بسم الله الرحمن الرحيم

College of Engineering and Technology

Mechanical Engineering department

Graduation Project

Computerized Hydraulic Tensile Test Machine

Project Team

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Palestine Polytechnic University

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Departments of Mechanical Engineering

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According to the directions of the project supervisor and by the agreement of all examination committee members, this project is presented to the Departments of Mechanical Engineering, for partial fulfillment of Bachelor of engineering degree requirements.

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June, 2013

الإهـــــــــــــــداء

إلـهي لا يطيب الليل إلا بشكرك ولا يطيب النـهار إلى بطاعتك .. ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك .. ولا تطيب الجنة إلا برؤيتك الله جل جلاله

.. إلى من بلغ الرسالة وأدى الأمانة .. ونصح الأمة .. إلى نبي الرحمة ونور العالمين
سيدنا محمد صلى الله عليه وسلم

إلى من جرع الكأس فارغاً ليسقيني قطرة حب الى من كلت انامله ليقدم لنا لحظة سعادة الى من حصد الاشواك عن دربي ليمهد لي طريق العلم الى القلب الكبير والدي العزيز

إلى من أرضعتني الحب والحنان الى رمز الحب وبلسم الشفاء الى القلب الناصع بالبياض والدتي الحبيبة

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي اخوتي

إلى الأرواح التي سكنت تحت تراب الوطن الحبيب الشهداء العظام

الآن تفتح الأشرعة وترفع المرساة لتنطلق السفينة في عرض بحر واسع مظلم هو بحر الحياة وفي هذه الظلمة لا يضيء إلا قنديل الذكريات ذكريات الأخوة البعيدة إلى الذين أحببتهم وأحبوني أصدقائي

إلى الذين بذلوا كل جهدٍ وعطاء لكي أصل إلى هذه اللحظة أساتذتي الكرام ولا سيما الدكتور الفاضل يوسف السويطي

إليكم جميعاً أهدي هذا العمل

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Finally, we gratefully thank everyone help or smile to us.

Love,

Abstract

The project goal is developing a computerized hydraulic tensile test machine which is able to test various materials and interface this to the computer. The mechanical structure of this project is available in the university, but it was missed some parts.

This machine shall be used by the students in mechanics laboratory in our university. The operation principle is applying force on the specimen until it gets fractured passing through many stages, two sensors acquire the needed data for the test (elongation and pressure), and then that data used by computer to plot the stress-strain curve.

The project integrates many fields such as: computer, sensor, mechanics and hydraulics.

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CHAPTER 1

Introduction to Computerized Hydraulic Tensile Test Machine project

This chapter gives an overview about Computerized Hydraulic Tensile Test Machine project.

1.1 Introduction

Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. If a material is to be used as part of an engineering structure that will be subjected to a load, it is important to know that the material is strong enough and rigid enough to withstand the loads that it will experience in service. As a result, engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading [1].

The most common type of test used to measure the mechanical properties of a material is the Tension Test. Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The major parameters that describe the stress-strain curve obtained during the tension test are the ultimate tensile strength (S_{ut}), yield strength or yield point (σ_y), elastic modulus (E), percent elongation (%ΔL) and the reduction in area (%RA) [1] ,[2].

The mechanical engineering department at Palestine polytechnic university needs this important test machine in applied mechanics laboratory, so that the students would use this machine in order to link the theoretical part to practical part and recognize the actual material behavior.

In this modern world, the technology age, it is vital that the engineering student should be able to understand and analyze the related material behavior they deal with. So, this computerized tensile test machine should be built to serve the students in Palestine polytechnic university.

This project came as the request of the recommendations of teachers within the university laboratories to the need for such a machine.

This project aims to build a computerized machine that do the tensile test which is able to scan different samples of materials to indicate the ability to withstand the loads that it will experience in service .The student in the laboratory will install a sample and see the results showing a data of Stress-Strain diagram and some material's properties (Elasticity, Yield Strength and Ultimate Strength). So the machine should has a robust and strong mechanical structure to withstand forces greater than applied.

1.2 Recognition of the need

This machine is needed in PPU-Mechanics Lab & PPU-Test Center; they have and old fashion one with some technical problems, the project integrates as our study ,Mechatronics, so that we within control by computer the mechanics and hydraulics of the system & interface them in addition to electronic sensors as system's feedback.

The students sector is the most sector will be benefiting from this project, and in particular students of mechanical engineering and civil and architectural at the university to fill has to do the courses of study many based on the practical application of laboratory science different and special test pulling minerals, as he came of this project at the request of the recommendations of teachers within the laboratories University of the need for a such a machine.

