing	47.1 - 44.2		[mm]
Face width (Pinion / Gear)	129.00	124.00	[mm]
Working face width	124		☑ [mm]
The ratio of the pinion width to its diameter	**1.75**	< 0.6	
Working center distance	102.93		[mm]
Working center distance	17.469		[mm]
Minimum coefficient of safety	0.295	0.220	





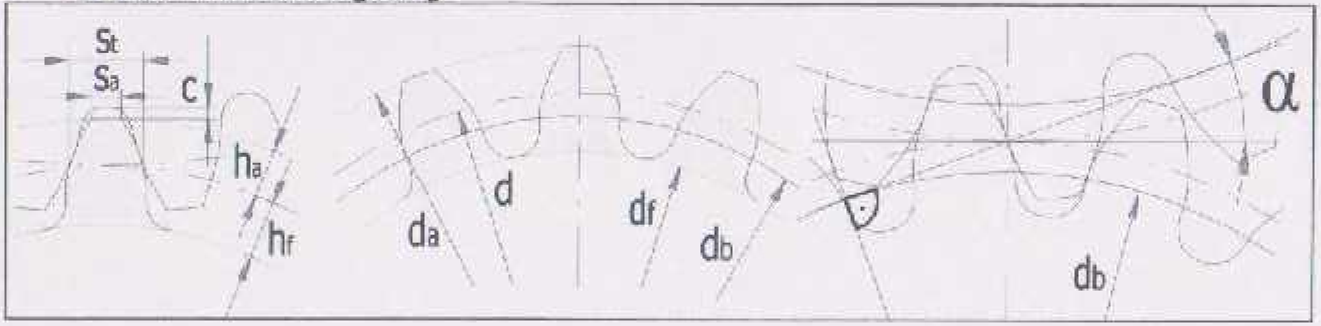
Normal backlash

- Recommended min. | max. value	0.061	0.243	[mm]
- Selected normal backlash	0.1230		[mm]

☐

Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	24	43	
Face width (Pinion / Gear)	129	124	[mm]
Normal module	3		[mm]
Transverse module	3.0670		[mm]
Circular pitch	9.425		[mm]
Transverse circular pitch	9.635		[mm]
Base circular pitch	9.030		[mm]
Center distance (pitch)	102.7452		[mm]
Center distance (production)	102.7452		[mm]
Center distance (working)	102.9250		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	79.9681	138.2415	[mm]
Reference diameter	73.6085	131.8819	[mm]
Base diameter	68.9873	123.6023	[mm]
Root diameter	66.1085	124.3819	[mm]
Operating pitch diameter	73.6085	131.8819	[mm]
Addendum	3.1798	3.1798	[mm]
Dedendum	3.7500	3.7500	[mm]
Tooth thickness on the tip diameter	1.9732	2.1416	[mm]
Tooth thickness on the tip diameter	2.0252	2.1941	[mm]
Tooth thickness on the pitch diameter	4.7124	4.7124	[mm]
Tooth thickness on the pitch diameter	4.8177	4.8177	[mm]
Tooth thickness on the root diameter	5.3762	6.5182	[mm]
Unit tooth thickness on the tip diameter	0.6751	0.7314	[modul]
Unit correction	-0.0599		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.57	
Meshing stiffness per unit face width	20.68	
Application factor	1	
Dynamic factor	1.38	
Number of cycles	4.80E+09	2.68E+09
For pitting safety calculation		
Face load factor (contact stress)	**6.99**	
Transverse load factor (contact stress)	1.77	
Total factor of additional loads	17.08	
Elasticity factor	189.81	
Zone factor	2.45	
Helix angle factor	0.99	
Contact ratio factor	0.77	
Lubricant factor	1.08	
Peripheral speed factor	0.97	
Roughness factor affecting surface durability	0.74	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
Face load factor (root stress)	6.36	
Transverse load factor (root stress)	1.77	
Total factor of additional loads	15.55	
Helix angle factor	0.90	
Contact ratio factor	0.67	
Notch sensitivity factor	1.10	
Size factor	1.00	
Tooth-root surface factor	0.88	
Alternating load factor	1.00	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	2.94	2.68
Stress correction factor	1.50	1.59
Tip factor, equal (YFa YSa)	4.43	4.26

☑ Safety coefficients

Safety coefficient for surface durability	**0.29**	**0.29**	
Safety coefficient for bending durability	**0.22**	**0.22**	
Safety in contact in one-time overloading	**0.66**	**0.66**	
Safety in bending in one-time overloading	**0.29**	**0.29**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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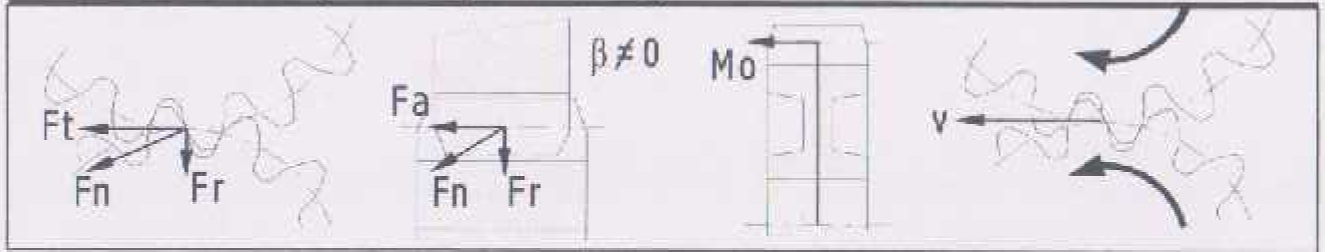
☑ Force conditions (forces acting on the toothing)



Tangential force	18163.66		[N]
Normal force	19761.19		[N]
Axial force	3860.80		[N]
Radial force	6758.73		[N]
Bending moment	154.37	266.86	[Nm]
Peripheral speed on the pitch diameter	**3.85**	< 3	[m/s]
Specific load / Unit load	146.48	48.83	[N/mm | MPa]

☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	785	785	[MPa]
Tensile Strength, Yield	539	539	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1140	1140	[MPa]
Bending Fatigue Limit	450	450	[MPa]
Tooth Hardness - Side	600	600	[HV]
Tooth Hardness - Core	250	250	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	

second gear

Spur gearing, Helical gearing [mm/ISO]

	Pinion	Gear	
Check lines:.;3.11;.;.;.;			
☐ **Project information**			

Input section

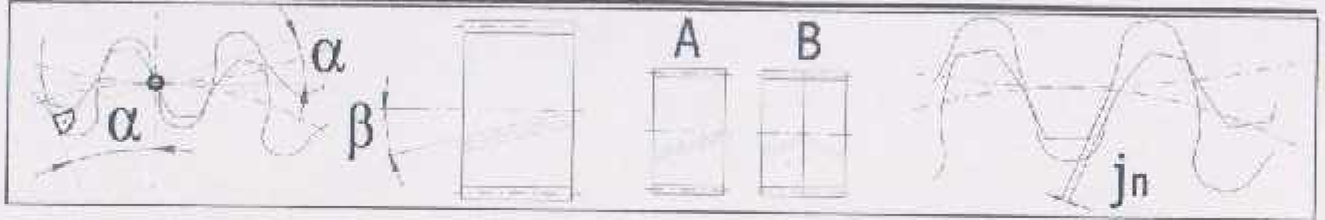
☑ Options of basic input parameters

	Pinion	Gear	
Transferred power	70.000	68.753	[kW]
Speed (Pinion / Gear)	1000.0	555.6	[/min]
Torsional moment (Pinion / Gear)	668.50	1181.86	[Nm]
Transmission ratio / from table	1.80		
Actual transmission ratio / deviation	1.80	0.00%	

☑ Options of material, loading conditions, operational and production parameters

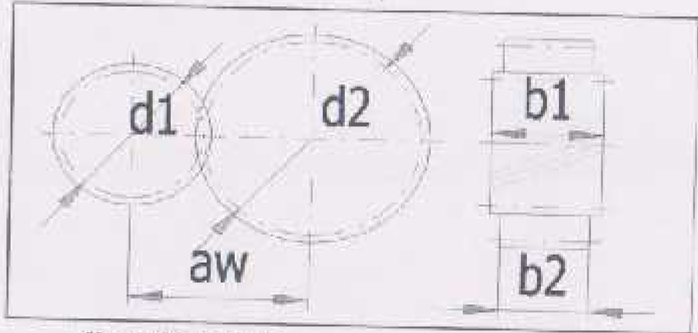
Material of the pinion :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.	
Material of the gear :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.	
Loading of the gearbox, driving machine - examples	A...Continuous	
Loading of gearbox, driven machine - examples	A...Continuous	
Type of gearing mounting	Overhung gearing - type 1	
Accuracy grade - ISO1328 |Ra max|v max	10.....(Ra max.= 12.5 / v max.= 3)	
Coefficient of one-off overloading (KAS)	2.00	
Desired service life (Lh)	80000	[h]
Coefficient of safety (contact/bend) (SH / SF)	1.10 / 1.30	
Automatic design	☐	

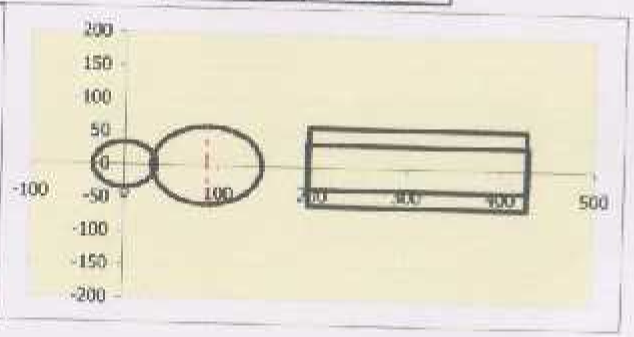
☑ Design of a module and geometry of toothing



Number of teeth Pinion / Gear	25	45	
Normal pressure angle	16		[°]
Base helix angle	0		[°]
Setting of the ratio of the width of the pinion to its diameter			

Parameter	Pinion	Gear	Unit
The ratio of the pinion width to its diameter	**1.05**	< 0.6	
Module / Standardized value	2.5		[mm]
Reference diameter Pinion / Gear	62.50	112.50	[mm]
Recommended width of gearing	40 - 37.5		[mm]
Face width (Pinion / Gear)	236.00	232.00	[mm]
Working face width	232		☑ [mm]
The ratio of the pinion width to its diameter	**3.78**	< 0.6	
Working center distance	87.72		[mm]
Working center distance	23.645		[mm]
Minimum coefficient of safety	0.153	0.040	





Normal backlash

Parameter	Min.	Max.	Unit
- Recommended min. | max. value	0.056	0.225	[mm]
- Selected normal backlash	0.1230		[mm]

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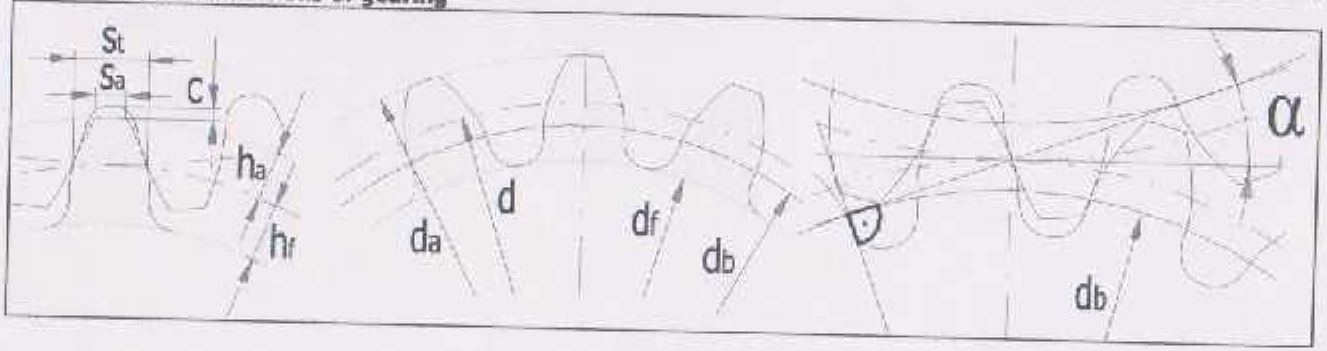
Results section

☑ **Basic dimensions of gearing**



Common for the gearing			
Stiffness of a tooth pair	c'	13.52	
Meshing stiffness per unit face width	C_{γ}	23.91	
Application factor	KA	1	
Dynamic factor	KV	1.56	
Number of cycles	NK	4.80E+09	2.67E+09
For pitting safety calculation			
Face load factor (contact stress)	$K_{H\beta}$	**24.73**	
Transverse load factor (contact stress)	$K_{H\alpha}$	1.52	
Total factor of additional loads	KH	58.67	
Elasticity factor	ZE	189.81	
Zone factor	ZH	2.75	
Helix angle factor	Zbeta	1.00	
Contact ratio factor	Zeps	0.81	
Lubricant factor	ZL	1.09	
Peripheral speed factor	ZV	0.97	
Roughness factor affecting surface durability	ZR	0.74	
Life factor for contact stress	ZN	0.85	0.85
Single pair tooth contact factor	ZB	1.01	1.01
For bending safety calculation			
Face load factor (root stress)	$K_{F\beta}$	23.90	
Transverse load factor (root stress)	$K_{F\alpha}$	2.56	
Total factor of additional loads	KF	95.55	
Helix angle factor	Ybeta	1.00	
Contact ratio factor	Yeps	0.63	
Notch sensitivity factor	Ydelta	1.10	
Size factor	YX	1.00	
Tooth-root surface factor	YR	0.88	
Alternating load factor	YA	1.00	
Production technology factor	YT	1.00	
Life factor	YN	1.00	1.00
Form factor (bending)	YFa	3.47	3.15
Stress correction factor	YSa	1.45	1.53
Tip factor, equal (YFa YSa)	YFS	5.02	4.81

☑ Safety coefficients

Safety coefficient for surface durability	SH	**0.15**	**0.15**	
Safety coefficient for bending durability	SF	**0.04**	**0.04**	
Safety in contact in one-time overloading	SHst	**0.34**	**0.34**	
Safety in bending in one-time overloading	SFst	**0.05**	**0.05**	
Variability coefficient for calculation of probability of a failı	vH/vF	0.08	0.1	
Probability of a failure	P	0.79		[%]

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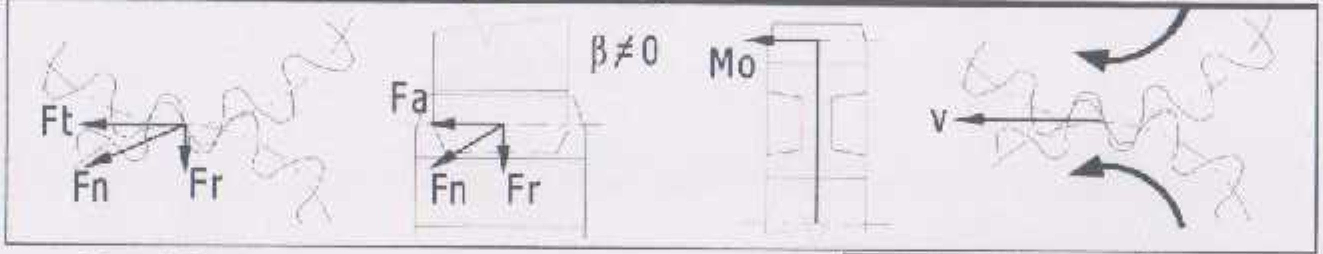
☑ Force conditions (forces acting on the toothing)



Tangential force	Ft	21392.00		[N]
Normal force	Fn	22254.09		[N]
Axial force	Fa	0.00		[N]
Radial force	Fr	6134.06		[N]
Bending moment	Mo	0.00	0.00	[Nm]
Peripheral speed on the pitch diameter	v | vmax	**3.27**	< 3	[m/s]
Specific load / Unit load	wt | wt*	92.21	36.88	[N/mm | MPa]

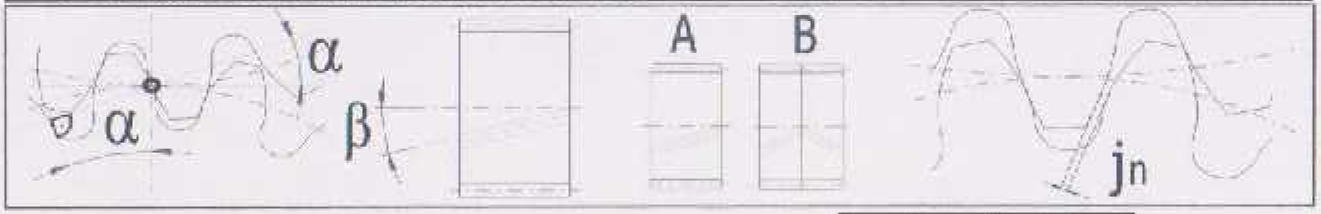
☑ Parameters of the chosen material

Density	Ro	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	E	206	206	[GPa]
Tensile Strength, Ultimate	Rm	785	785	[MPa]
Tensile Strength, Yield	Rp0.2	539	539	[MPa]
Poison's Ratio		0.3	0.3	
Contact Fatigue Limit	SHlim	1140	1140	[MPa]
Bending Fatigue Limit	SFlim	450	450	[MPa]
Tooth Hardness - Side	VHV	600	600	[HV]
Tooth Hardness - Core	JHV	250	250	[HV]
Base Number of Load Cycles in Contact	NHlim	1.00E+08	1.00E+08	

Third gear

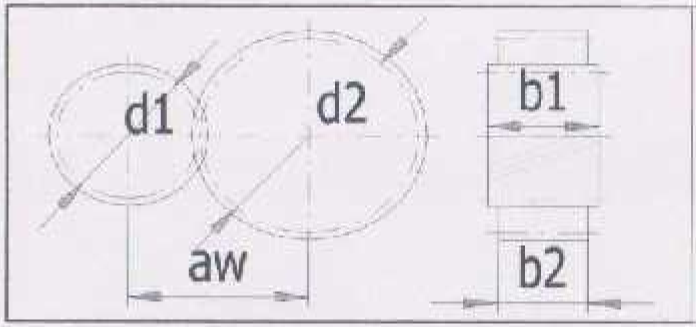
Spur gearing, Helical gearing [mm/ISO]

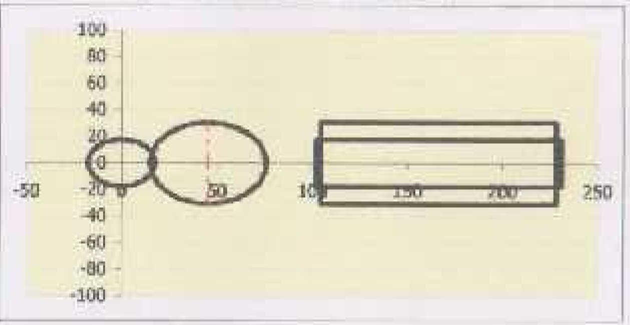
	Pinion	Gear	
Check lines:3.11;.;.;			
☐ **Project information**			
Input section			
☑ **Options of basic input parameters**			
Transferred power	70.000	67.299	[kW]
Speed (Pinion / Gear)	1000.0	552.6	[/min]
Torsional moment (Pinion / Gear)	668.50	1162.99	[Nm]
Transmission ratio / from table	1.80		
Actual transmission ratio / deviation	1.81	0.53%	
☑ **Options of material, loading conditions, operational and production parameters**			
Material of the pinion :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Material of the gear :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Loading of the gearbox, driving machine - examples	A...Continuous		
Loading of gearbox, driven machine - examples	A...Continuous		
Type of gearing mounting	Overhung gearing - type I		
Accuracy grade - ISO1328 [Ra max]v max	10.....(Ra max.= 12.5 / v max.= 3)		
Coefficient of one-off overloading	2.00		
Desired service life	80000		[h]
Coefficient of safety (contact/bend)	1.10	1.30	
Automatic design ☐			
☑ **Design of a module and geometry of toothing**			



Number of teeth Pinion / Gear	21	38	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

Parameter	Pinion	Gear	Unit
The ratio of the pinion width to its diameter	0.6	< 0.6	
Module / Standardized value	1.5		[mm]
Reference diameter Pinion / Gear	32.20	58.27	[mm]
Recommended width of gearing	20.6 - 19.3		[mm]
Face width (Pinion / Gear)	129.00	124.00	[mm]
Working face width	124		☑ [mm]
The ratio of the pinion width to its diameter	**4.01**	< 0.6	
Working center distance	45.42		[mm]
Working center distance	3.402		[mm]
Minimum coefficient of safety	0.077	0.016	





Normal backlash

- Recommended min. | max. value	0.040	0.162	[mm]
- Selected normal backlash	0.1230		[mm]

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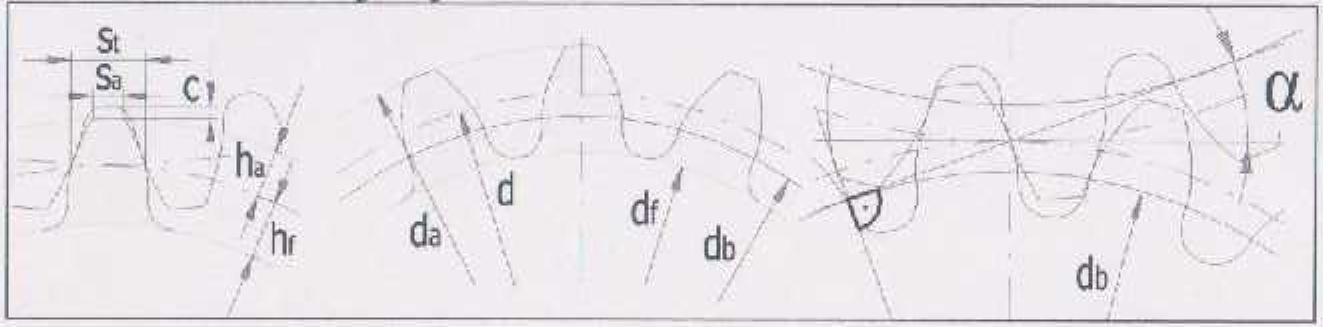
Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	21	38