1.3 Project Objectives

1. To build a device that integrally combines the mechanical, electrical, hydraulic and computer engineering.
2. To build a computerized hydraulic tensile test machine, which will be used in Palestine Polytechnic University Mechanics Lab.
3. To show all of application that studied in 5 years in this project.
4. To introduce the computerized machine as a local alternative solution for customers instead of importing it from other countries.

1.4 Literature Review

After searching for a similar Computerized Hydraulic Tensile Test Machines, There are many manufacturers who produce such machines, like: TecQuipment (TQ) [8] , MTI Instruments Incorporation, and Physical Test Solutions (PTS) [10] , GUNT companies for Education equipment[9] , but the cost is considerably high. Here is a comparison between different machines and our project (Table 1.1)[1], [12].

[1] A recent price quotation for some tensile test machines is referenced in appendix #A

Table 1.1: Comparison of tensile test machines

Tensile Test Machines Comparison

Comparison	FMCC-50	PTS-EP-FM	HLCR-300	This Proposed Machine
Actuator Type	Motor plus a rack-pinion	Motor plus a rack-pinion	Hydraulic Piston	Hydraulic Piston
Load capacity	50 kN	50 kN	300 kN	43 kN
Stress' sensor	Load cell	Load cell	Load cell	Pressure sensor
Displacement Sensor	Extensometer	Extensometer	Photoelectric Encoder	Photoelectric Encoder
Displacement Resolution	0.001 mm	0.01 mm	0.001 mm	0.001 mm
Price	$ 31,000	$ 20,000	$ 43,000	$ 6,000
Picture				

1.5 Time plan

The time plane explains the stages in designing and building the system components. The section includes the first one show what is done in the first semester while the second semester shows the tasks scheduling for the second semester.Table1-2 shows the first semester and Table 1-3 shows the second semester:

Table 1-2: Time table for the first semester time (week)

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Selection	■	■													
Search For Information			■	■	■	■	■	■	■	■	■				
Literature Review						■	■	■	■						
Mechanical Design & Mathematical Modelling									■	■	■	■			
Evaluating & Reviewing													■	■	
Writing& Typing					■	■	■	■	■	■	■	■	■	■	■
Final Edition															■

Table 1-3: Time table for the second semester time (week)

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Software Design	■	■	■	■	■										
Hardware Design	■	■	■	■	■	■	■	■	■	■					
Software Testing						■	■	■	■	■	■				
Hardware Testing				■	■	■	■	■	■	■	■	■	■		
Interface System												■	■	■	
System Testing														■	■
Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

1.6 Cost Estimation and Budget Breakdown

This section lists the overall cost of the project the cost includes the hardware cost, the software cost, and the human resources budget.

Hardware cost: includes the cost of the components that was used to implement the project. Table1-3 shows these costs.

Table 1-4: Hardware cost

Components		Price
Hydraulic pump		120 JD
Pressure sensor		160 JD
Optical linear displacement sensor		450 JD
DAQ card		170 JD
PC computer		200 JD
Mechanical maintenance		50 JD
	Total cost	1150JD

*This price does not include the mechanical structure.

1.7 Risk Management

The implementation of any project nay face many risks during each stage of the project, determining and analyzing the system requirements, designing, implementing and testing the whole system. This section illustrates what is the problem which occurred during the implementation.

1.7.1 Technology Risk

Technology risks can be classified as hardware and software risks:

Hardware Risks Include:

-Malfunctions of many chips such as PIC microcontroller and DAQ and encoding chip which are used in the interfacing circuit.
-Some chips were unavailable at beginning of the semester, so there was a late in time waiting for these chips.

Software Includes:

-The program may follow undesirable algorithm, but this project algorithm was clear and understandable.

1.7.2 Risks Avoidance

-Taking care when using hardware components and using them according to their specifications.
-Taking care of the team member's health during the project development.
-Including an extra amount of the hardware components, so when any problem occurs the alternative components could be found and replaced easily.

CHAPTER 2

Introduction to Tensile Testing

2.1 Introduction

The results of tensile test is used in selecting materials for engineering applications, tensile properties frequently are included in material specifications to ensure quality, tensile properties often are measured during development of new materials and processes, so that different materials and processes can be compared. Finally, tensile properties often are used to predict the behavior of a material under forms of loading other than uniaxial tension [6].

The strength of a material often is the primary concern. The strength of interest may be measured in terms of either the stress necessary to cause appreciable plastic deformation or the maximum stress that the material can withstand. These measures of strength are used, with appropriate caution (in the form of safety factors), in engineering design. Also of interest is the material's ductility, which is a measure of how much it can be deformed before it fractures. Rarely is ductility incorporated directly in design; rather, it is included in material specifications to ensure quality and toughness. Low ductility in a tensile test often is accompanied by low resistance to fracture under other forms of loading. Elastic properties also may be of interest, but special techniques must be used to measure these properties during tensile testing [3].

This chapter provides a brief overview of some of the more important topics associated with tensile testing.

2.2 Tensile Specimens and Testing Machines

In this section will we talk for standard tensile Specimens and testing machines.

2.2.1 Standard Tensile Specimens

Consider the typical tensile specimen shown in Fig 2.1 It has enlarged ends or shoulders for gripping. The important part of the specimen is the gage section.

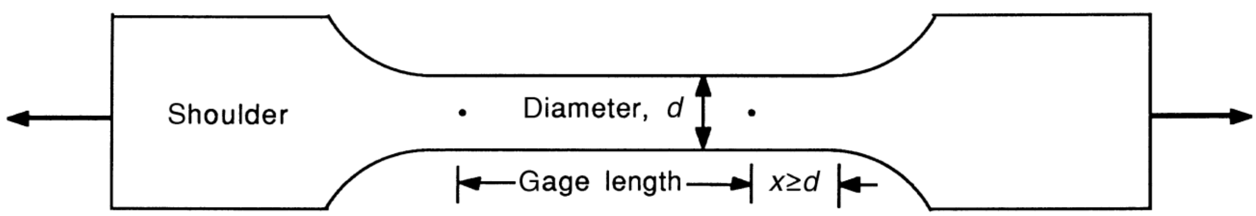


Fig 2.1: Typical tensile specimen, showing a reduced gage section and enlarged shoulders. To avoid end effects from the shoulders, the length of the transition region should be at least as great as the diameter, and the total length of the reduced section should be at least four times the diameter [6].

The cross-sectional area of the gage section is reduced relative to that of the remainder of the specimen so that deformation and failure will be localized in this region. The gage length is the region over which measurements are made and is centered within the reduced section. The distances between the ends of the gage section and the shoulders should be great enough so that the larger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension [1].

There are various ways of gripping the specimen, some of which are illustrated in Fig2.2 the end may be screwed into a threaded grip, or it may be pinned; butt ends may be used, or the grip section may be held between wedges. The most important concern in the selection of a gripping method is to ensure that the specimen can be held at the maximum load without slippage or failure in the grip section [2].