Parameter	Pinion	Gear	Unit
Face width (Pinion / Gear)	129	124	[mm]
Normal module	1.5		[mm]
Transverse module	1.5335		[mm]
Circular pitch	4.712		[mm]
Transverse circular pitch	4.818		[mm]
Base circular pitch	4.515		[mm]
Center distance (pitch)	45.2386		[mm]
Center distance (production)	45.2386		[mm]
Center distance (working)	45.4184		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	35.5633	61.6330	[mm]
Reference diameter	32.2037	58.2734	[mm]
Base diameter	30.1820	54.6150	[mm]
Root diameter	28.4537	54.5234	[mm]
Operating pitch diameter	32.2037	58.2734	[mm]
Addendum	1.6798	1.6798	[mm]
Dedendum	1.8750	1.8750	[mm]
Tooth thickness on the tip diameter	0.8578	0.9677	[mm]
Tooth thickness on the tip diameter	0.8811	0.9918	[mm]
Tooth thickness on the pitch diameter	2.3562	2.3562	[mm]
Tooth thickness on the pitch diameter	2.4088	2.4088	[mm]
Tooth thickness on the root diameter	2.5800	3.1193	[mm]
Unit tooth thickness on the tip diameter	0.5874	0.6612	[modul]
Unit correction	-0.1199		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.21	
Meshing stiffness per unit face width	20.65	
Application factor	1	
Dynamic factor	1.07	
Number of cycles	4.80E+09	2.65E+09
For pitting safety calculation		
Face load factor (contact stress)	**25.94**	
Transverse load factor (contact stress)	1.82	
Total factor of additional loads	50.36	
Elasticity factor	189.81	
Zone factor	2.45	
Helix angle factor	0.99	
Contact ratio factor	0.76	
Lubricant factor	1.11	
Peripheral speed factor	0.95	
Roughness factor affecting surface durability	0.74	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
Face load factor (root stress)	23.98	
Transverse load factor (root stress)	1.82	
Total factor of additional loads	46.55	
Helix angle factor	0.90	
Contact ratio factor	0.66	
Notch sensitivity factor	1.10	
Size factor	1.00	
Tooth-root surface factor	0.88	
Alternating load factor	1.00	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	3.11	2.80
Stress correction factor	1.47	1.56
Tip factor, equal (YFa YSa)	4.58	4.37

☑ **Safety coefficients**

Safety coefficient for surface durability	**0.08**	**0.08**	
Safety coefficient for bending durability	**0.02**	**0.02**	
Safety in contact in one-time overloading	**0.17**	**0.17**	
Safety in bending in one-time overloading	**0.02**	**0.02**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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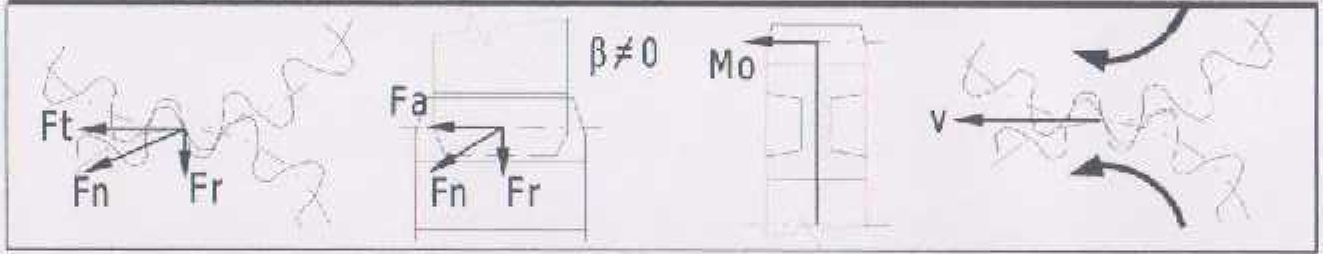
☑ Force conditions (forces acting on the toothing)



Tangential force	41516.93		[N]
Normal force	45168.43		[N]
Axial force	8824.70		[N]
Radial force	15448.51		[N]
Bending moment	156.92	271.95	[Nm]
Peripheral speed on the pitch diameter	1.69	< 3	[m/s]
Specific load / Unit load	334.81	223.21	[N/mm | MPa]

☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	785	785	[MPa]
Tensile Strength, Yield	539	539	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1140	1140	[MPa]
Bending Fatigue Limit	450	450	[MPa]
Tooth Hardness - Side	600	600	[HV]
Tooth Hardness - Core	250	250	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	
Wohler Curve Exponent for Contact	10	10	

Fourth gear

Spur gearing, Helical gearing [mm/ISO]

		Pinion	Gear	
Check lines:3.11;.;.;				
☐ Project information				

Input section

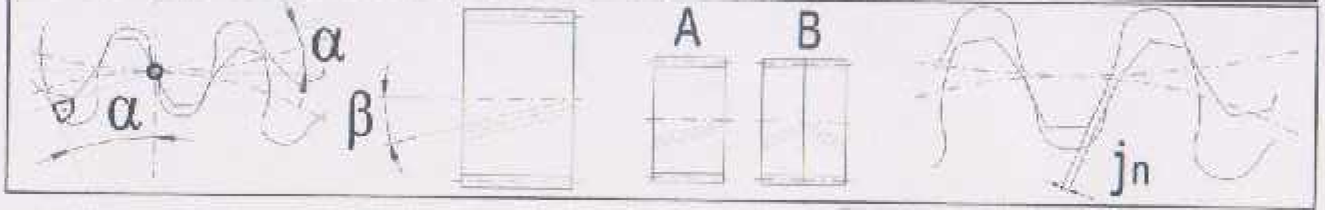
☑ Options of basic input parameters

Parameter		Pinion	Gear	Unit
Transferred power		70.000	66.877	[kW]
Speed (Pinion / Gear)		1000.0	552.6	[/min]
Torsional moment (Pinion / Gear)		668.50	1155.71	[Nm]
Transmission ratio / from table		1.80		
Actual transmission ratio / deviation		1.81	0.53%	

☑ Options of material, loading conditions, operational and production parameters

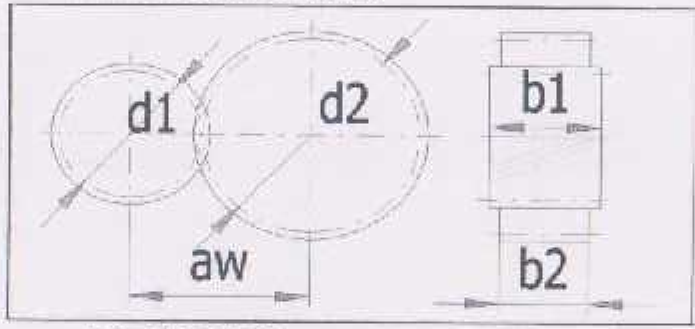
Material of the pinion :		E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Material of the gear :		E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Loading of the gearbox, driving machine - examples		A...Continuous		
Loading of gearbox, driven machine - examples		A...Continuous		
Type of gearing mounting		Overhung gearing - type 1		
Accuracy grade - ISO1328 |Ra max|v max		10.....(Ra max.= 12.5 / v max.= 3)		
Coefficient of one-off overloading	0	2.00		
Desired service life	0	80000		[h]
Coefficient of safety (contact/bend)	0	1.10	1.30	
Automatic design ☐				

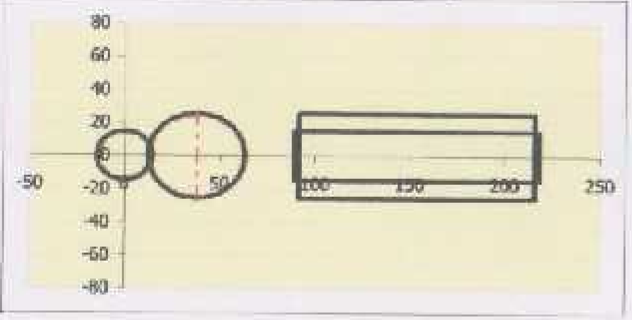
☑ Design of a module and geometry of toothing



Parameter	Pinion	Gear	Unit
Number of teeth Pinion / Gear	21	38	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

The ratio of the pinion width to its diameter	0.6	< 0.6	
Module / Standardized value	1.25		[mm]
Reference diameter Pinion / Gear	26.84	48.56	[mm]
Recommended width of gearing	17.2 - 16.1		[mm]
Face width (Pinion / Gear)	129.00	124.00	[mm]
Working face width	124		☑ [mm]
The ratio of the pinion width to its diameter	**4.81**	< 0.6	
Working center distance	37.88		[mm]
Working center distance	2.366		[mm]
Minimum coefficient of safety	0.058	0.009	





Normal backlash

- Recommended min. | max. value	0.037	0.148	[mm]
- Selected normal backlash	0.1230		[mm]

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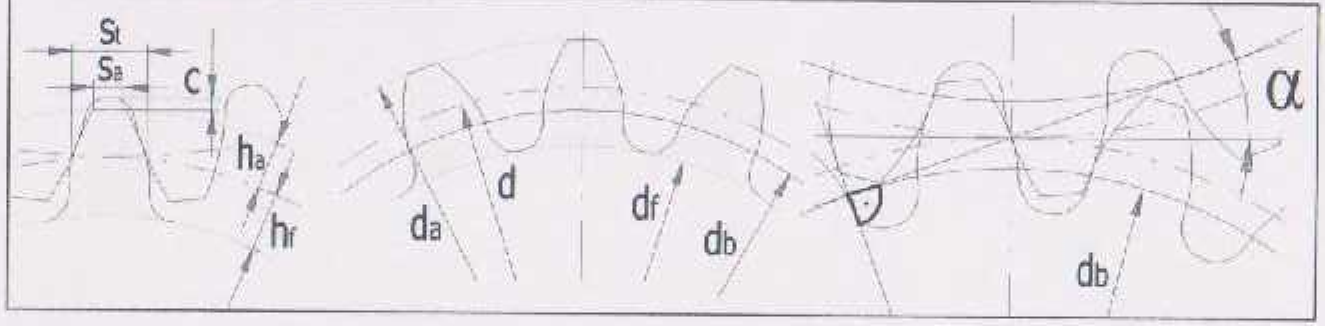
Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	21	38	
Face width (Pinion / Gear)	129	124	[mm]
Normal module	1.25		[mm]
Transverse module	1.2779		[mm]
Circular pitch	3.927		[mm]
Transverse circular pitch	4.015		[mm]
Base circular pitch	3.763		[mm]
Center distance (pitch)	37.6988		[mm]
Center distance (production)	37.6988		[mm]
Center distance (working)	37.8786		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	29.6961	51.4208	[mm]
Reference diameter	26.8364	48.5612	[mm]
Base diameter	25.1516	45.5125	[mm]
Root diameter	23.7114	45.4362	[mm]
Operating pitch diameter	26.8364	48.5612	[mm]
Addendum	1.4298	1.4298	[mm]
Dedendum	1.5625	1.5625	[mm]
Tooth thickness on the tip diameter	0.6797	0.7766	[mm]
Tooth thickness on the tip diameter	0.6982	0.7960	[mm]
Tooth thickness on the pitch diameter	1.9635	1.9635	[mm]
Tooth thickness on the pitch diameter	2.0074	2.0074	[mm]
Tooth thickness on the root diameter	2.1500	2.5995	[mm]
Unit tooth thickness on the tip diameter	0.5586	0.6368	[modul]
Unit correction	-0.1438		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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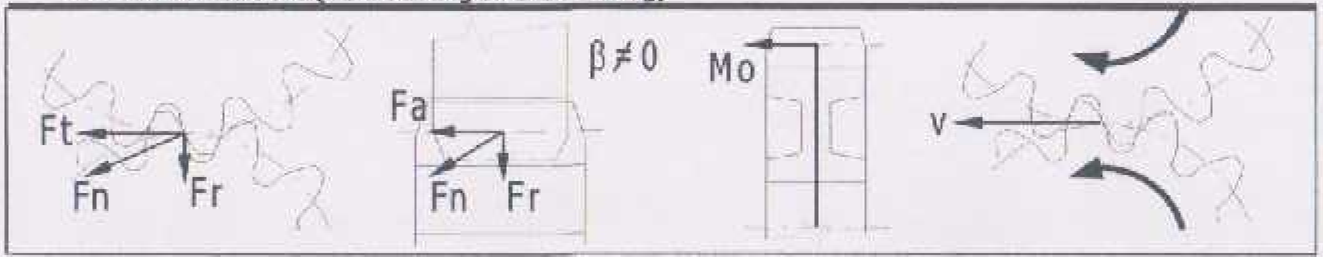
Common for the gearing		
. Stiffness of a tooth pair	13.21	
. Meshing stiffness per unit face width	20.97	
. Application factor	1	
. Dynamic factor	1.05	
. Number of cycles	4.80E+09	2.65E+09
For pitting safety calculation		
. Face load factor (contact stress)	**32.68**	
. Transverse load factor (contact stress)	1.85	
. Total factor of additional loads	63.41	
. Elasticity factor	189.81	
. Zone factor	2.45	
. Helix angle factor	0.99	
. Contact ratio factor	0.75	
. Lubricant factor	1.11	
. Peripheral speed factor	0.95	
. Roughness factor affecting surface durability	0.74	
. Life factor for contact stress	0.85	0.85
. Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
. Face load factor (root stress)	30.46	
. Transverse load factor (root stress)	1.85	
. Total factor of additional loads	59.10	
. Helix angle factor	0.90	
. Contact ratio factor	0.65	
. Notch sensitivity factor	1.10	
. Size factor	1.00	
. Tooth-root surface factor	0.88	
. Alternating load factor	1.00	
. Production technology factor	1.00	
. Life factor	1.00	1.00
. Form factor (bending)	3.14	2.82
. Stress correction factor	1.47	1.56
. Tip factor, equal (YFa YSa)	4.62	4.40

☑ Safety coefficients

Safety coefficient for surface durability	**0.06**	**0.06**	
Safety coefficient for bending durability	**0.01**	**0.01**	
Safety in contact in one-time overloading	**0.13**	**0.13**	
Safety in bending in one-time overloading	**0.01**	**0.01**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

☐

☑ Force conditions (forces acting on the toothing)



Tangential force	49820.32		[N]
Normal force	54202.12		[N]
Axial force	10589.64		[N]
Radial force	18538.22		[N]
Bending moment	157.24	272.26	[Nm]
Peripheral speed on the pitch diameter	1.41	< 3	[m/s]
Specific load / Unit load	401.78	321.42	[N/mm | MPa]

☑ Parameters of the chosen material

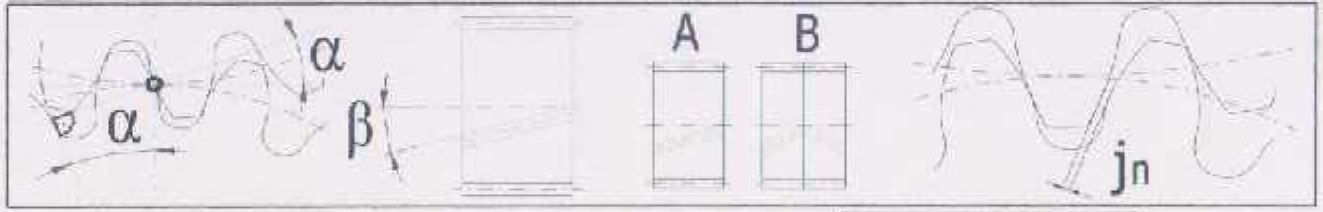
Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	785	785	[MPa]
Tensile Strength, Yield	539	539	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1140	1140	[MPa]
Bending Fatigue Limit	450	450	[MPa]
Tooth Hardness - Side	600	600	[HV]
Tooth Hardness - Core	250	250	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	

Fifth gear

Spur gearing, Helical gearing [mm/ISO]

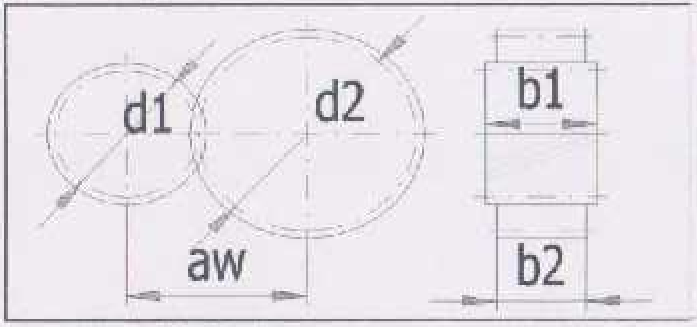
Check lines:3.11;.;.;		Pinion	Gear	
☐ Project information				
Input section				
☑ **Options of basic input parameters**				
Transferred power		70.000	66.246	[kW]
Speed (Pinion / Gear)		1000.0	552.6	[/min]
Torsional moment (Pinion / Gear)		668.50	1144.79	[Nm]
Transmission ratio / from table		1.80		
Actual transmission ratio / deviation		1.81	0.53%	
☑ **Options of material, loading conditions, operational and production parameters**				
Material of the pinion :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.			
Material of the gear :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.			
Loading of the gearbox, driving machine - examples		A...Continuous		
Loading of gearbox, driven machine - examples		A...Continuous		
Type of gearing mounting		Overhung gearing - type 1		
Accuracy grade - ISO1328 |Ra max|v max		10.....(Ra max.= 12.5 / v max.= 3)		
Coefficient of one-off overloading	0	2.00		
Desired service life	0	80000		[h]
Coefficient of safety (contact/bend)	0	1.10	1.30	
Automatic design ☐				

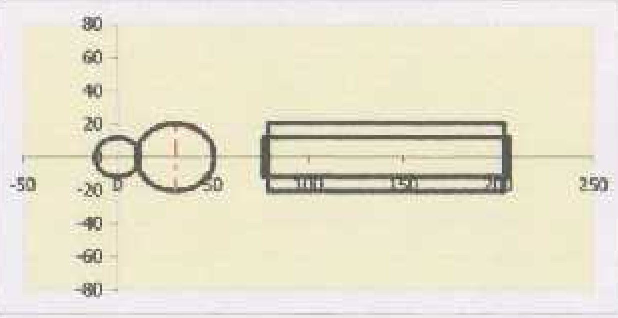
☑ **Design of a module and geometry of toothing**



Number of teeth Pinion / Gear	21	38	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

The ratio of the pinion width to its diameter	0.6	< 0.6	
Module / Standardized value	1		[mm]
Reference diameter Pinion / Gear	21.47	38.85	[mm]
Recommended width of gearing	13.7 - 12.9		[mm]
Face width (Pinion / Gear)	129.00	124.00	[mm]
Working face width	124		☑ [mm]
The ratio of the pinion width to its diameter	**6.01**	< 0.6	
Working center distance	30.34		[mm]
Working center distance	1.518		[mm]
Minimum coefficient of safety	0.041	0.004	





Normal backlash

- Recommended min. | max. value	0.033	0.132	[mm]
- Selected normal backlash	0.1230		[mm]

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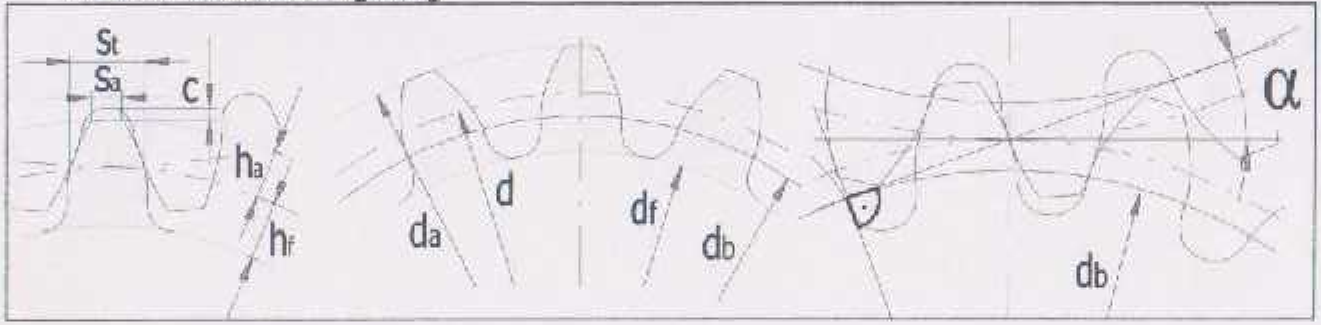
Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	21	38	
Face width (Pinion / Gear)	129	124	[mm]
Normal module	1		[mm]
Transverse module	1.0223		[mm]
Circular pitch	3.142		[mm]
Transverse circular pitch	3.212		[mm]
Base circular pitch	3.010		[mm]
Center distance (pitch)	30.1590		[mm]
Center distance (production)	30.1590		[mm]
Center distance (working)	30.3389		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	23.8288	41.2086	[mm]
Reference diameter	21.4692	38.8489	[mm]
Base diameter	20.1213	36.4100	[mm]
Root diameter	18.9692	36.3489	[mm]
Operating pitch diameter	21.4691	38.8489	[mm]
Addendum	1.1798	1.1798	[mm]
Dedendum	1.2500	1.2500	[mm]
Tooth thickness on the tip diameter	0.5011	0.5852	[mm]
Tooth thickness on the tip diameter	0.5148	0.5999	[mm]
Tooth thickness on the pitch diameter	1.5708	1.5708	[mm]
Tooth thickness on the pitch diameter	1.6059	1.6059	[mm]
Tooth thickness on the root diameter	1.7200	2.0796	[mm]
Unit tooth thickness on the tip diameter	0.5148	0.5999	[modul]
Unit correction	-0.1798		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
. Stiffness of a tooth pair	13.21	
. Meshing stiffness per unit face width	21.44	
. Application factor	1	
. Dynamic factor	1.03	
. Number of cycles	4.80E+09	2.65E+09
For pitting safety calculation		
. Face load factor (contact stress)	**42.79**	
. Transverse load factor (contact stress)	1.90	
. Total factor of additional loads	83.93	
. Elasticity factor	189.81	
. Zone factor	2.45	
. Helix angle factor	0.99	
. Contact ratio factor	0.74	
. Lubricant factor	1.12	
. Peripheral speed factor	0.95	
. Roughness factor affecting surface durability	0.74	
. Life factor for contact stress	0.85	0.85
. Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
. Face load factor (root stress)	40.27	
. Transverse load factor (root stress)	1.90	
. Total factor of additional loads	79.00	
. Helix angle factor	0.90	
. Contact ratio factor	0.64	
. Notch sensitivity factor	1.10	
. Size factor	1.00	
. Tooth-root surface factor	0.88	
. Alternating load factor	1.00	
. Production technology factor	1.00	
. Life factor	1.00	1.00
. Form factor (bending)	3.18	2.87
. Stress correction factor	1.47	1.55

Tip factor, equal (YFa YSa)	4.67	4.46	

☑ Safety coefficients

Safety coefficient for surface durability	**0.04**	**0.04**	
Safety coefficient for bending durability	**0.00**	**0.00**	
Safety in contact in one-time overloading	**0.09**	**0.09**	
Safety in bending in one-time overloading	**0.01**	**0.01**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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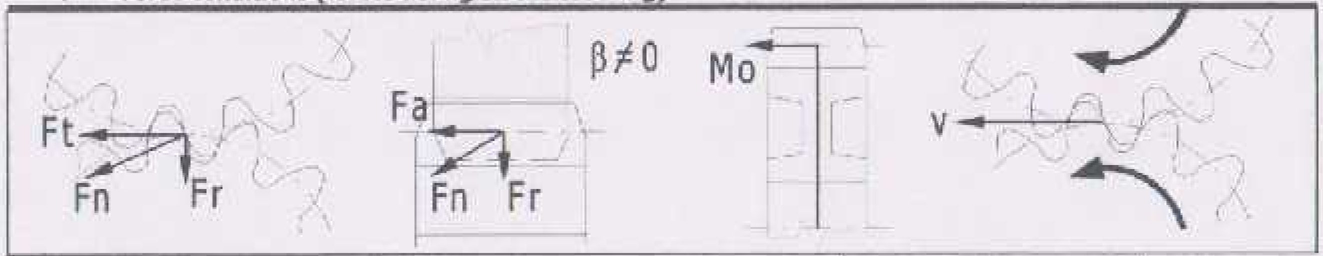
☑ Force conditions (forces acting on the toothing)



Tangential force	62275.40		[N]
Normal force	67752.65		[N]
Axial force	13237.04		[N]
Radial force	23172.77		[N]
Bending moment	157.71	272.74	[Nm]
Peripheral speed on the pitch diameter	1.12	< 3	[m/s]
Specific load / Unit load	502.22	502.22	[N/mm | MPa]

☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	785	785	[MPa]
Tensile Strength, Yield	539	539	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1140	1140	[MPa]
Bending Fatigue Limit	450	450	[MPa]
Tooth Hardness - Side	600	600	[HV]

Reverse gear

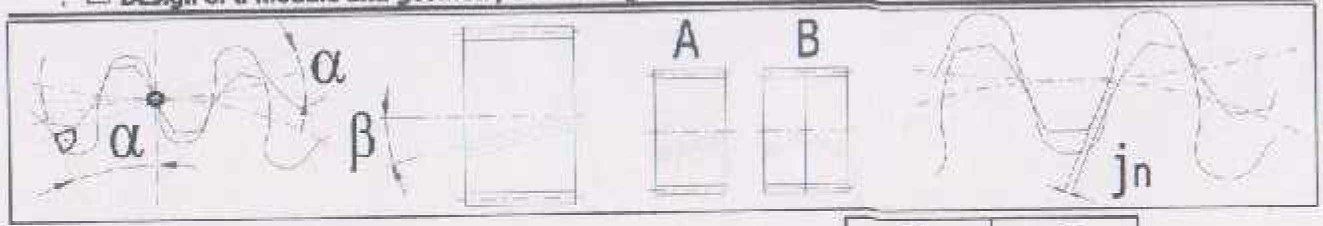
Spur gearing, Helical gearing [mm/ISO]

	Pinion	Gear	
Check lines:.;3.11;.;.;.;			
☐ **Project information**			
Input section			
☑ **Options of basic input parameters**			
Transferred power	70.000	68.753	[kW]
Speed (Pinion / Gear)	1000.0	555.6	[/min]
Torsional moment (Pinion / Gear)	668.50	1181.86	[Nm]
Transmission ratio / from table	1.80		
Actual transmission ratio / deviation	1.80	0.00%	

☑ Options of material, loading conditions, operational and production parameters

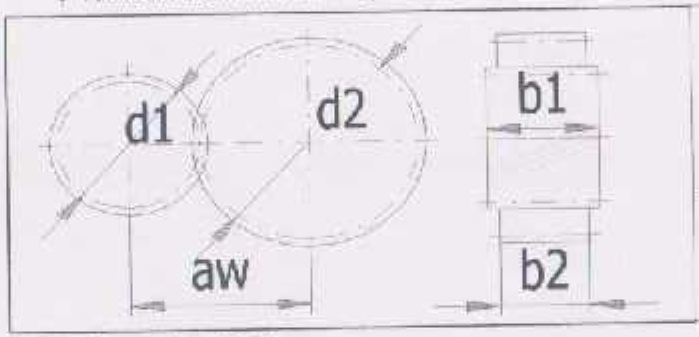
Material of the pinion :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Material of the gear :	E,F...Alloy structural steel T2(683/7-70) (Rm=785 MPa) tooth face hard.		
Loading of the gearbox, driving machine - examples	A...Continuous		
Loading of gearbox, driven machine - examples	A...Continuous		
Type of gearing mounting	Overhung gearing - type 1		
Accuracy grade - ISO1328 |Ra max|v max	10.....(Ra max.= 12.5 / v max.= 3)		
Coefficient of one-off overloading	KAS	2.00	
Desired service life	Lh	80000	[h]
Coefficient of safety (contact/bend)	SH / SF	1.10 / 1.30	
Automatic design ☐			

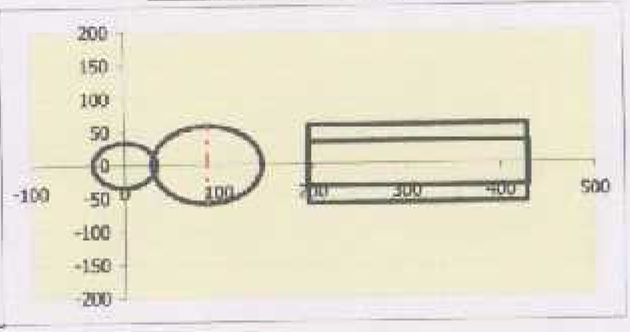
☑ Design of a module and geometry of toothing



Number of teeth Pinion / Gear	25	45	
Normal pressure angle	16		[°]
Base helix angle	0		[°]
Setting of the ratio of the width of the pinion to its diameter	◄ ►		

Parameter	Value		Unit
The ratio of the pinion width to its diameter	**1.05**	< 0.6	
Module / Standardized value	2.5		[mm]
Reference diameter Pinion / Gear	62.50	112.50	[mm]
Recommended width of gearing	40 - 37.5		[mm]
Face width (Pinion / Gear)	236.00	232.00	[mm]
Working face width	232		☑ [mm]
The ratio of the pinion width to its diameter	**3.78**	< 0.6	
Working center distance	87.72		[mm]
Working center distance	23.645		[mm]
Minimum coefficient of safety	0.153	0.040	





Normal backlash

- Recommended min. | max. value	0.056	0.225	[mm]
- Selected normal backlash	0.1230		[mm]

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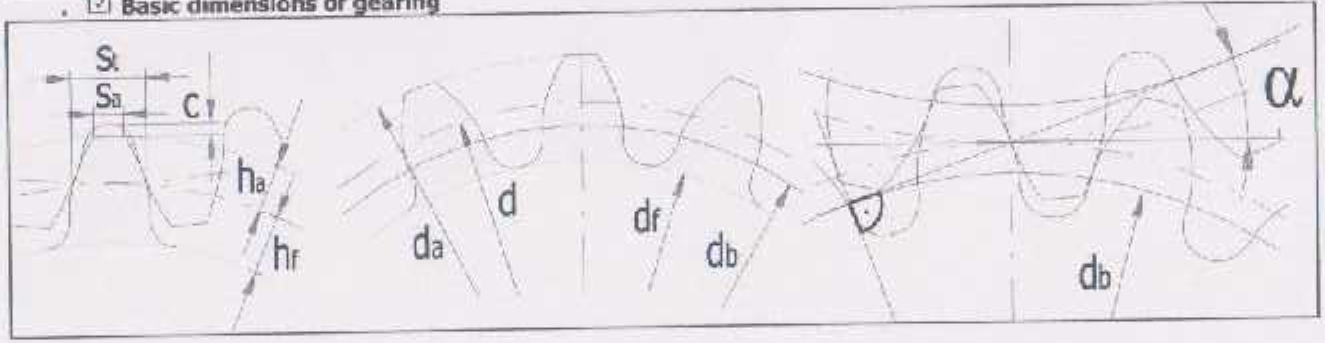
Results section

☑ **Basic dimensions of gearing**



Parameter	Pinion	Gear	Unit
Number of teeth Pinion / Gear	25	45	
Face width (Pinion / Gear)	236	232	[mm]
Normal module	2.5		[mm]
Transverse module	2.5000		[mm]
Circular pitch	7.854		[mm]
Transverse circular pitch	7.854		[mm]
Base circular pitch	7.550		[mm]
Center distance (pitch)	87.5000		[mm]
Center distance (production)	87.5000		[mm]
Center distance (working)	87.7231		[mm]
Pressure angle	16.00		[°]
Transverse pressure angle	16.0000		[°]
Pressure angle at the pitch cylinder	16.0000		[°]
Transverse pressure angle at the pitch cylinder	16.0000		[°]
Helix angle	0.00		[°]
Base helix angle	0.0000		[°]
Tip diameter	67.9463	117.9463	[mm]
Reference diameter	62.5000	112.5000	[mm]
Base diameter	60.0789	108.1419	[mm]
Root diameter	56.2500	106.2500	[mm]
Operating pitch diameter	62.5000	112.5000	[mm]
Addendum	2.7231	2.7231	[mm]
Dedendum	3.1250	3.1250	[mm]
Tooth thickness on the tip diameter	1.9069	2.0819	[mm]
Tooth thickness on the tip diameter	1.9069	2.0819	[mm]
Tooth thickness on the pitch diameter	3.9270	3.9270	[mm]
Tooth thickness on the pitch diameter	3.9270	3.9270	[mm]
Tooth thickness on the root diameter	3.9558	4.5049	[mm]
Unit tooth thickness on the tip diameter	0.7628	0.8328	[modul]
Unit correction	-0.0893		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing			
Stiffness of a tooth pair	c'	13.52	
Meshing stiffness per unit face width	cγ	23.91	
Application factor	KA	1	
Dynamic factor	KV	1.56	
Number of cycles	NK	4.80E+09	2.67E+09
For pitting safety calculation			
Face load factor (contact stress)	$K_{H\beta}$	**24.73**	
Transverse load factor (contact stress)	$K_{H\alpha}$	1.52	
Total factor of additional loads	KH	58.67	
Elasticity factor	ZE	189.81	
Zone factor	ZH	2.75	
Helix angle factor	Zbeta	1.00	
Contact ratio factor	Zeps	0.81	
Lubricant factor	ZL	1.09	
Peripheral speed factor	ZV	0.97	
Roughness factor affecting surface durability	ZR	0.74	
Life factor for contact stress	ZN	0.85	0.85
Single pair tooth contact factor	ZB	1.01	1.01
For bending safety calculation			
Face load factor (root stress)	$K_{F\beta}$	23.90	
Transverse load factor (root stress)	$K_{F\alpha}$	2.56	
Total factor of additional loads	KF	95.55	
Helix angle factor	Ybeta	1.00	
Contact ratio factor	Yeps	0.63	
Notch sensitivity factor	Ydelta	1.10	
Size factor	YX	1.00	
Tooth-root surface factor	YR	0.88	
Alternating load factor	YA	1.00	
Production technology factor	YT	1.00	
Life factor	YN	1.00	1.00
Form factor (bending)	YFa	3.47	3.15
Stress correction factor	YSa	1.45	1.53
Tip factor, equal (YFa YSa)	YFS	5.02	4.81

☑ Safety coefficients

Safety coefficient for surface durability	SH	**0.15**	**0.15**	
Safety coefficient for bending durability	SF	**0.04**	**0.04**	
Safety in contact in one-time overloading	SHst	**0.34**	**0.34**	
Safety in bending in one-time overloading	SFst	**0.05**	**0.05**	
Variability coefficient for calculation of probability of a fail	vH/vF	0.08	0.1	
Probability of a failure	P	0.79		[%]

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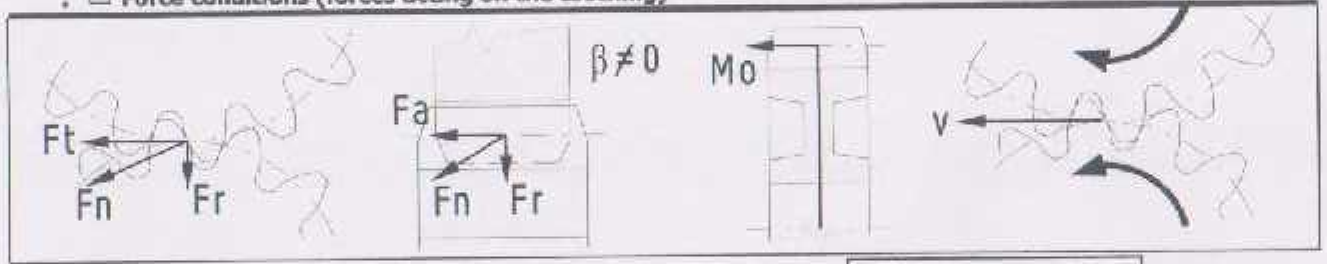
☑ Force conditions (forces acting on the toothing)



Tangential force	Ft	21392.00		[N]
Normal force	Fn	22254.09		[N]
Axial force	Fa	0.00		[N]
Radial force	Fr	6134.06		[N]
Bending moment	Mo	0.00	0.00	[Nm]
Peripheral speed on the pitch diameter	v | vmax	**3.27**	< 3	[m/s]
Specific load / Unit load	wt | wt*	92.21	36.88	[N/mm | MPa]

☑ Parameters of the chosen material

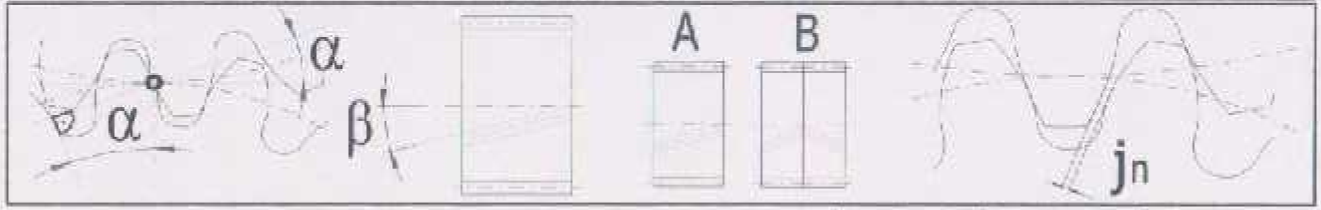
Density	Ro	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	E	206	206	[GPa]
Tensile Strength, Ultimate	Rm	785	785	[MPa]
Tensile Strength, Yield	Rp0.2	539	539	[MPa]
Poison's Ratio		0.3	0.3	
Contact Fatigue Limit	SHlim	1140	1140	[MPa]
Bending Fatigue Limit	SFlim	450	450	[MPa]
Tooth Hardness - Side	VHV	600	600	[HV]
Tooth Hardness - Core	JHV	250	250	[HV]
Base Number of Load Cycles in Contact	NHlim	1.00E+08	1.00E+08	

Calculation of the modified design

First gear

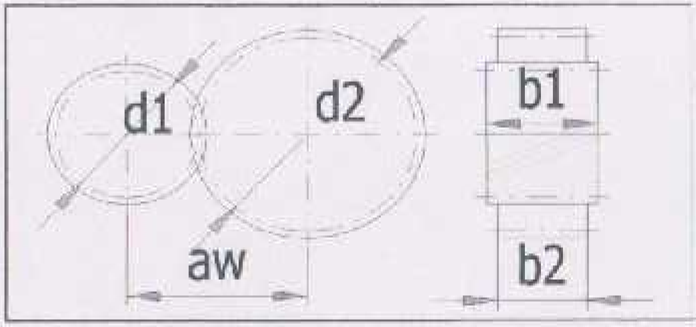
Spur gearing, Helical gearing [mm/ISO]

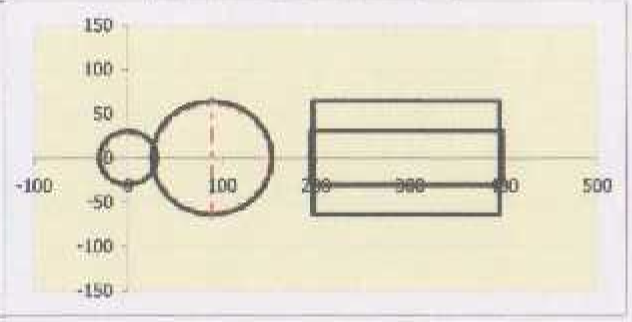
	Pinion	Gear	
Check lines:3.11;.;.;			
☐ **Project information**			
Input section			
☑ **Options of basic input parameters**			
Transferred power	100.000	97.654	[kW]
Speed (Pinion / Gear)	1000.0	450.0	[/min]
Torsional moment (Pinion / Gear)	955.00	2072.44	[Nm]
transmission ratio	2.24		
Actual transmission ratio / deviation	2.22	-0.80%	
☑ **Options of material, loading conditions, operational and production parameters**			
Material of the pinion :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Material of the gear :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Loading of the gearbox, driving machine - examples	D...Heavy shocks		
Loading of gearbox, driven machine - examples	D...Heavy shocks		
Type of gearing mounting	Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max	7.......(Ra max.= 1.6 / v max.= 12)		
Coefficient of one-off overloading	2.00		
Desired service life	120000		[h]
Coefficient of safety (contact/bend)	2.00	2.40	
Automatic design ☐			
☑ **Design of a module and geometry of toothing**			



Number of teeth Pinion / Gear	18	40	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter	◄ ►		

The ratio of the pinion width to its diameter	1.05	< 1.1	
Module / Standardized value	3		[mm]
Reference diameter Pinion / Gear	55.21	122.68	[mm]
Recommended width of gearing	32.6 - 60.7		[mm]
Face width (Pinion / Gear)	204.00	199.00	[mm]
Working face width	199		☑ [mm]
The ratio of the pinion width to its diameter	**3.70**	< 1.1	
Working center distance	89.12		[mm]
Working center distance	22.103		[mm]
Minimum coefficient of safety	0.540	0.618	





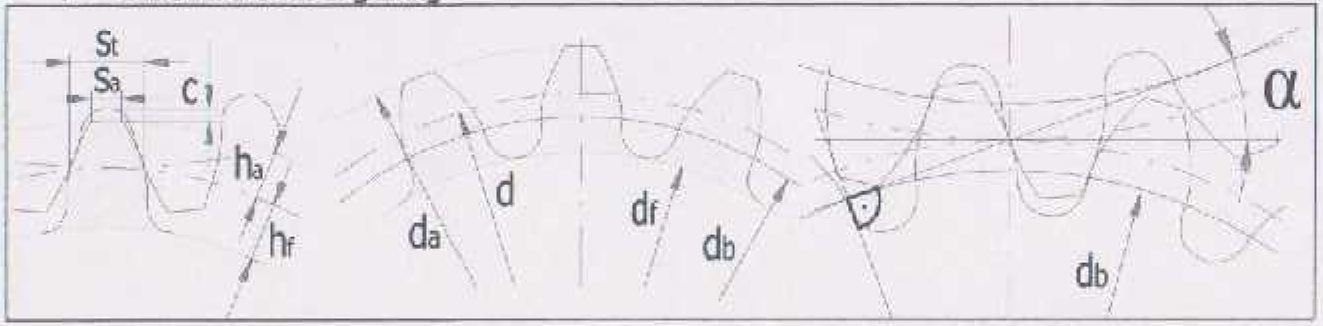
Normal backlash

- Recommended min. | max. value	0.057	0.227	[mm]
- Selected normal backlash	0.1200		[mm]