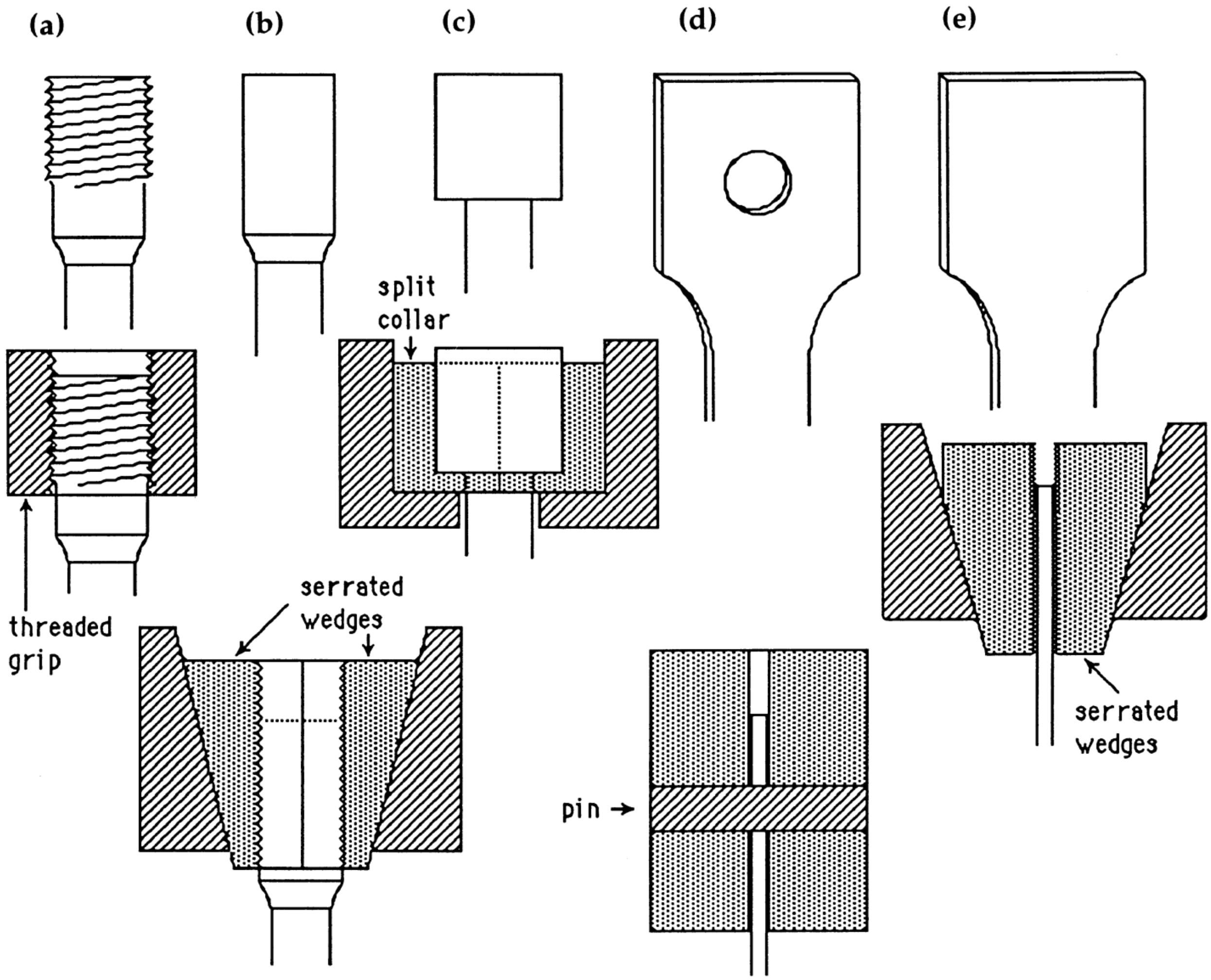


Fig 2.2: Systems for gripping tensile specimens. For round specimens, these include threaded grips (a), serrated wedges (b), and, for butt end specimens, split collars constrained by a solid collar (c). Sheet specimens may be gripped with pins (d) or serrated wedges (e). [6]

In this project, a threaded grip is used to grip the specimen in its location.

2.2.2 Testing Machines

The most common testing machines are universal testers, which test materials in tension, compression, or bending. Their primary function is to create the stress strain curve described in the following section in this chapter.

Testing machines are either electromechanical or hydraulic. The principal difference is the method by which the load is applied.

Electromechanical machines are based on a variable-speed electric motor; a gear reduction system; and one, two, or four screws that move the crosshead up or down. This motion loads the specimen in tension or compression. Crosshead speeds can be changed by changing the speed of the motor. A microprocessor-based closed-loop servo system can be implemented to accurately control the speed of the crosshead [13].

Hydraulic testing machines (Fig 2.3) are based on either a single or dual-acting piston that moves the crosshead up or down. However, most static hydraulic testing machines have a single acting piston or ram. In a manually operated machine, the operator adjusts the orifice of a pressure-compensated needle valve to control the rate of loading. In a closed-loop hydraulic servo system, the need leave is replaced by an electrically operated servo valve for precise control.

Fig 2.3: Components of a hydraulic testing machine

In general, electromechanical machines are capable of a wider range of test speeds and longer crosshead displacements, whereas hydraulic machines are more cost effective for generating higher forces [6].

2.3 Stress-strain curves, including discussion of elastic versus plastic deformation, yield points, and ductility.

2.3.1 Stress-Strain Curves

A tensile test involves mounting the specimen in a machine, such as those described in the previous section, and subjecting it to tension. The tensile force is recorded as a function of the increase in gage length. Figure 2.4(a) shows a typical curve for a ductile material. Such plots of tensile force versus tensile elongation would be of little value if they were not normalized with respect to specimen dimensions [2].