☐

Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	18	40

Face width (Pinion / Gear)	204	199	[mm]
Normal module	3		[mm]
Transverse module	3.0670		[mm]
Circular pitch	9.425		[mm]
Transverse circular pitch	9.635		[mm]
Base circular pitch	9.030		[mm]
Center distance (pitch)	88.9436		[mm]
Center distance (production)	88.9436		[mm]
Center distance (working)	89.1190		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	61.5572	129.0317	[mm]
Reference diameter	55.2064	122.6809	[mm]
Base diameter	51.7405	114.9789	[mm]
Root diameter	47.7064	115.1809	[mm]
Operating pitch diameter	55.2064	122.6808	[mm]
Addendum	3.1754	3.1754	[mm]
Dedendum	3.7500	3.7500	[mm]
Tooth thickness on the tip diameter	1.8642	2.1288	[mm]
Tooth thickness on the tip diameter	1.9158	2.1814	[mm]
Tooth thickness on the pitch diameter	4.7124	4.7124	[mm]
Tooth thickness on the pitch diameter	4.8177	4.8177	[mm]
Tooth thickness on the root diameter	4.9205	6.3516	[mm]
Unit tooth thickness on the tip diameter	0.6386	0.7271	[modul]
Unit correction	-0.0585		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.02	
Meshing stiffness per unit face width	19.41	
Application factor	2.25	
Dynamic factor	1.03	
Number of cycles	7.20E+09	3.24E+09
For pitting safety calculation		
Face load factor (contact stress)	**2.36**	
Transverse load factor (contact stress)	1.20	
Total factor of additional loads	6.59	
Elasticity factor	189.81	
Zone factor	2.45	
Helix angle factor	0.99	
Contact ratio factor	0.78	
Lubricant factor	1.09	
Peripheral speed factor	0.97	
Roughness factor affecting surface durability	0.91	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
Face load factor (root stress)	2.30	
Transverse load factor (root stress)	1.20	
Total factor of additional loads	6.42	
Helix angle factor	0.90	
Contact ratio factor	0.69	
Notch sensitivity factor	1.12	
Size factor	1.00	
Tooth-root surface factor	0.95	
Alternating load factor	0.81	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	3.15	2.70
Stress correction factor	1.46	1.58
Tip factor, equal (YFa YSa)	4.59	4.27

☑ **Safety coefficients**

Safety coefficient for surface durability	**0.54**	**0.54**	
Safety coefficient for bending durability	**0.62**	**0.65**	
Safety in contact in one-time overloading	**0.89**	**0.89**	
Safety in bending in one-time overloading	**0.90**	**0.94**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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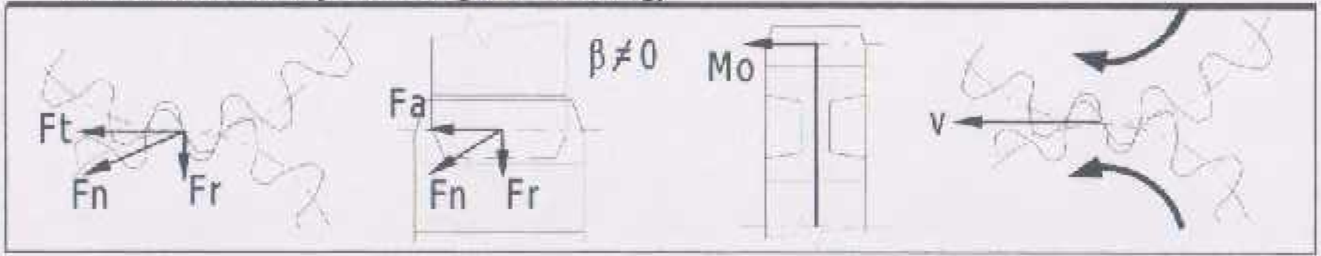
☑ Force conditions (forces acting on the toothing)



Tangential force	34597.44		[N]
Normal force	37640.36		[N]
Axial force	7353.91		[N]
Radial force	12873.76		[N]
Bending moment	226.34	474.44	[Nm]
Peripheral speed on the pitch diameter	2.89	< 12	[m/s]
Specific load / Unit load	391.18	130.39	[N/mm | MPa]

☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	
Wohler Curve Exponent for Contact	10	10	

second gear

Spur gearing, Helical gearing [mm/ISO]

		Pinion	Gear	
Check lines:3.11;.;.;				
☐ Project information				

Input section

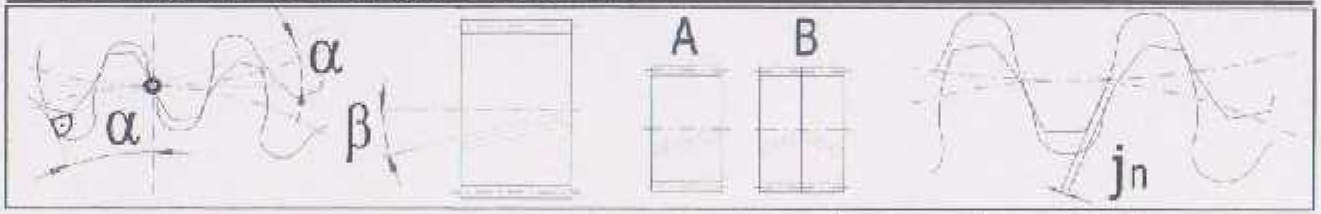
☑ **Options of basic input parameters**

		Pinion	Gear	
Transferred power		100.000	97.307	[kW]
Speed (Pinion / Gear)		1000.0	450.0	[/min]
Torsional moment (Pinion / Gear)		955.00	2065.07	[Nm]
transmission ratio		2.24		
Actual transmission ratio / deviation		2.22	-0.80%	

☑ **Options of material, loading conditions, operational and production parameters**

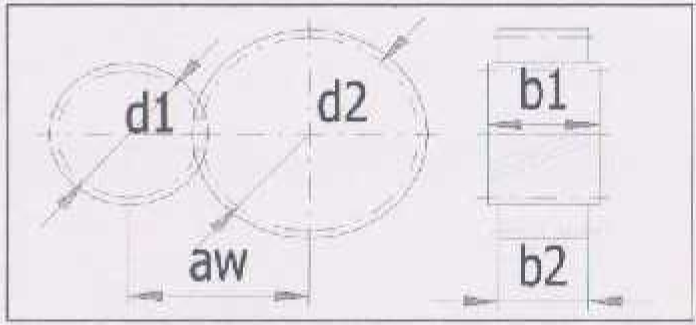
Material of the pinion :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.			
Material of the gear :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.			
Loading of the gearbox, driving machine - examples		D...Heavy shocks		
Loading of gearbox, driven machine - examples		D...Heavy shocks		
Type of gearing mounting		Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max		7......(Ra max.= 1.6 / v max.= 12)		
Coefficient of one-off overloading	0	2.00		
Desired service life	0	80000		[h]
Coefficient of safety (contact/bend)	0	2.00	2.40	
Automatic design ☐				

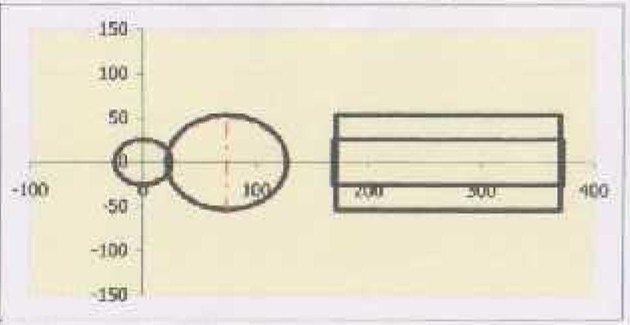
☑ **Design of a module and geometry of toothing**



Number of teeth Pinion / Gear	18	40	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

. The ratio of the pinion width to its diameter	1.05	< 1.1	
. Module / Standardized value	2.5		[mm]
. Reference diameter Pinion / Gear	46.01	102.23	[mm]
. Recommended width of gearing	27.1 - 50.6		[mm]
. Face width (Pinion / Gear)	204.00	199.00	[mm]
. Working face width	199		☑ [mm]
. The ratio of the pinion width to its diameter	**4.43**	< 1.1	
. Working center distance	74.30		[mm]
. Working center distance	15.361		[mm]
. Minimum coefficient of safety	0.428	0.384	





. **Normal backlash**

. - Recommended min. | max. value	0.052	0.207	[mm]
. - Selected normal backlash	0.1220		[mm]

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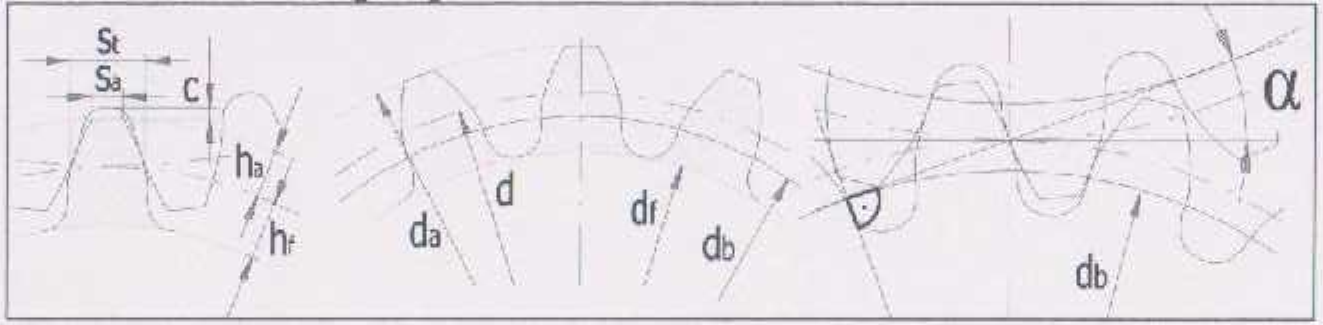
Results section

. ☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	18	40	
Face width (Pinion / Gear)	204	199	[mm]
Normal module	2.5		[mm]
Transverse module	2.5559		[mm]
Circular pitch	7.854		[mm]
Transverse circular pitch	8.029		[mm]
Base circular pitch	7.525		[mm]
Center distance (pitch)	74.1197		[mm]
Center distance (production)	74.1197		[mm]
Center distance (working)	74.2980		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	51.3620	107.5907	[mm]
Reference diameter	46.0053	102.2341	[mm]
Base diameter	43.1171	95.8157	[mm]
Root diameter	39.7553	95.9841	[mm]
Operating pitch diameter	46.0053	102.2340	[mm]
Addendum	2.6783	2.6783	[mm]
Dedendum	3.1250	3.1250	[mm]
Tooth thickness on the tip diameter	1.5149	1.7430	[mm]
Tooth thickness on the tip diameter	1.5569	1.7861	[mm]
Tooth thickness on the pitch diameter	3.9270	3.9270	[mm]
Tooth thickness on the pitch diameter	4.0147	4.0147	[mm]
Tooth thickness on the root diameter	4.1004	5.2930	[mm]
Unit tooth thickness on the tip diameter	0.6228	0.7144	[modul]
Unit correction	-0.0713		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.02	
Meshing stiffness per unit face width	19.58	
Application factor	2.25	
Dynamic factor	1.02	
Number of cycles	4.80E+09	2.16E+09
For pitting safety calculation		
Face load factor (contact stress)	**2.67**	
Transverse load factor (contact stress)	1.20	
Total factor of additional loads	7.37	
Elasticity factor	189.81	
Zone factor	2.45	
Helix angle factor	0.99	
Contact ratio factor	0.77	
Lubricant factor	1.10	
Peripheral speed factor	0.97	
Roughness factor affecting surface durability	0.91	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
Face load factor (root stress)	2.60	
Transverse load factor (root stress)	1.20	
Total factor of additional loads	7.19	
Helix angle factor	0.90	
Contact ratio factor	0.68	
Notch sensitivity factor	1.12	
Size factor	1.00	
Tooth-root surface factor	0.95	
Alternating load factor	0.81	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	3.17	2.72
Stress correction factor	1.46	1.58

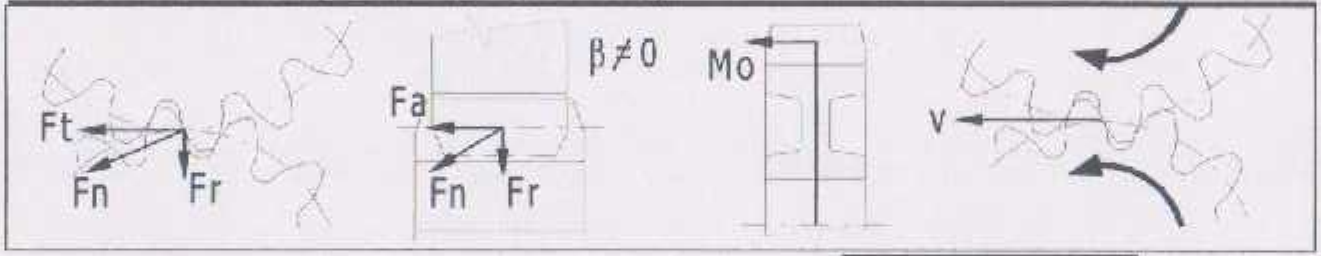
Tip factor, equal (YFa YSa)	4.61	4.29	

☑ Safety coefficients

Safety coefficient for surface durability	**0.43**	**0.43**	
Safety coefficient for bending durability	**0.38**	**0.40**	
Safety in contact in one-time overloading	**0.70**	**0.70**	
Safety in bending in one-time overloading	**0.56**	**0.59**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

☐

☑ Force conditions (forces acting on the toothing)



Tangential force	41516.93		[N]
Normal force	45168.43		[N]
Axial force	8824.70		[N]
Radial force	15448.51		[N]
Bending moment	226.63	474.73	[Nm]
Peripheral speed on the pitch diameter	2.41	< 12	[m/s]
Specific load / Unit load	469.41	187.77	[N/mm | MPa]

☑ Parameters of the chosen material

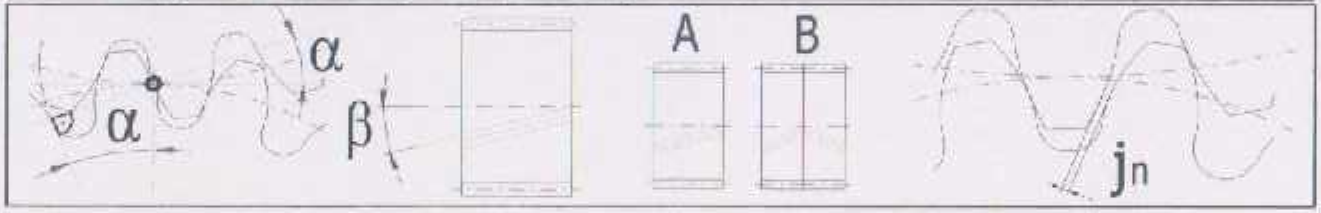
Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]

Third gear

Spur gearing, Helical gearing [mm/ISO]

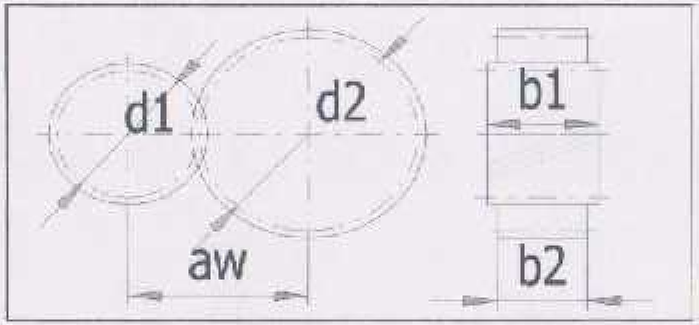
	Pinion	Gear	
Check lines:3.11;.;.;			
☐ **Project information**			
Input section			
☑ **Options of basic input parameters**			
Transferred power	100.000	95.919	[kW]
Speed (Pinion / Gear)	1000.0	450.0	[/min]
Torsional moment (Pinion / Gear)	955.00	2035.62	[Nm]
transmission ratio	2.24		
Actual transmission ratio / deviation	2.22	-0.80%	
☑ **Options of material, loading conditions, operational and production parameters**			
Material of the pinion :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Material of the gear :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Loading of the gearbox, driving machine - examples	D...Heavy shocks		
Loading of gearbox, driven machine - examples	D...Heavy shocks		
Type of gearing mounting	Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max	7......(Ra max.= 1.6 / v max.= 12)		
Coefficient of one-off overloading 0	2.00		
Desired service life 0	80000		[h]
Coefficient of safety (contact/bend) 0	2.00	2.40	
Automatic design ☐			

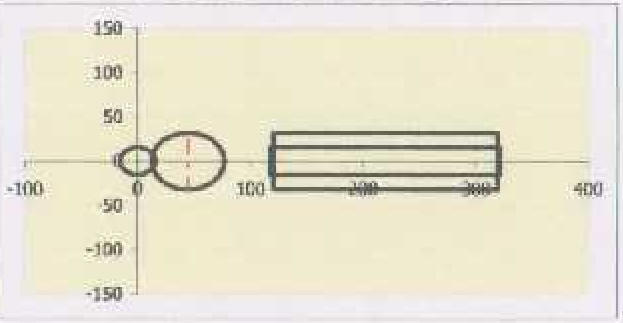
☑ **Design of a module and geometry of toothing**



Number of teeth Pinion / Gear	18	40	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

The ratio of the pinion width to its diameter	1.06	< 1.1	
Module / Standardized value	1.5		[mm]
Reference diameter Pinion / Gear	27.60	61.34	[mm]
Recommended width of gearing	16.3 - 30.4		[mm]
Face width (Pinion / Gear)	204.00	199.00	[mm]
Working face width	199		☑ [mm]
The ratio of the pinion width to its diameter	**7.39**	< 1.1	
Working center distance	44.65		[mm]
Working center distance	5.546		[mm]
Minimum coefficient of safety	0.218	0.097	





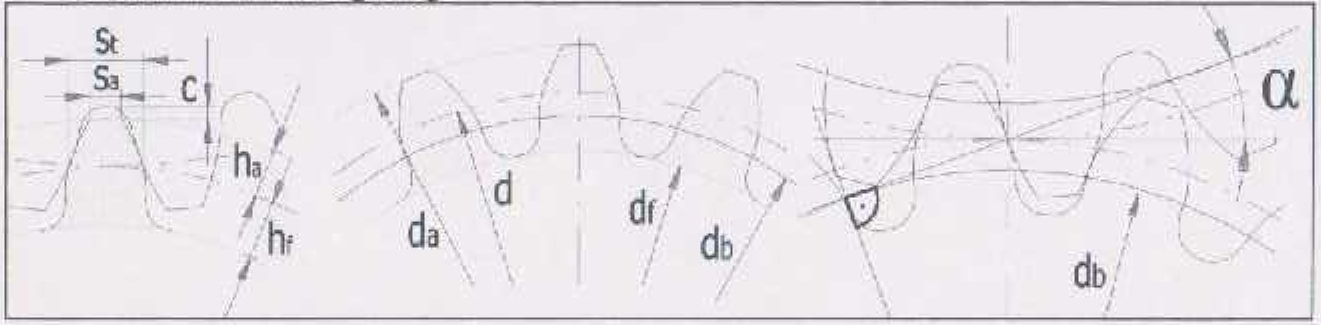
Normal backlash

- Recommended min. | max. value	0.040	0.160	[mm]
- Selected normal backlash	0.1220		[mm]

☐

Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	18	40	
Face width (Pinion / Gear)	204	199	[mm]
Normal module	1.5		[mm]
Transverse module	1.5335		[mm]
Circular pitch	4.712		[mm]
Transverse circular pitch	4.818		[mm]
Base circular pitch	4.515		[mm]
Center distance (pitch)	44.4718		[mm]
Center distance (production)	44.4718		[mm]
Center distance (working)	44.6502		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	30.9599	64.6971	[mm]
Reference diameter	27.6032	61.3404	[mm]
Base diameter	25.8702	57.4894	[mm]
Root diameter	23.8532	57.5904	[mm]
Operating pitch diameter	27.6032	61.3404	[mm]
Addendum	1.6783	1.6783	[mm]
Dedendum	1.8750	1.8750	[mm]
Tooth thickness on the tip diameter	0.8222	0.9764	[mm]
Tooth thickness on the tip diameter	0.8452	1.0007	[mm]
Tooth thickness on the pitch diameter	2.3562	2.3562	[mm]
Tooth thickness on the pitch diameter	2.4088	2.4088	[mm]
Tooth thickness on the root diameter	2.4602	3.1758	[mm]
Unit tooth thickness on the tip diameter	0.5635	0.6671	[modul]
Unit correction	-0.1189		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
. Stiffness of a tooth pair	13.02	
. Meshing stiffness per unit face width	20.20	
. Application factor	2.25	
. Dynamic factor	1.01	
. Number of cycles	4.80E+09	2.16E+09
For pitting safety calculation		
. Face load factor (contact stress)	**3.89**	
. Transverse load factor (contact stress)	1.20	
. Total factor of additional loads	10.61	
. Elasticity factor	189.81	
. Zone factor	2.45	
. Helix angle factor	0.99	
. Contact ratio factor	0.76	
. Lubricant factor	1.11	
. Peripheral speed factor	0.96	
. Roughness factor affecting surface durability	0.91	
. Life factor for contact stress	0.85	0.85
. Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
. Face load factor (root stress)	3.81	
. Transverse load factor (root stress)	1.20	
. Total factor of additional loads	10.40	
. Helix angle factor	0.90	
. Contact ratio factor	0.67	
. Notch sensitivity factor	1.12	
. Size factor	1.00	
. Tooth-root surface factor	0.95	
. Alternating load factor	0.81	
. Production technology factor	1.00	
. Life factor	1.00	1.00
. Form factor (bending)	3.23	2.78
. Stress correction factor	1.45	1.57

Tip factor, equal (YFa YSa)	4.68	4.36	

☑ **Safety coefficients**

Safety coefficient for surface durability	**0.22**	**0.22**	
Safety coefficient for bending durability	**0.10**	**0.10**	
Safety in contact in one-time overloading	**0.36**	**0.36**	
Safety in bending in one-time overloading	**0.14**	**0.15**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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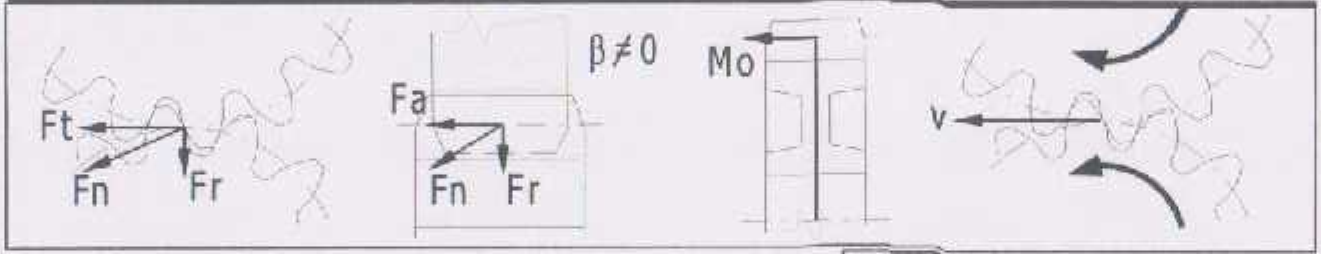
☑ **Force conditions (forces acting on the toothing)**



Tangential force	69194.89		[N]
Normal force	75280.72		[N]
Axial force	14707.83		[N]
Radial force	25747.52		[N]
Bending moment	227.68	475.78	[Nm]
Peripheral speed on the pitch diameter	1.45	< 12	[m/s]
Specific load / Unit load	782.35	521.57	[N/mm | MPa]

☑ **Parameters of the chosen material**

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]

Fourth gear

Spur gearing, Helical gearing [mm/ISO]

	Pinion	Gear	
Check lines:3.11;.;.;			
☐ Project information			

Input section

☑ Options of basic input parameters

	Pinion	Gear	
Transferred power	100.000	95.226	[kW]
Speed (Pinion / Gear)	1000.0	450.0	[/min]
Torsional moment (Pinion / Gear)	955.00	2020.90	[Nm]
transmission ratio	2.24		
Actual transmission ratio / deviation	2.22	-0.80%	

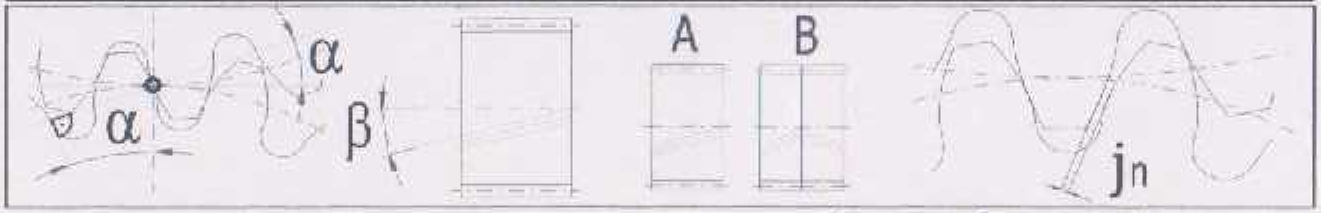
☑ Options of material, loading conditions, operational and production parameters

Material of the pinion :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Material of the gear :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Loading of the gearbox, driving machine - examples	D...Heavy shocks		
Loading of gearbox, driven machine - examples	D...Heavy shocks		
Type of gearing mounting	Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max	7......(Ra max.= 1.6 / v max.= 12)		
Coefficient of one-off overloading	0	2.00	
Desired service life	0	120000	[h]
Coefficient of safety (contact/bend)	0	2.00 / 2.40	

Automatic design

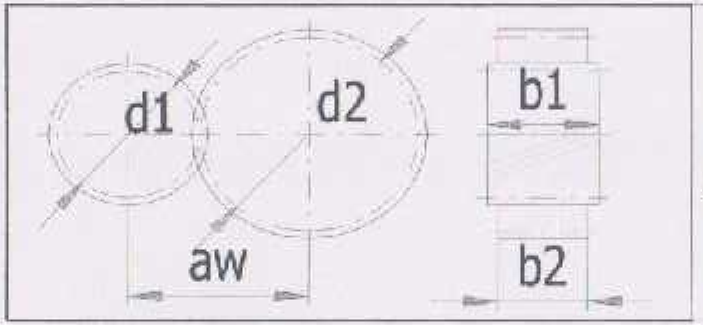
☐

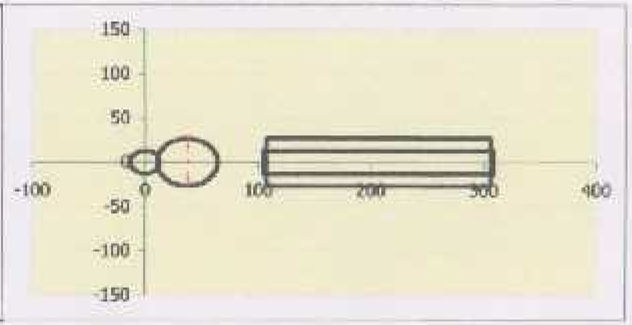
☑ Design of a module and geometry of toothing



	Pinion	Gear	
Number of teeth Pinion / Gear	18	40	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter	◄ ►		

The ratio of the pinion width to its diameter	1.06	< 1.1	
Module / Standardized value	1.25		[mm]
Reference diameter Pinion / Gear	23.00	51.12	[mm]
Recommended width of gearing	13.6 - 25.3		[mm]
Face width (Pinion / Gear)	204.00	199.00	[mm]
Working face width	199		☑ [mm]
The ratio of the pinion width to its diameter	**8.87**	< 1.1	
Working center distance	37.24		[mm]
Working center distance	3.857		[mm]
Minimum coefficient of safety	0.170	0.058	





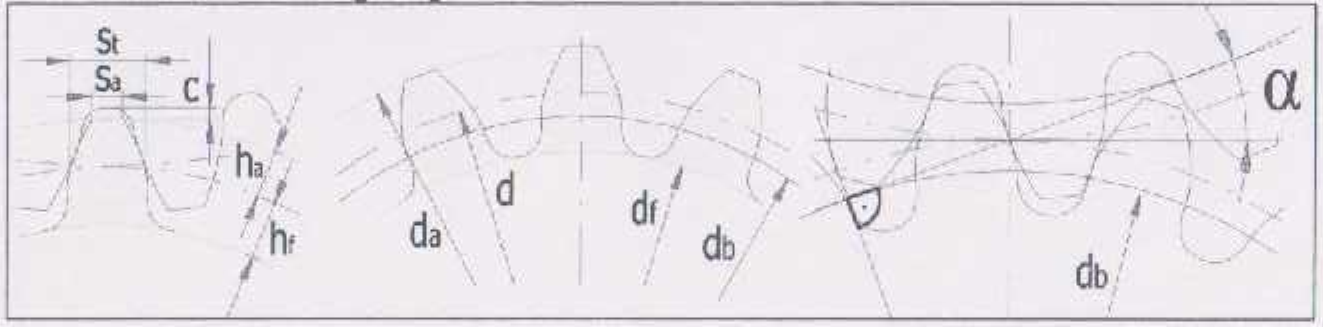
Normal backlash

- Recommended min. | max. value	0.037	0.146	[mm]
- Selected normal backlash	0.1220		[mm]

☐

Results section

☑ **Basic dimensions of gearing**



Parameter	Pinion	Gear	Unit
Number of teeth Pinion / Gear	18	40	
Face width (Pinion / Gear)	204	199	[mm]
Normal module	1.25		[mm]
Transverse module	1.2779		[mm]
Circular pitch	3.927		[mm]
Transverse circular pitch	4.015		[mm]
Base circular pitch	3.763		[mm]
Center distance (pitch)	37.0598		[mm]
Center distance (production)	37.0598		[mm]
Center distance (working)	37.2382		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	25.8594	53.9737	[mm]
Reference diameter	23.0027	51.1170	[mm]
Base diameter	21.5585	47.9079	[mm]
Root diameter	19.8777	47.9920	[mm]
Operating pitch diameter	23.0027	51.1170	[mm]
Addendum	1.4283	1.4283	[mm]
Dedendum	1.5625	1.5625	[mm]
Tooth thickness on the tip diameter	0.6484	0.7845	[mm]
Tooth thickness on the tip diameter	0.6667	0.8040	[mm]
Tooth thickness on the pitch diameter	1.9635	1.9635	[mm]
Tooth thickness on the pitch diameter	2.0074	2.0074	[mm]
Tooth thickness on the root diameter	2.0502	2.6465	[mm]
Unit tooth thickness on the tip diameter	0.5333	0.6432	[modul]
Unit correction	-0.1427		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.02	
Meshing stiffness per unit face width	20.51	
Application factor	2.25	
Dynamic factor	1.01	
Number of cycles	7.20E+09	3.24E+09
For pitting safety calculation		
Face load factor (contact stress)	**4.51**	
Transverse load factor (contact stress)	1.20	
Total factor of additional loads	12.25	
Elasticity factor	189.81	
Zone factor	2.45	
Helix angle factor	0.99	
Contact ratio factor	0.75	
Lubricant factor	1.11	
Peripheral speed factor	0.96	
Roughness factor affecting surface durability	0.91	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
Face load factor (root stress)	4.42	
Transverse load factor (root stress)	1.20	
Total factor of additional loads	12.02	
Helix angle factor	0.90	
Contact ratio factor	0.66	
Notch sensitivity factor	1.12	
Size factor	1.00	
Tooth-root surface factor	0.95	
Alternating load factor	0.81	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	3.26	2.80
Stress correction factor	1.45	1.57
Tip factor, equal (YFa YSa)	4.72	4.39

☑ Safety coefficients

Safety coefficient for surface durability	**0.17**	**0.17**	
Safety coefficient for bending durability	**0.06**	**0.06**	
Safety in contact in one-time overloading	**0.28**	**0.28**	
Safety in bending in one-time overloading	**0.08**	**0.09**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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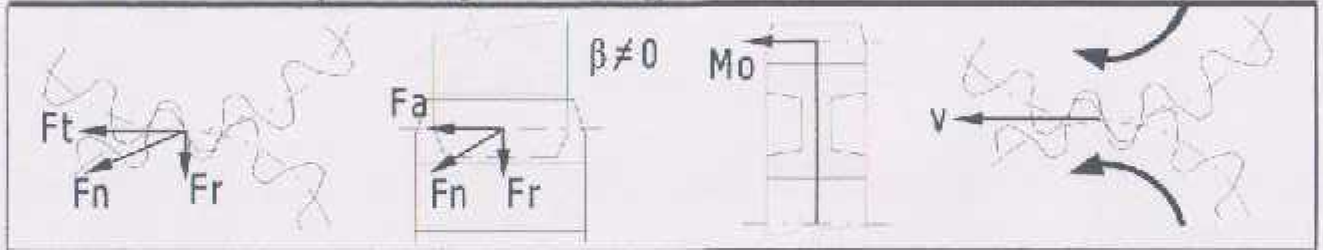
☑ Force conditions (forces acting on the toothing)



Tangential force	83033.86		[N]
Normal force	90336.87		[N]
Axial force	17649.39		[N]
Radial force	30897.03		[N]
Bending moment	228.20	476.30	[Nm]
Peripheral speed on the pitch diameter	1.20	< 12	[m/s]
Specific load / Unit load	938.83	751.06	[N/mm | MPa]

☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	

Fifth gear

Spur gearing, Helical gearing [mm/ISO]

	Pinion	Gear	
Check lines:3.11;.;.;			
☐ Project information			

Input section

☑ Options of basic input parameters

	Pinion	Gear	
Transferred power	100.000	94.185	[kW]
Speed (Pinion / Gear)	1000.0	450.0	[/min]
Torsional moment (Pinion / Gear)	955.00	1998.82	[Nm]
transmission ratio	2.24		
Actual transmission ratio / deviation	2.22	-0.80%	

☑ Options of material, loading conditions, operational and production parameters

Material of the pinion :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Material of the gear :	E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.		
Loading of the gearbox, driving machine - examples	D...Heavy shocks		
Loading of gearbox, driven machine - examples	D...Heavy shocks		
Type of gearing mounting	Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max	7......(Ra max.= 1.6 / v max.= 12)		
Coefficient of one-off overloading 0	2.00		
Desired service life 0	120000		[h]
Coefficient of safety (contact/bend) 0	2.00	2.40	

Automatic design

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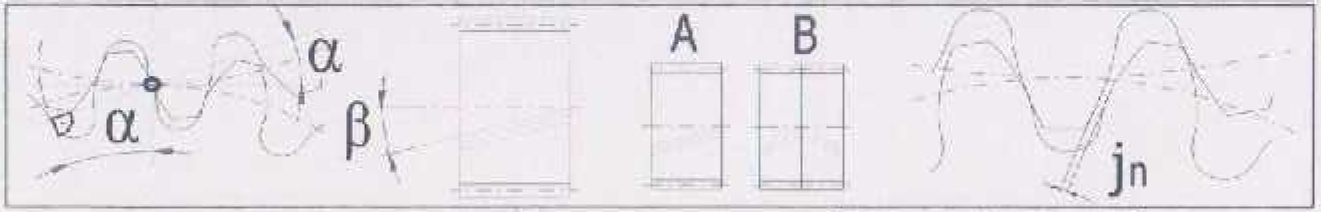
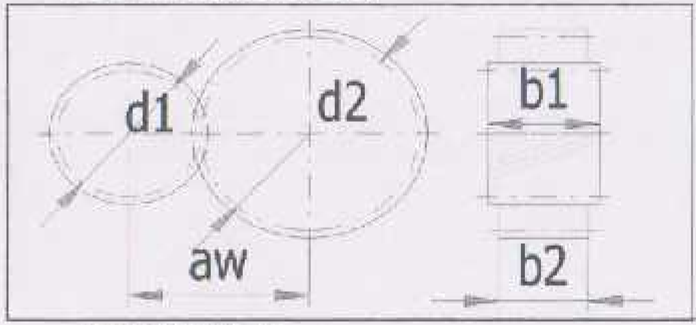
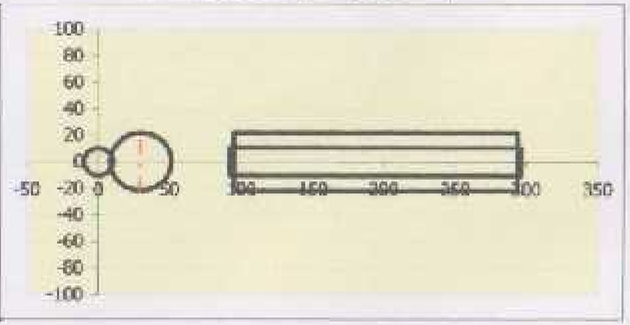
☑ Design of a module and geometry of toothing



	Pinion	Gear	
Number of teeth Pinion / Gear	18	40	
Normal pressure angle	20		[°]
Base helix angle	12		[°]
Setting of the ratio of the width of the pinion to its diameter			

Parameter	Pinion	Gear	Unit
The ratio of the pinion width to its diameter	1.06	< 1.1	
Module / Standardized value	1		[mm]
Reference diameter Pinion / Gear	18.40	40.89	[mm]
Recommended width of gearing	10.9 - 20.2		[mm]
Face width (Pinion / Gear)	204.00	199.00	[mm]
Working face width	199		☑ [mm]
The ratio of the pinion width to its diameter	**11.09**	< 1.1	
Working center distance	29.83		[mm]
Working center distance	2.473		[mm]
Minimum coefficient of safety	0.126	0.031	





Normal backlash

- Recommended min. | max. value	0.033	0.131	[mm]
- Selected normal backlash	0.1220		[mm]

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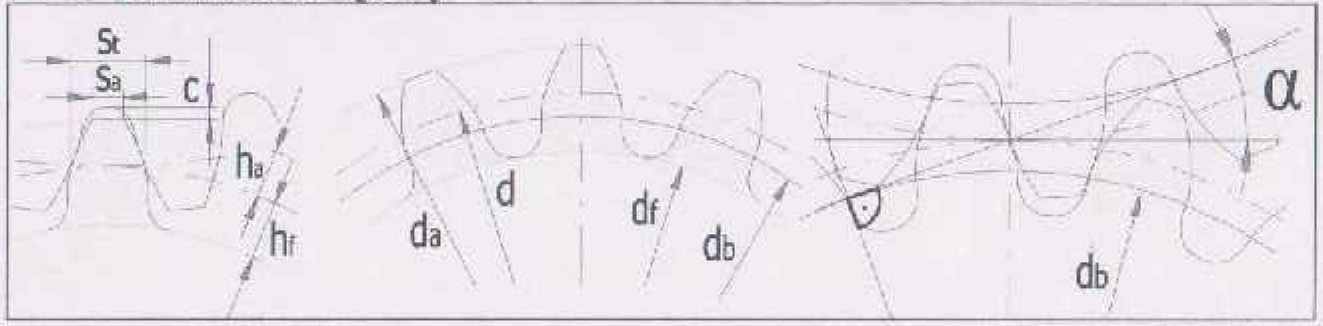
Results section

☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	18	40	
Face width (Pinion / Gear)	204	199	[mm]
Normal module	1		[mm]
Transverse module	1.0223		[mm]
Circular pitch	3.142		[mm]
Transverse circular pitch	3.212		[mm]
Base circular pitch	3.010		[mm]
Center distance (pitch)	29.6479		[mm]
Center distance (production)	29.6479		[mm]
Center distance (working)	29.8262		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.4103		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.4103		[°]
Helix angle	12.00		[°]
Base helix angle	11.2665		[°]
Tip diameter	20.7588	43.2503	[mm]
Reference diameter	18.4021	40.8936	[mm]
Base diameter	17.2468	38.3263	[mm]
Root diameter	15.9021	38.3936	[mm]
Operating pitch diameter	18.4021	40.8936	[mm]
Addendum	1.1783	1.1783	[mm]
Dedendum	1.2500	1.2500	[mm]
Tooth thickness on the tip diameter	0.4741	0.5923	[mm]
Tooth thickness on the tip diameter	0.4876	0.6071	[mm]
Tooth thickness on the pitch diameter	1.5708	1.5708	[mm]
Tooth thickness on the pitch diameter	1.6059	1.6059	[mm]
Tooth thickness on the root diameter	1.6402	2.1172	[mm]
Unit tooth thickness on the tip diameter	0.4876	0.6071	[modul]
Unit correction	-0.1783		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
. Stiffness of a tooth pair	13.02	
. Meshing stiffness per unit face width	20.97	
. Application factor	2.25	
. Dynamic factor	1.00	
. Number of cycles	7.20E+09	3.24E+09
For pitting safety calculation		
. Face load factor (contact stress)	**5.43**	
. Transverse load factor (contact stress)	1.20	
. Total factor of additional loads	14.72	
. Elasticity factor	189.81	
. Zone factor	2.45	
. Helix angle factor	0.99	
. Contact ratio factor	0.74	
. Lubricant factor	1.11	
. Peripheral speed factor	0.95	
. Roughness factor affecting surface durability	0.91	
. Life factor for contact stress	0.85	0.85
. Single pair tooth contact factor	1.00	1.00
For bending safety calculation		
. Face load factor (root stress)	5.33	
. Transverse load factor (root stress)	1.20	
. Total factor of additional loads	14.47	
. Helix angle factor	0.90	
. Contact ratio factor	0.65	
. Notch sensitivity factor	1.12	
. Size factor	1.00	
. Tooth-root surface factor	0.95	
. Alternating load factor	0.81	
. Production technology factor	1.00	
. Life factor	1.00	1.00
. Form factor (bending)	3.30	2.85
. Stress correction factor	1.44	1.56
. Tip factor, equal (YFa YSa)	4.77	4.45

☑ Safety coefficients

Safety coefficient for surface durability	**0.13**	**0.13**	
Safety coefficient for bending durability	**0.03**	**0.03**	
Safety in contact in one-time overloading	**0.21**	**0.21**	
Safety in bending in one-time overloading	**0.05**	**0.05**	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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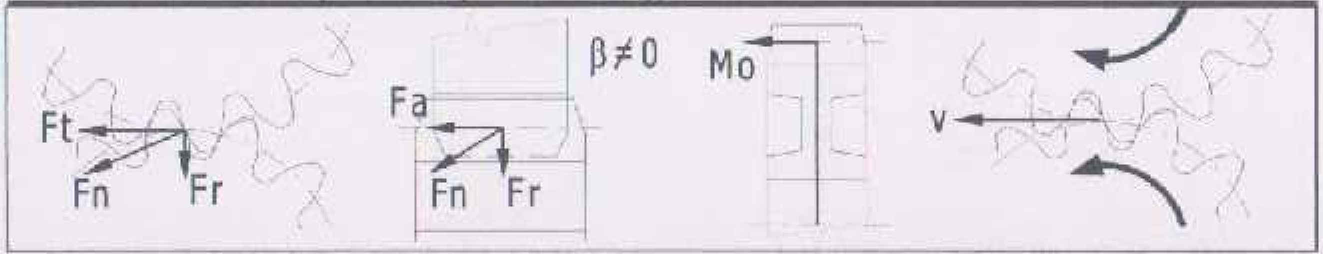
☑ Force conditions (forces acting on the toothing)



Tangential force	103792.33		[N]
Normal force	112921.09		[N]
Axial force	22061.74		[N]
Radial force	38621.29		[N]
Bending moment	228.99	477.09	[Nm]
Peripheral speed on the pitch diameter	0.96	< 12	[m/s]
Specific load / Unit load	1173.53	1173.53	[N/mm | MPa]

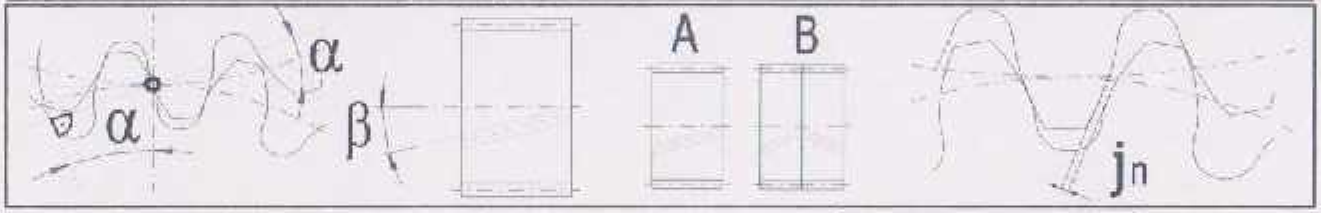
☑ Parameters of the chosen material

Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]
Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	

Reverse gear

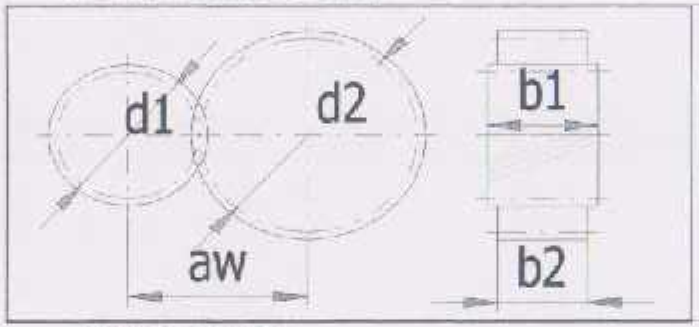
Spur gearing, Helical gearing [mm/ISO]

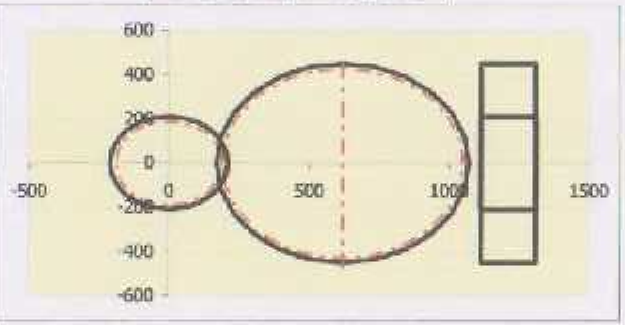
	Pinion	Gear	
Check lines:3.11;.;			
☐ **Project information**			
Input section			
☑ **Options of basic input parameters**			
Transferred power	100.000	98.821	[kW]
Speed (Pinion / Gear)	1000.0	441.9	[/min]
Torsional moment (Pinion / Gear)	955.00	2135.84	[Nm]
transmission ratio	2.24		
Actual transmission ratio / deviation	2.26	1.02%	
☑ **Options of material, loading conditions, operational and production parameters**			
Material of the pinion : E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.			
Material of the gear : E...Alloy structural steel T2(683/7-70) (Rm=1570 MPa) nitro-case-hard.			
Loading of the gearbox, driving machine - examples	D...Heavy shocks		
Loading of gearbox, driven machine - examples	D...Heavy shocks		
Type of gearing mounting	Double-sided symmetrically supported gearing - type		
Accuracy grade - ISO1328 |Ra max|v max	7......(Ra max.= 1.6 / v max.= 8)		
Coefficient of one-off overloading	2.00		
Desired service life	120000		[h]
Coefficient of safety (contact/bend)	2.00	2.40	
Automatic design ☐			
☑ **Design of a module and geometry of toothing**			



Number of teeth Pinion / Gear	19	43	
Normal pressure angle	20		[°]
Base helix angle	0		[°]
Setting of the ratio of the width of the pinion to its diameter			

. The ratio of the pinion width to its diameter	0.6	< 1.1	
. Module / Standardized value	20		[mm]
. Reference diameter Pinion / Gear	380.00	860.00	[mm]
. Recommended width of gearing	224 - 418		[mm]
. Face width (Pinion / Gear)	204.00	194.00	[mm]
. Working face width	194		☑ [mm]
. The ratio of the pinion width to its diameter	0.54	< 1.1	
. Working center distance	620.18		[mm]
. Working center distance	1054.440		[mm]
. Minimum coefficient of safety	2.765	13.314	





. **Normal backlash**

. - Recommended min. | max. value	0.149	0.598	[mm]
. - Selected normal backlash	0.1200		[mm]

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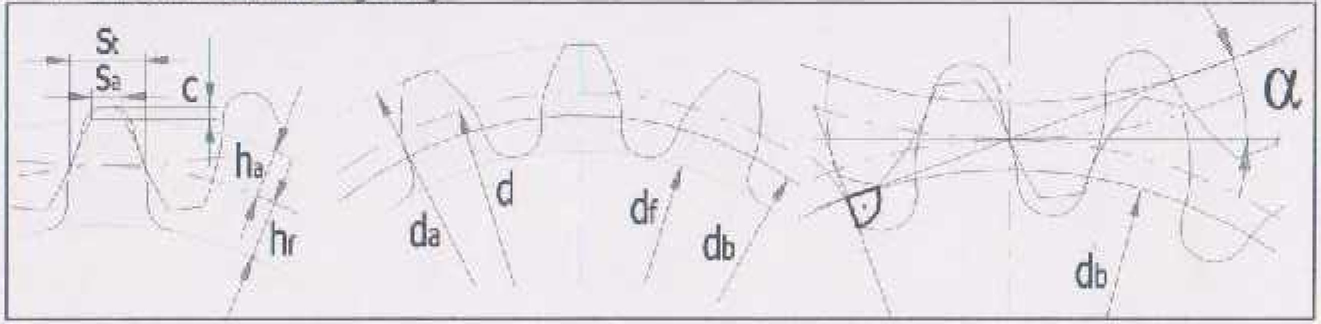
Results section

. ☑ **Basic dimensions of gearing**



Number of teeth Pinion / Gear	19	43	
Face width (Pinion / Gear)	204	194	[mm]
Normal module	20		[mm]
Transverse module	20.0000		[mm]
Circular pitch	62.832		[mm]
Transverse circular pitch	62.832		[mm]
Base circular pitch	59.043		[mm]
Center distance (pitch)	620.0000		[mm]
Center distance (production)	620.0000		[mm]
Center distance (working)	620.1754		[mm]
Pressure angle	20.00		[°]
Transverse pressure angle	20.0000		[°]
Pressure angle at the pitch cylinder	20.0000		[°]
Transverse pressure angle at the pitch cylinder	20.0000		[°]
Helix angle	0.00		[°]
Base helix angle	0.0000		[°]
Tip diameter	420.3509	900.3509	[mm]
Reference diameter	380.0000	860.0000	[mm]
Base diameter	357.0832	808.1357	[mm]
Root diameter	330.0000	810.0000	[mm]
Operating pitch diameter	380.0000	860.0000	[mm]
Addendum	20.1754	20.1754	[mm]
Dedendum	25.0000	25.0000	[mm]
Tooth thickness on the tip diameter	13.5652	15.1486	[mm]
Tooth thickness on the tip diameter	13.5652	15.1486	[mm]
Tooth thickness on the pitch diameter	31.4159	31.4159	[mm]
Tooth thickness on the pitch diameter	31.4159	31.4159	[mm]
Tooth thickness on the root diameter	32.2007	41.6620	[mm]
Unit tooth thickness on the tip diameter	0.6783	0.7574	[modul]
Unit correction	-0.0088		[modul]
Total unit correction	0.0000		[modul]
Addendum modification coefficient	0.0000	0.0000	[modul]

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Common for the gearing		
Stiffness of a tooth pair	13.03	
Meshing stiffness per unit face width	19.36	
Application factor	2.25	
Dynamic factor	1.99	
Number of cycles	7.20E+09	3.18E+09
For pitting safety calculation		
Face load factor (contact stress)	1.17	
Transverse load factor (contact stress)	1.28	
Total factor of additional loads	6.68	
Elasticity factor	189.81	
Zone factor	2.49	
Helix angle factor	1.00	
Contact ratio factor	0.89	
Lubricant factor	0.99	
Peripheral speed factor	1.02	
Roughness factor affecting surface durability	0.91	
Life factor for contact stress	0.85	0.85
Single pair tooth contact factor	1.07	1.00
For bending safety calculation		
Face load factor (root stress)	1.15	
Transverse load factor (root stress)	2.01	
Total factor of additional loads	10.34	
Helix angle factor	1.00	
Contact ratio factor	0.71	
Notch sensitivity factor	1.12	
Size factor	0.85	
Tooth-root surface factor	0.95	
Alternating load factor	0.81	
Production technology factor	1.00	
Life factor	1.00	1.00
Form factor (bending)	3.10	2.64
Stress correction factor	1.46	1.59

Tip factor, equal (YFa YSa)	4.53	4.20	

☑ Safety coefficients

Safety coefficient for surface durability	2.77	2.97	
Safety coefficient for bending durability	13.31	13.66	
Safety in contact in one-time overloading	4.77	5.12	
Safety in bending in one-time overloading	19.34	19.84	
Variability coefficient for calculation of probability of a failure	0.08	0.1	
Probability of a failure	0.79		[%]

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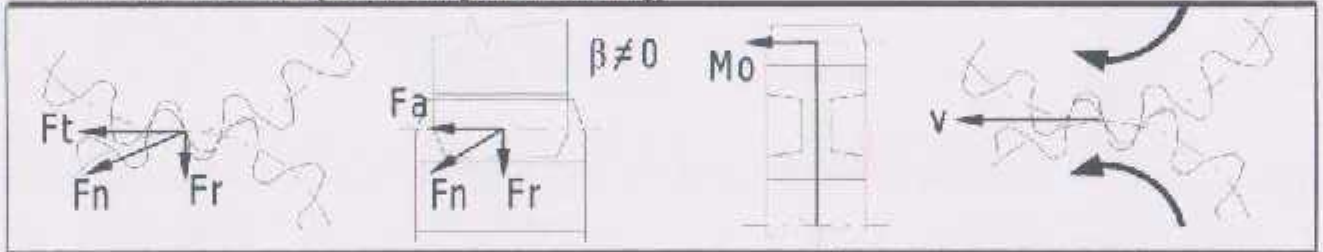
☑ Force conditions (forces acting on the toothing)



Tangential force	5026.32		[N]
Normal force	5348.89		[N]
Axial force	0.00		[N]
Radial force	1829.43		[N]
Bending moment	0.00	0.00	[Nm]
Peripheral speed on the pitch diameter	**19.90**	< 8	[m/s]
Specific load / Unit load	58.29	2.91	[N/mm | MPa]

☑ Parameters of the chosen material

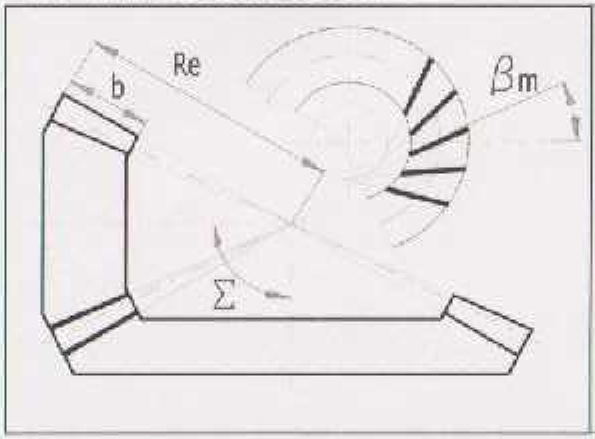
Density	7870	7870	[kg/m^3]
Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
Tensile Strength, Ultimate	1570	1570	[MPa]
Tensile Strength, Yield	1350	1350	[MPa]
Poison's Ratio	0.3	0.3	
Contact Fatigue Limit	1288	1288	[MPa]
Bending Fatigue Limit	740	740	[MPa]
Tooth Hardness - Side	615	615	[HV]
Tooth Hardness - Core	485	485	[HV]

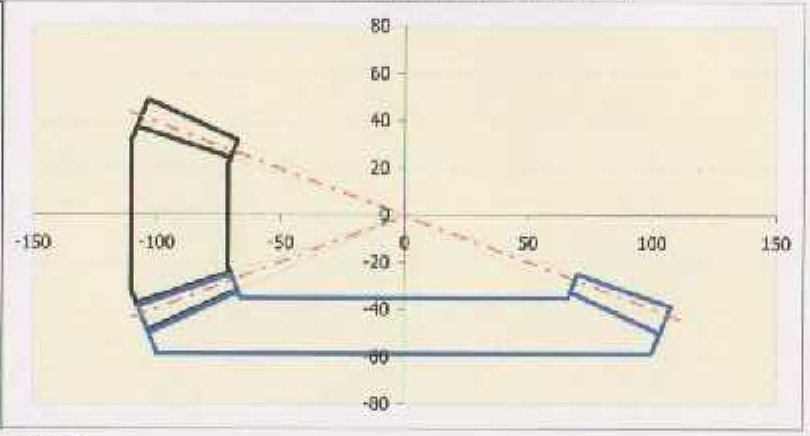
Bevel gear

Bevel gearing with straight, oblique and curved teeth [mm/DIN]

No.	Parameter	Pinion	Gear	Unit
i	#DIV/0!	Pinion	Gear	
ii	☐ **Project information**			
?	**Input section**			
1.0	☑ **Options of basic input parameters**			
1.1	Transferred power		0.000	[kW]
1.2	Speed (Pinion / Gear)	1500.0	592.1	[/min]
1.3	Torsional moment (Pinion / Gear)	0.00	0.00	[Nm]
1.4	transmission ratio	2.50		
1.5	Actual transmission ratio / deviation	2.5333	1.32%	
2.0	☑ **Options of material, loading conditions, operational and production parameters**			
2.1	Material of the pinion : E...Alloy structural steel 37 Cr 4 (Rm=1570 MPa) nitro-case-hard.			
2.2	Material of the gear : E...Alloy structural steel 37 Cr 4 (Rm=1570 MPa) nitro-case-hard.			
2.3	Loading of the gearbox, driving machine - examples	D...Heavy shocks		
2.4	Loading of gearbox, driven machine - examples	D...Heavy shocks		
2.5	Type of gearing mounting	C...Double-sided supported gearing - type 2		
2.6	Accuracy grade - DIN3965 / ISO1328 [Ra max|v max	6 / 7......(Ra max.= 1.6 / v max.= 12)		
2.7	Coefficient of one-off overloading	2.00		
2.8	Desired service life	10000		[h]
2.9	Coefficient of safety (contact/bend)	2.00	2.40	
2.10	Automatic design: B. Helical gearing			
3.0	☑ **Parameters of the tooth profile, gearing type**			
3.1	Guiding curve of the toothing (Type of toothing): A,B. Straight line, type I (Standard straight and oblique toothing)			☑
3.2	Addendum - Coefficient of the height of the tooth head	1.000	1.000	[modul]
3.3	Unit head clearance	0.200	0.200	[modul]
3.4	Recommended coefficient of the root radius	0.304	0.304	[modul]
3.5	Coefficient of the root radius	0.304	0.304	☑ [modul]
4.0	☑ **Design of a module (Diametral Pitch) and geometry of toothing**			
4.1	Number of teeth Pinion / Gear	15	38	
4.2	Angle of shaft axes	90	90	[°]
4.3	B. Normal pressure angle	20.0	25.0	[°]
4.4	Base helix angle	30.0	0	[°]
4.5	Direction of the teeth pitch (pinion)	Left-Hand		
4.6	Width of toothing to the surface straight line of the cone (b/Re)			
4.7	Width of toothing to the surface straight line of the cone (b/Re)	0.4	< 0.35	
4.8	B. Normal module (mean) — mmn	4.000		[mm]
4.9	Face width / max. recommendet value	40	< 40	☑ [mm]
4.10	Approximate weight of the gearing	5.651		[kg]

4.11	Minimum coefficient of safety	#DIV/0!	#DIV/0!



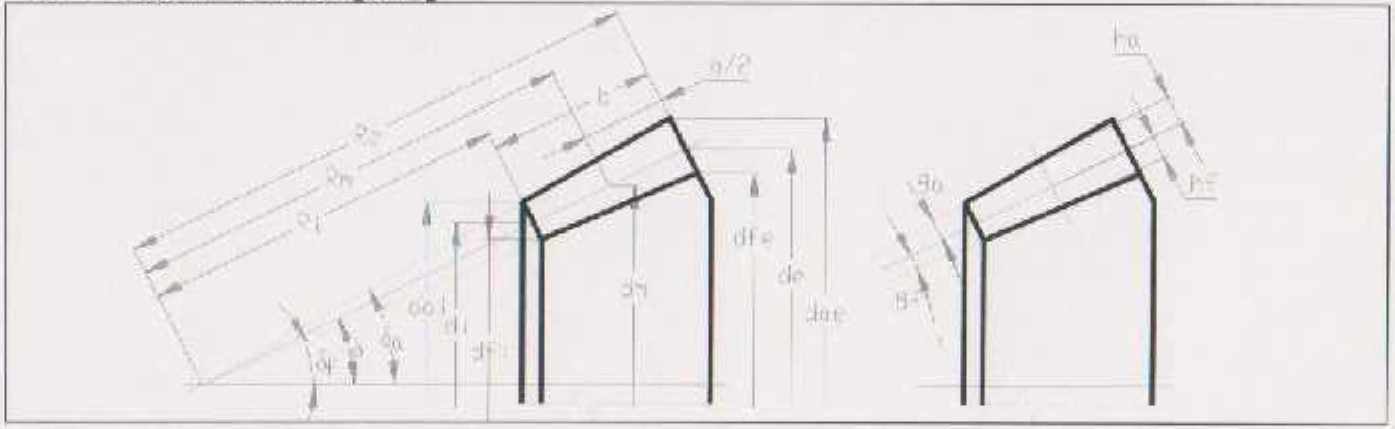


5.0 Correction of toothing (Addendum modification)

5.1	Correction type	A. Straight toothing VN, increased bending strength	
5.2	Recommendet value	0.580	0.000
5.3	- Permissible undercutting of teeth (min. value)	-0.5643	-8.1366
5.4	- Preventing undercutting of teeth (min. value)	-0.3977	-7.9699
5.5	Pinion addendum modification coefficient setting		
5.6	Addendum modification coefficient Pinion / Gear	0.3200	-0.3200
5.7	Tooth thicknes modification coefficient	0.0400	-0.0400
5.8	Total contact ratio	2.8365	
5.9	Unit tooth thickness on the tip diameter	0.3426	1.0241
5.10	Safety coefficient for surface durability	#DIV/0!	#DIV/0!
5.11	Safety coefficient for bending durability	#DIV/0!	#DIV/0!

Results section

6.0 Basic dimensions of gearing



6.1	Number of teeth Pinion / Gear			15	38	
6.2	Transverse module (outer, midle, inner)	met,mmt,mit	5.5979	4.6188	3.6397	[mm]
6.3	Normal module (outer, midle, inner)	men,mmn,min	4.8479	4.0000	3.1521	[mm]
6.4	Cone length (outer, midle, inner)	Re,Rm,Ri	114.347	94.347	74.347	[mm]
6.5	Pitch cone angle			21.5410	68.4590	[°]
6.6	Addendum cone angle			25.2384	70.3657	[°]
6.7	Dedendum cone angle			19.0741	64.2033	[°]
6.8	Tip diameter (outer)			97.715	215.516	[mm]
6.9	Tip diameter (midle)			80.624	177.821	[mm]
6.10	Tip diameter (inner)			63.533	140.126	[mm]
6.11	Pitch diameter (outer)			83.969	212.721	[mm]
6.12	Pitch diameter (midle)			69.282	175.514	[mm]
6.13	Pitch diameter (inner)			54.595	138.308	[mm]
6.14	Root diameter (outer)			74.805	206.472	[mm]
6.15	Root diameter (midle)			61.721	170.359	[mm]
6.16	Root diameter (inner)			48.637	134.246	[mm]
6.17	Addendum angle			3.6974	1.9067	[°]
6.18	Dedendum angle			2.4668	4.2557	[°]
6.19	Addendum (outer)			7.3892	3.8066	[mm]
6.20	Addendum (midle)			6.0968	3.1408	[mm]
6.21	Addendum (inner)			4.8044	2.4750	[mm]
6.22	Dedendum (outer)			4.9262	8.5088	[mm]
6.23	Dedendum (midle)			4.0645	7.0206	[mm]
6.24	Dedendum (inner)			3.2029	5.5323	[mm]
6.25	Normal pressure angle			20.0000		[°]
6.26	Transverse pressure angle			22.7959		[°]
6.27	Helix angle			30.00		[°]
6.28	Base helix angle			28.0243		[°]
6.29	Pressure angle at the pitch cylinder			20.0000		[°]
6.30	Transverse pressure angle at the pitch cylinder			22.7959		[°]
6.31	Circular pitch			15.230		[mm]
6.32	Transverse circular pitch			17.586		[mm]
6.33	Tooth thickness on the pitch diameter			9.1130	6.1172	[mm]
6.34	Tooth thickness on the pitch diameter			7.5191	5.0473	[mm]
6.35	Tooth thickness on the pitch diameter			5.9252	3.9773	[mm]
6.36	Tooth thickness on the tip diameter			1.6609	4.9647	[mm]
6.37	Tooth thickness on the tip diameter			1.3704	4.0963	[mm]
6.38	Tooth thickness on the tip diameter			1.0799	3.2280	[mm]
6.39	Unit tooth thickness on the tip diameter			0.3426	1.0241	[modul]

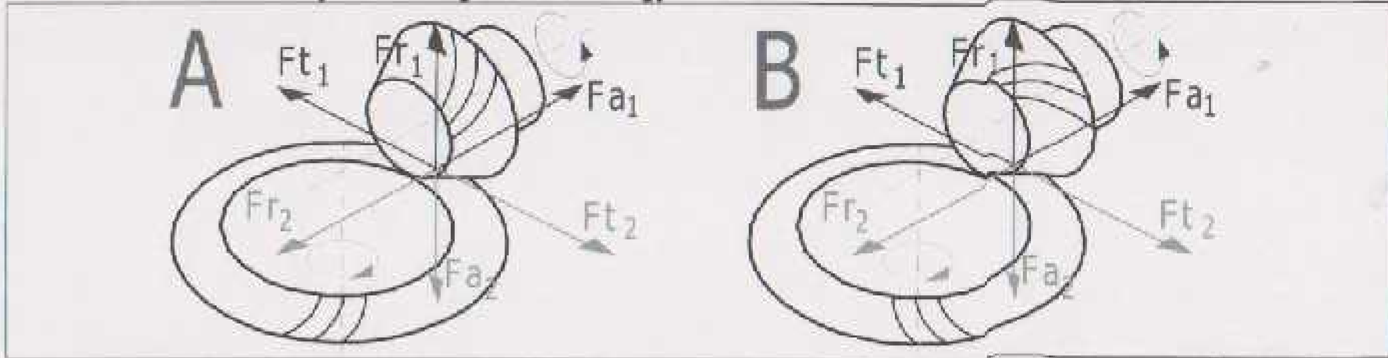
7.0	☑ **Virtual spur gear toothing**			
7.1	Number of teeth of a virtual wheel with oblique teeth	16.126	103.495	
7.2	Number of teeth of a virtual wheel with straight teeth	23.896	153.361	
7.3	Reference diameter	74.484	478.024	[mm]
7.4	Tip diameter	86.678	484.306	[mm]
7.5	Base diameter	68.666	440.686	[mm]
7.6	Root diameter	66.355	463.983	[mm]
7.7	Virtual center distance	276.2543		[mm]
7.8	Virtual Gear Ratio	6.4178		
8.0	☑ **Qualitative indexes of a gearing**			
8.1	Transverse contact ratio / overlap ratio	1.4837	1.3528	
8.2	Total contact ratio	2.8365		
8.3	Resonance speed	24597.81		[/min]
8.4	Resonance ratio	0.06		
8.5	Approximate weight of the gearing	5.6512		[kg]
8.6	Efficiency of the gearing	98.09%		
8.7	Selected / Recomended lubricant viscosity	218	218	☑ [mm2/sec]
9.0	☑ **Coefficients for safety calculation**			
	Common for the gearing			
9.1	Stiffness of a tooth pair	14.90		
9.2	Meshing stiffness per unit face width	20.31		
9.4	Application factor	2.25		
9.5	Dynamic factor	1.124		
9.6	Number of cycles	9.00E+08	3.55E+08	
	For pitting safety calculation			
9.7	Face load factor (contact stress)	1.570		
9.8	Transverse load factor (contact stress)	1.904		
9.9	Total factor of additional loads	7.559		
9.10	Elasticity factor	189.81		
9.11	Zone factor	2.223		
9.12	Helix angle factor	0.931		
9.13	Contact ratio factor	0.821		
9.14	Lubricant factor	1.057		
9.15	Peripheral speed factor	0.984		
9.16	Roughness factor affecting surface durability	0.936		
9.17	Bevel gear factor (flank)	0.850		
9.18	Life factor for contact stress	0.850	0.881	
9.19	Single pair tooth contact factor	1.000	1.000	
	For bending safety calculation			

9.19	Face load factor (root stress)	1.570		
9.20	Transverse load factor (root stress)	1.904		
9.21	Total factor of additional loads	7.559		
9.22	Helix angle factor	0.750		
9.23	Contact ratio factor	0.644		
9.24	Notch sensitivity factor	1.005	0.996	
9.25	Size factor	1.000	1.000	
9.26	Tooth-root surface factor	0.975	0.975	
9.27	Alternating load factor	1.000		
9.28	Production technology factor	1.000		
9.29	Life factor for bending stress	1.000	1.000	
9.30	Tip factor, equal (YFa YSa)	3.921	3.878	☑

10.0 ☑ Safety coefficients

10.1	Safety coefficient for surface durability	#DIV/0!	#DIV/0!
10.2	Safety coefficient for bending durability	#DIV/0!	#DIV/0!
10.3	Safety in contact in one-time overloading	#DIV/0!	#DIV/0!
10.4	Safety in bending in one-time overloading	#DIV/0!	#DIV/0!

11.0 ☑ Force conditions (forces acting on the toothing)



11.1	Tangential force	0.00		[N]
11.2	Normal force	0.00		[N]
11.3	Axial force - (rotation acc. to the picture)	0.00	0.00	[N]
11.4	Radial force (rotation acc. to the picture)	0.00	0.00	
11.5	Axial force (rotation opposite to the picture)	0.00	0.00	[N]
11.6	Radial force (rotation opposite to the picture)	0.00	0.00	
11.7	Peripheral speed on the pitch diameter	5.44	< 12	[m/s]
11.8	Specific load / Unit load	0.00	0.00	[N/mm | MPa]

12.0 ☑ Parameters of the chosen material

12.1	Density	7870	7870	[kg/m^3]

12.2	Young's Modulus (Modulus of Elasticity)	206	206	[GPa]
12.3	Tensile Strength, Ultimate	1570	1570	[MPa]
12.4	Tensile Strength, Yield	1350	1350	[MPa]
12.5	Poison's Ratio	0.3	0.3	
12.6	Contact Fatigue Limit	1288	1288	[MPa]
12.7	Bending Fatigue Limit	740	740	[MPa]
12.8	Tooth Hardness - Side	615	615	[HV]
12.9	Tooth Hardness - Core	485	485	[HV]
12.10	Base Number of Load Cycles in Contact	1.00E+08	1.00E+08	
12.11	Wohler Curve Exponent for Contact	10	10	
12.12	Base Number of Load Cycles in Bend	3.00E+06	3.00E+06	
12.13	Wohler Curve Exponent for Bend	9	9	

Additions section

13.0 ☑ **Power, warming-up, gearbox surface**

13.1	Ambient air temperature	20.00	[°C]
13.2	Maximum oil temperature	60.00	[°C]
13.3	Coefficient of heat dissipation	10.00	[W/m2/K]
13.4	Power losses	0.00	[kW]
13.5	Gearbox surface (min.)	0.00	[m2]

14.0 ☐

15.0 ☐

16.0 ☐

Rolling bearing selection

Rolling bearings INA/FAG

i	**Check lines: 2.9; 3.6;**
ii	**Project information**

? Input parameters section

1.0 ☑ Selection of bearing type, bearing loads

1.1	Calculation units		SI Units (N, mm, kW...)	
1.2	**Bearing type**		FAG : Spherical roller thrust bearings	
1.7	**Bearing load**			
1.8	Rotational speed	n	1000.0	[/min]
1.9	Radial load	Fr	1000.0	[N]
1.10	Axial load	Fa	200.0	[N]
1.11	Factor of additional dynamic forces		1	
1.12	**Required parameters of bearing**			
1.13	Bearing life	Lh	10000	[h]
1.14	Static safety factor	s0	2.00	

1.3	**Bearing design**			
1.4				
1.5				
1.6				
1.15	**Additional dynamic forces**			
1.16	● **None**			
1.17	○ **From geared transmissions**			
1.18	Ordinary machined gears (deviations of shape and pitch 0.02-0.1mm			
1.19	Factor	fk	1.1 - 1.3	1.20
1.20	Electric rotary machines, turbines, turbo-compressors			
1.21	Factor	fd	1 - 1.2	1.10
1.22	○ **From belt drives**			
1.23	V-belts			
1.24	Factor	fb	1.9 - 2.5	2.20

2.0 ☑ Selection of bearing size

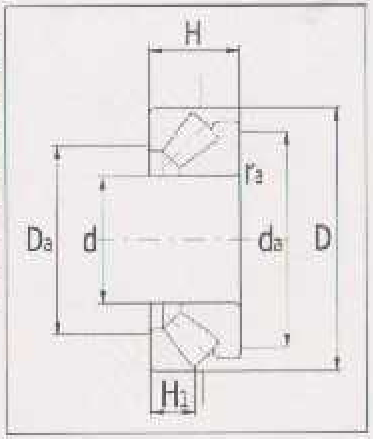
2.1 **Bearing size**

ID	d	D	H	C	C0	nr	nmax	Bearing
1	60.0	130.0	42.0	335000	900000	3400	3400	29412-E

2.2 **Bearing parameters**

2.3	Basic dynamic load rating	C	335000	[N]
2.4	Equivalent dynamic load	P	1400	[N]
2.5	Basic rating life	L10h	1417657503	[h]
2.6	Basic static load rating	C0	900000	[N]
2.7	Equivalent static load	P0	2900	[N]
2.8	Static safety factor	s0	310.34	
2.9	Permissible radial load	Frmax	**110**	[N]
2.10	Permissible axial load	Famax	-	[N]
2.11	Reference speed	nr	3400	[/min]
2.12	Limiting speed	nmax	3400	[/min]
2.13	Power loss	NR	7.92	[W]
2.14	Bearing mass	g	2.23	[kg]

d	60
D	130
H	42
H1	20
ramax	1.5
Damax	107
damin	90
dbmax	70



3.0 ☑ Operating parameters, adjusted bearing life

3.1 **Kinematic viscosity of the lubricant**

3.2	Rated viscosity	ν_1	14.6	[mm^2/s]
3.3	Operating viscosity	ν	25.0	[mm^2/s]
3.4	Viscosity ratio	κ	1.71	

3.5 **Requisite minimum load**

3.6	Minimum axial load	Famin	**1800**	[N]

3.7 **Calculation of the adjusted rating life**

3.8	Fatigue load limit	Pu	65000		[N]
3.9	Required reliability		90 %		
3.10	Contamination of the lubricant		Typical contamination		
3.11	Factor for contamination level	η	0.3 - 0.1	0.20	☑
3.12	Life modification factor	a1/a23	1	50	
3.13	Adjusted rating life	Lmh	70882875150		[h]

Supplements section

4.0 ☑ Auxiliary calculations

4.1 **Calculation of operating viscosity**

4.2	Operating temperature	T		70.0	[°C]
4.3	**Mineral oils**				
4.4	ISO viscosity grade			ISO VG 68 ☑	
4.5	Reference viscosity	ν_{40}		68.0	[mm^2/s]
4.6	Operating viscosity	ν		20.1	[mm^2/s]
4.7	**Other lubricants**				
4.8	Temperature		40.0	100.0	[°C]
4.9	Viscosity		100.0	11.3	[mm^2/s]
4.10	Operating viscosity	ν		27.4	[mm^2/s]

4.11 **Bearing lubrication**

4.12	Method of lubrication		Grease lubrication	
4.13	Power loss	NR	17.54	[W]
4.14	Desired oil volume flow	V	-	[l/min]
4.15	Relubrication interval	tf	0	[h]

4.16 **Calculation of permissible speed**

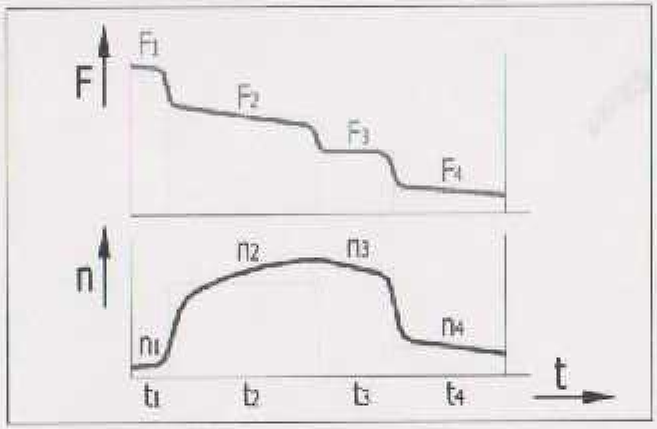
4.17	Reference speed	nr	3400	[/min]
4.18	Temperature difference	Δ_A	50.0	[°C]
4.19	Difference of oil temperature	Δ_L	5.0	[°C]
4.20	Oil volume flow	V	0.100	[l/min]
4.21	Permissible speed	nperm	6726	[/min]

5.0 ☑ Fluctuating bearing load

5.1 Number of different load conditions: 2

5.2 Table of load conditions

i	Fri [N]	Fai [N]	ni [/min]	ti/t [%]
1	500.0	250.0	4500.0	25.0
2	200.0	100.0	7000.0	75.0
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				



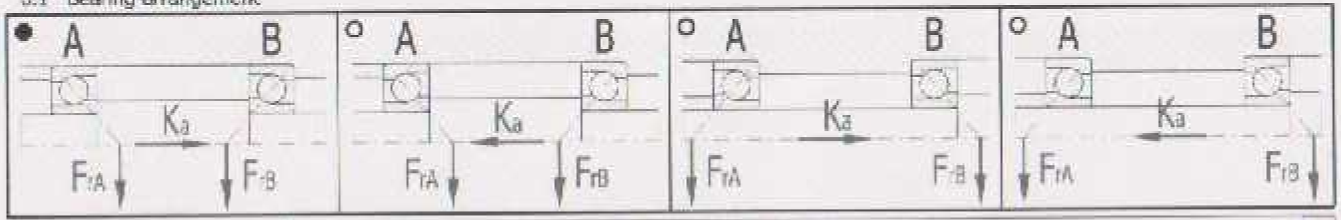
5.3 **Mean load**

5.4	Rotational speed	n	6375	[/min]
5.5	Radial load	Fr	315.4	[N]
5.6	Axial load	Fa	157.7	[N]

5.7 Transfer of load into main calculation

6.0 ☑ Calculation of bearings with angular contact

6.1 Bearing arrangement



6.2 Bearing type — Angular contact ball bearings, single row (contact angle 40°); Open design

6.3 External axial load — Ka 2000.0 [N]

6.4 **Bearing A**

6.5 Bearing design — Single bearing

6.6 Radial load — FrA 4000.0 [N]

6.7 Bearing size

ID	d	D	B	nmax	Bearing
35	35.0	80.0	21.0	9500	7307-B-TVP

6.8 Axial load — Fa 0 [N]

6.9 Equivalent dynamic load — P 4000 [N]

6.10 Basic rating life — L10h 16667 [h]

6.11 Transfer into main calculation ☐

6.12 **Bearing B**

6.13 Bearing design — Single bearing

6.14 Radial load — FrB 2000.0 [N]

6.15 Bearing size

ID	d	D	B	nmax	Bearing
25	30.0	72.0	19.0	11000	7306-B-JP

6.16 Axial load — Fa 5508.8 [N]

6.17 Equivalent dynamic load — P 3840 [N]

6.18 Basic rating life — L10h 10578 [h]

6.19 Transfer into main calculation

Shaft design

Shaft design and calculation — Shaft calculation — Clear table of results

i Calculation without errors.

ii Project information

? Input sectinon

1 Preliminary shaft diameter design

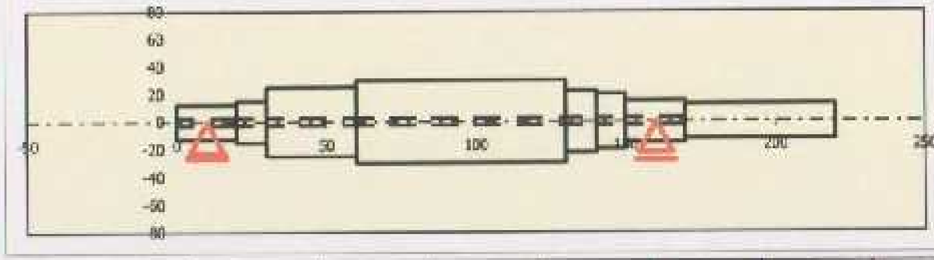
1.1	Calculation units	SI Units (N, mm, kW...)	
1.2	Transmitted power	100.00	[kW]
1.3	Shaft speed	1500	[/min]
1.4	Torsion moment	636.67	[Nm]
1.5	Preliminary min. diameter	55.57	[mm]

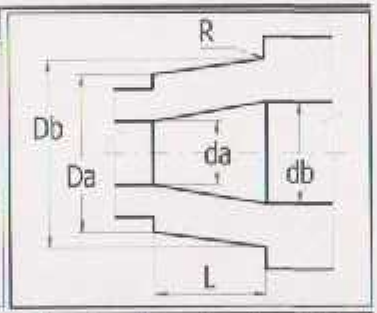
1.6 Type of shaft load: C. Repeated torsion - bending

1.7 Material of the shaft: C ..High strength structural steel (1200)

2.0 Shaft shape and dimensions

2.1 The scale of the displayed shaft diameter. ☑ Calculation units: SI Units (N, mm, kW...)





2.2

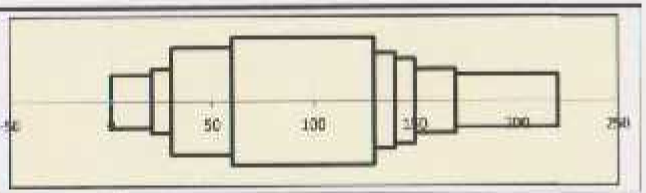
Table	1	2	3	4	5	6	7	8	9	10
Origin	0.00	20.00	30.00	60.00	130.00	140.00	150.00	170.00	220.00	220.00
L	20.000	10.000	30.000	70.000	10.000	10.000	20.000	50.000		
ø Da	25.000	30.000	50.000	60.000	45.000	40.000	30.000	25.000		
ø Db	25.000	30.000	50.000	60.000	45.000	40.000	30.000	25.000		
ø da	5.000	5.000	5.000	5.000	5.000	5.000	5.000	0.000		
ø db	5.000	5.000	5.000	5.000	5.000	5.000	5.000	0.000		
R	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000		

2.3	Total length of the shaft		220.00	[mm]
2.4	X-coordinate of the left support (bearing)	Fixed	10.00 ◉	[mm]
2.5	X-coordinate of the right support (bearing)	Free	160.00 ○	[mm]

2.6 The shaft surface (Roughness Ra): C..Ground (0.8)

3.0 Notches and necking-down on the shaft

3.1	The ultimate tensile strength (Su, Rm)	595.0 ☑	[MPa]
3.2	Notch sensitivity factor (q)	0.45	

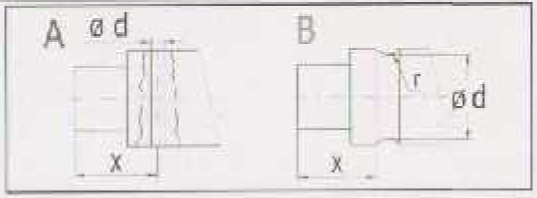


3.3 **A. Transverse hole**

X[mm]	d[mm]	β c	β b	β t
		1.00	1.00	1.00
		1.00	1.00	1.00

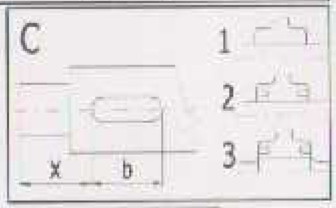
3.4 **B. Necking-down**

X[mm]	d[mm]	r[mm]	β c	β b	β t
			1.00	1.00	1.00
			1.00	1.00	1.00
			1.00	1.00	1.00



3.5 **C. General notch**

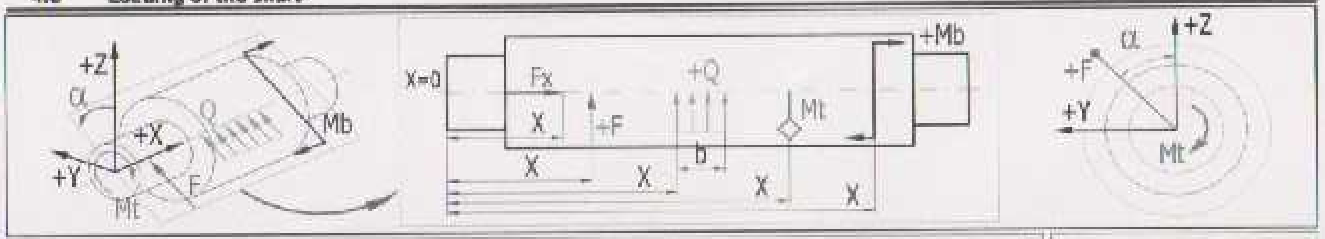
X[mm]	b[mm]	βc	βb	βt	
		1.00	1.00	1.00	User values
		1.00	1.00	1.00	User values
		1.00	1.00	1.00	User values
		1.00	1.00	1.00	User values
		1.00	1.00	1.00	User values

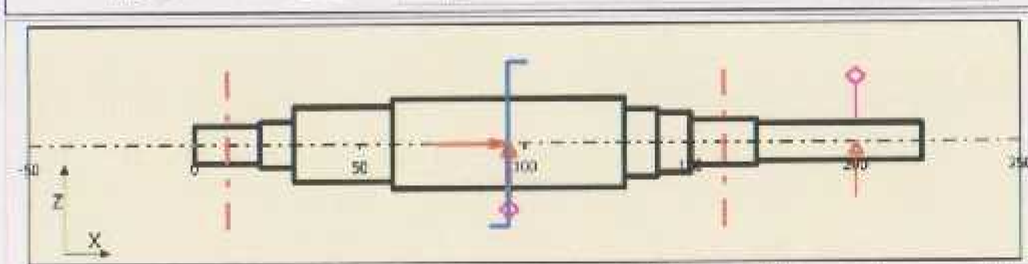


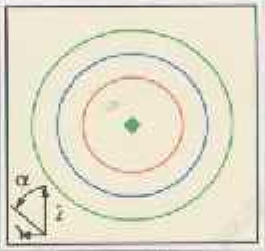
3.6 **D. Rounding between cylindrical sections of the shaft**

	1	2	3	4	5	6	7	8	9
βc	1.59	1.79	1.86	1.90	1.68	1.72	1.59	1.00	1.00
βb	1.50	1.64	1.73	1.75	1.59	1.60	1.50	1.00	1.00
βt	1.25	1.34	1.37	1.38	1.29	1.31	1.25	1.00	1.00

4.0 Loading of the shaft







4.1 Loading

	X	Fx	F	alfa	Mt	Mb	alfa	Q	b	alfa
	[mm]	[N]		[°]	[Nm]		[°]	[N/mm]	[mm]	[°]
1	95.00	100.0	2000.0	0	50.00	30.00				
2	200.00		1000.0	90	-50.00	0.00				
3										
4										
5										
6										
7										
8										
9										
10										

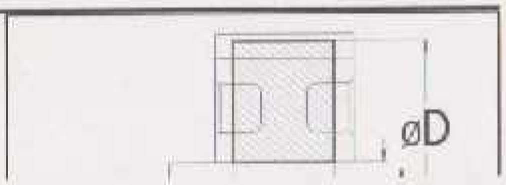
5.0 Rotating masses

5.1 Additional rotating masses (resonance speed)

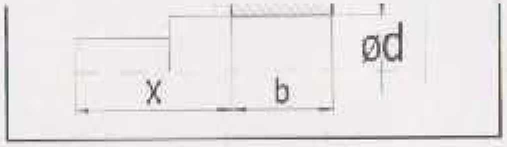
5.2 Use loading from the weight of disks in the calculation? Yes

5.3

	X	D	d	b	Ro	m
	[mm]				[kg/m^3]	[kg]
M1	0.00	0.00	0.00	0.00	7800.0	0.00



M2	0.00	0.00	0.00	0.00	7800.0	0.00
M3	0.00	0.00	0.00	0.00	7800.0	0.00
M4	0.00	0.00	0.00	0.00	7800.0	0.00
M5	0.00	0.00	0.00	0.00	7800.0	0.00



6.0 Material and the type of loading

6.1 Shaft material (Ultimate tensile strength min-max)

A...Structural steel (330 - 700) | 595 | [MPa]

6.2	Ultimate tensile strength	595	[MPa]
6.3	Yield strength in tension	345	[MPa]
6.4	Yield strength in bending	449	[MPa]
6.5	Yield strength in shear	242	[MPa]
6.6	**For reversed loading**		
6.7	Fatigue limit - tension-press	226	[MPa]
6.8	Fatigue limit - bending	292	[MPa]
6.9	Fatigue limit - torsion	208	[MPa]
6.10	**For cyclic loading**		
6.11	Fatigue limit - tension-press	339	[MPa]
6.12	Fatigue limit - bending	437	[MPa]
6.13	Fatigue limit - torsion	239	[MPa]
6.14	Specific mass	7850.0	[kg/m^3]
6.15	Modulus of elasticity in tensi	210000	[MPa]
6.16	Modulus of elasticity in shea	80000	[MPa]

6.17	Dead load	Yes
6.18	Max. displayed coefficient of safety	20
6.19	Stress ratio factor α_0	0.85
6.20	**Coefficient of maximum loading**	
6.21	Bending	1.70
6.22	Radial load	1.70
6.23	Torsion	1.70
6.24	Tension/Compression	1.70
6.25	**Loading conditions**	
6.26	Loading from bending moment	C...Reversed
6.27	Loading from radial force	C...Reversed
6.28	Load from torsional moment	B...Repeated
6.29	Loading from tension/pressure force	B...Repeated
6.30	**Dynamic strength check**	
6.31	Impact from shaft surface	Yes
6.32	Impact from shaft size	Yes
6.33	Impact from stress concentration (not	Yes

7

Results section

7.0 Results - summary

		x	y	z	Σ y+z	
7.1	Reaction in the support R1	-100	266.66667	-1055.6682	1088.828	[N]
7.2	Reaction in the support R2	0	-1266.6667	-918.351	1564.5488	[N]

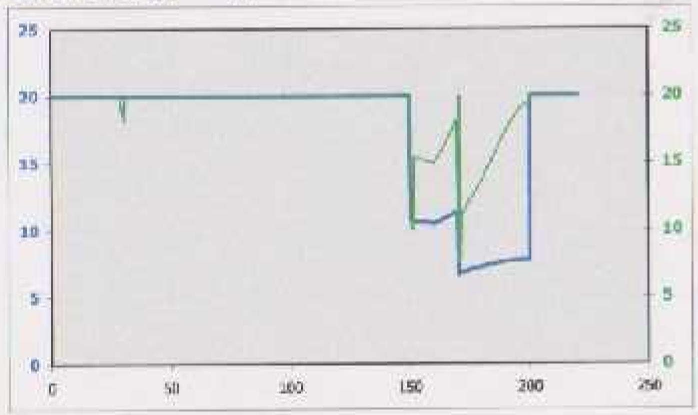
7.3	Total shaft weight	2.65	[kg]
7.4	Maximum deflection	0.0112	[mm]
7.5	Maximum angular deflection	0.0401	[°]
7.6	Angular deflection in R1	0.0037	[°]
7.7	Angular deflection in R2	0.0046	[°]
7.8	Max. bending stress	19.4	[MPa]
7.9	Max. stress in shear	2.3	[MPa]
7.10	Max. stress in torsion	16.3	[MPa]
7.11	Max. stress in tension/press	0.2	[MPa]
7.12	Max. equivalent stress	33.4	[MPa]
7.13	Min. static safety	6.70	
7.14	Min. dynamic safety	7.59	
7.15	Critical speed (A)	0.0	[/min]
	Critical speed (B)	290187.7	[/min]
	Critical speed (C)	265410.0	[/min]

Shaft freely rotating in bearings, rotating disc between the bearings (K=1)

7.17 Graph

41. Safety coefficient (static)

42. Safety coefficient (dynamic)



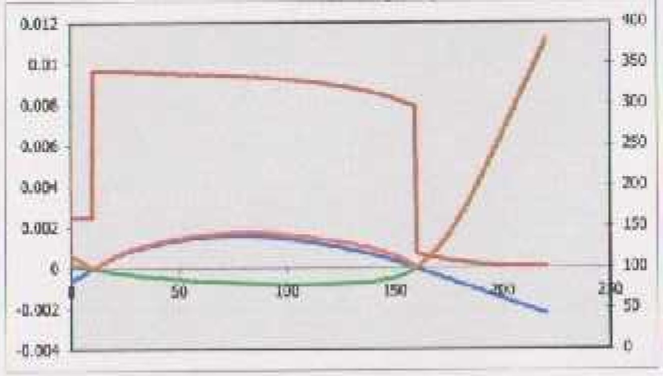
7.16 Results for X co-ordinate	174.63	1371.60	1397.00	2095.50	2127.25	2127.25	2127.25	2127.25
04. Z - Deflection [mm]	-0.0005316	-0.002248	-0.002248	-0.002248	-0.002248	-0.002248	-0.002248	-0.002248
42. Safety coefficient (dynamic)	11.94605	20	20	20	20	20	20	20

31..Total coefficient - bending	▼	1.1441648	1.1441648	1.1441648	1.1441648	1.1441648	1.1441648	1.1441648	1.1441648
42..Safety coefficient (dynamic)	▼	11.94605	20	20	20	20	20	20	20
43..Empty graph	▼	0	0	0	0	0	0	0	0

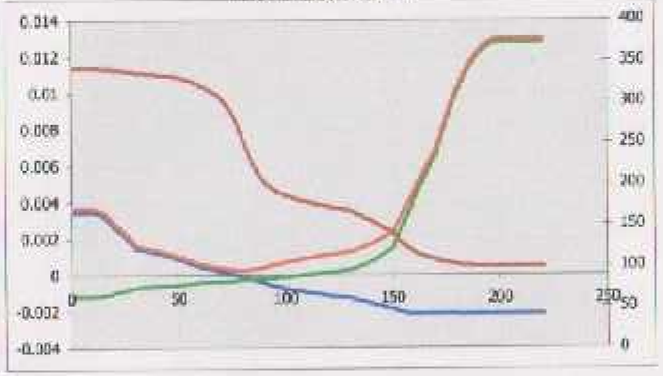
8.0 Graph - Deflection, Bending angle

8.1 Curves in graph ☑ XZ Plane ☑ XY Plane ☑ Sum ☑ Angle

Deflection [mm]



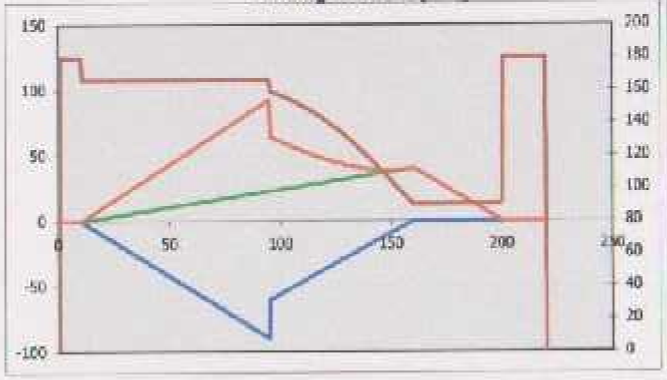
Bending angle [°]



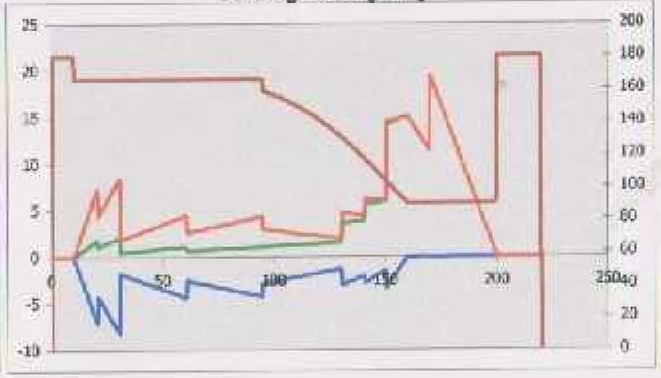
9.0 Graph - Bending moment, Bending stress

9.1 Curves in graph ☑ XZ Plane ☑ XY Plane ☑ Sum ☑ Angle

Bending moment [Nm]



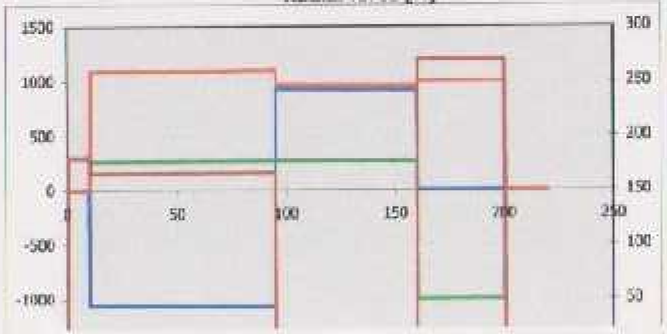
Bending stress [MPa]



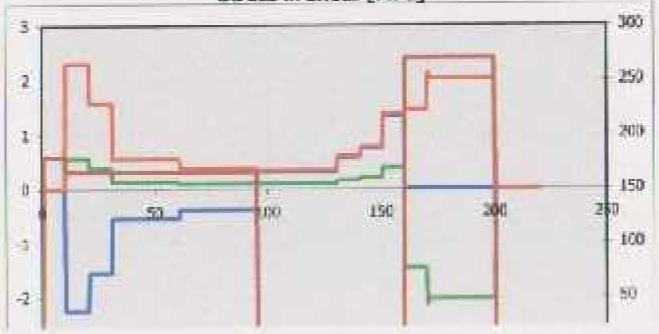
10.0 Graph - Radial force, Stress in shear

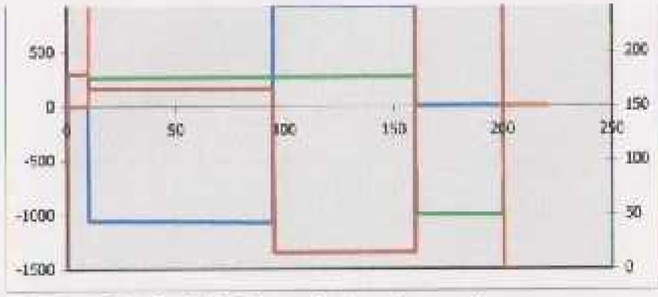
10.1 Curves in graph ☑ XZ Plane ☑ XY Plane ☑ Sum ☑ Angle

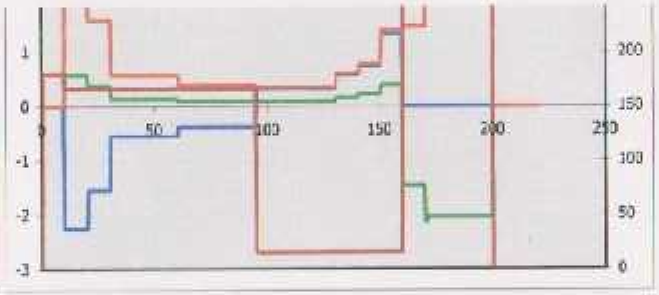
Radial force [N]



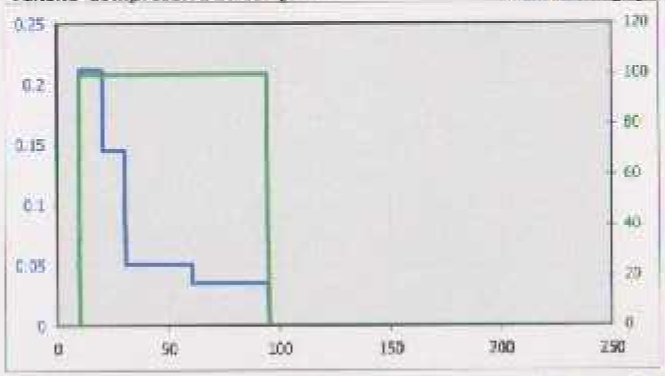
Stress in shear [MPa]

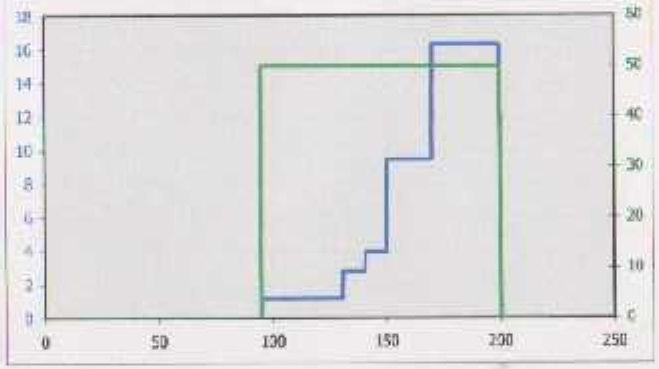




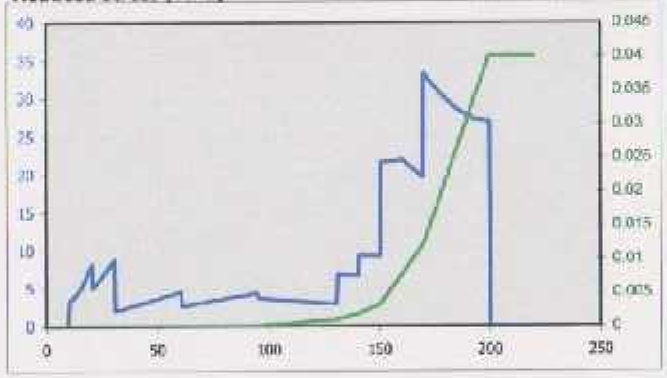


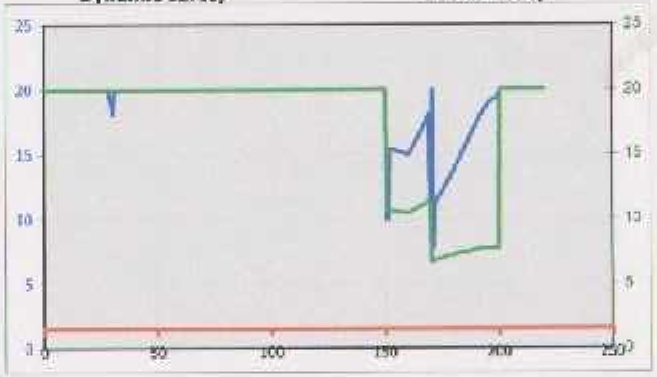
11.0 Graph - Axial force, Torsional moment





12.0 Graph - Torsional angle, Reduced stress, Safety coeficient





References:

1. Mechanisms and dynamics of machinery by H.H. Mabia, C.F. Reiholtz
2. W.D. Callister. John Wiley & Sons, Materials Science and Engineering, An Introduction
3. William F. Smith (McGraw-Hill, 1993), Foundations of Materials Science and Engineering
4. Stockel, Johanson, the Goodheart Willcox Company, Inc., 1996, Auto-fundamentals
5. Michael F. Ashby, Materials Selection in Mechanical design
6. M.F. Hassan (Editor), S.M. Megahed, Current Advances in Mechanical Design and Production VII
7. Peter Childs, Mechanical Design, Second Edition
8. J. A. Collins , Jack A. Collins , Failure of Materials in Mechanical Design: Analysis, Prediction, Prevention
9. Jack Collins, George H. Staab , Henry R. Busby, Mechanical Design of Machine Elements and Machines: A Failure Prevention Perspective
10. David G Ullman (Author), David Ullman, The Mechanical Design Process Robert L. Mott, Machine Elements in Mechanical Design SI Version
11. Stokes, Manual Gearbox Design
12. http://www.aarons-books.co.uk/cat/TGB/manual-gearbox-design
13. http://www.engineersedge.com/wwwboard/messages/675.html
14. http://www.roymech.co.uk/Useful_Tables/Drive/Drive_trains.html
15. http://www.gearboxdesign.net
16. http://www.agma.org/Content/NavigationMenu/EducationTraining/GearboxCSI/gearboxcsi-1107.pdf
17. http://www.patentstorm.us/patents/6435054-description.html
18. http://www.bga.org.uk/publish/techpub/gtm-tpgt/gtm02.htm
19. http:// motion-controls.globalspec.com/Industrial-Directory/box_gear_transmission
20. http://www.gearboxwebdesign.com
21. http://www.edmunds.com/ownership/techcenter/articles/46029/article.html

22.
http://www.delphielite.com/modules/gallery/pictures/Documents/2004GearboxDesign.pdf
23. http://www.manualgear.com/en/driven-3-Lamborghini+Gallardo+Spyder.html
24. http://www.in.jobstreet.com/jobs/2008/5/default/60/1321880.htm
25. http://www.nationaltransmission.ca/manual_transmission.htm
26. http://www.ahgears.com
27. http://www.cranfield.ac.uk/soe/shortcourses/em/page4147.jsp
27. http://www.csa.com/discoveryguides/auto/review4.php
28. http://www.automobiles.mapsofindia.com/useful-information/development-in-transmission-system.html
29. http://www.engineeringtalk.com/news/zeo/zeo101.html
30. http://www.mechdir.com/webs/subject/75374/index.html
31. http://www.city-data.com/forum/automotive/178679-best-standard-transmission-cars-you-ve.html
32. http://www.sae.org/technical/papers/841605
33. http://www.hitachi.com/ICSFiles/afieldfile/2004/11/26/r2004_04_103_3.pdf
34. http://www.just-auto.com/store/product.aspx?ID=52529
35. http://www.powertraintechnologies.com/powertrain_design.html
36. http://www.swri.org/4ORG/d03/vehsys/drivetrn/whtpprs/powrpath.htm
37. http://www.lmsintl.com/Elasis-uses-detailed-CAE-model-gearbox-reduces-design-time
38. http://www.barmacinc.com/.../productsheets/SyntheticManualTransmissionTransax120Gea20Lbe.pdf
39. http://www.chevyhiperformance.com/hotnews/0701ch_gear_vendors_6_speed/index.html
40. http://www.gudel.com/en/power-transmission/gear-box.php
41. http://www.agma.org/Content/NavigationMenu/EducationTraining/GearboxCSI/Gear_Design_vs_Gearb.htm
42. http://www.ferret.com.au/c/Bonfiglioli-Transmission-Aust/Mosaico-system-for-optimising-gearbox-design-n666275
43. http://www.encyclopedia.com/doc/1E1-transmis.html
44. http://www.encyclopedia.com/doc/1G1-123708899.html