Engineering stress, or nominal stress, σ is defined as:

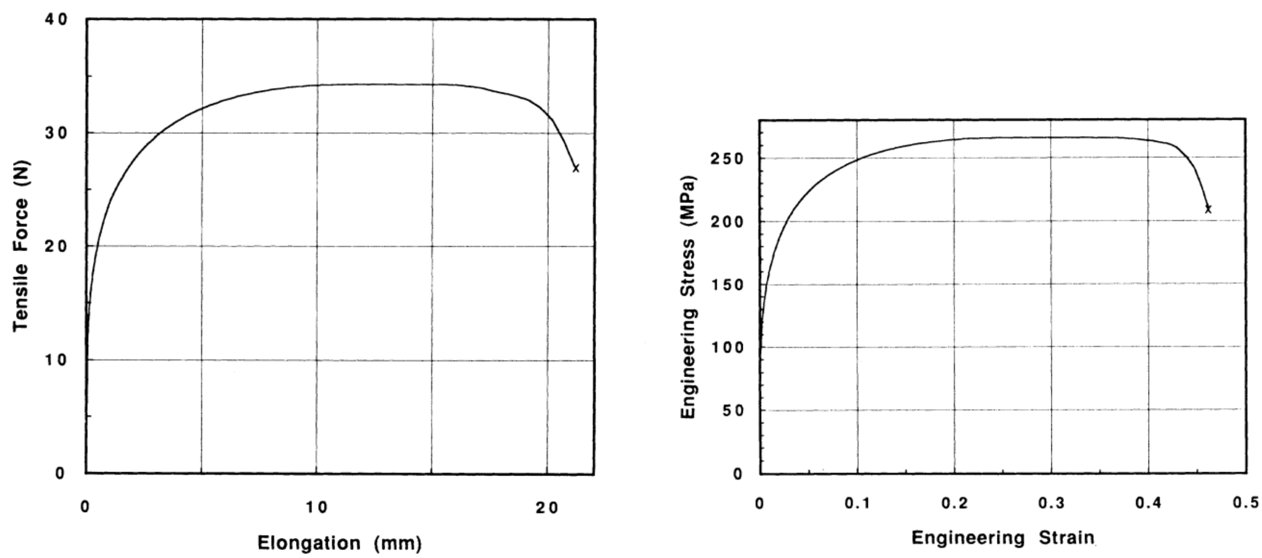
$$\sigma = \frac{F}{Ao} \qquad (2.1)$$

Where F is the tensile force and Ao is the initial cross-sectional area of the gage section. Engineering strain, or nominal strain, ε is defined as:

$$\varepsilon = \frac{\Delta L}{Lo} = \frac{L - Lo}{Lo} \qquad (2.2)$$

Where Lo is the initial gage length and ΔL is the change in gage length (L _ Lo).

When force-elongation data are converted to engineering stress and strain, a stress-strain curve (Fig 2.4b) that is identical in shape to the force-elongation curve can be plotted. The advantage of dealing with stress versus strain rather than load versus elongation is that the stress-strain curve is virtually independent of specimen dimensions [3].



(a) (b)

Fig 2.4: (a) Load-elongation curve from a tensile test and (b) corresponding engineering stress-strain curve. Specimen diameter, 12.5 mm; gage length, 50 mm [3].

2.3.2 Elastic versus Plastic Deformation

When a solid material is subjected to small stresses, the bonds between the atoms are stretched. When the stress is removed, the bonds relax and the material returns to its original shape. This reversible deformation is called *elastic deformation*. (The deformation of a rubber band is entirely elastic). At higher stresses, planes of atoms slide over one another. This deformation, which is not recovered when the stress is removed, is termed *plastic deformation*. Note that the term "plastic deformation" does not mean that the deformed material is a plastic (a polymeric material). If the wire is bent a little bit, it will snap back when released (top). With larger bends, it will unbend elastically to some extent on release, but there will be a permanent bend because of the plastic deformation [1].

For most materials, the initial portion of the curve is linear. The slope of this linear region is called the *elastic modulus* or *Young's modulus:*

$$E = \frac{\sigma}{\varepsilon} \qquad (2.3)$$

In the elastic range, the ratio, υ, of the magnitude of the lateral contraction strain to the axial strain is called *Poisson's ratio:*

$\upsilon = -\frac{\varepsilon x}{\varepsilon y}$ (in an *x*-direction tensile test) (2.4)

Because elastic strains are usually very small, reasonably accurate measurement of Young's modulus and Poisson's ratio in a tensile test requires that strain be measured with a very sensitive extensometer. (Strain gages should be used for lateral strains.) Accurate results can also be obtained by velocity-of-sound measurements (unless the modulus is very low or the damping is high, as with polymers) [3].

When the stress rises high enough, the stress strain behavior will cease to be linear and the strain will not disappear completely on unloading. The strain that remains is called plastic strain. The first plastic strain usually corresponds to the first deviation from linearity. (For some materials, the elastic deformation may be nonlinear, and so there is not always this correspondence).Once plastic deformation has begun, there will be both elastic and plastic contributions to the total strain, εT. This can be expressed as ε T = ε e_ ε p, where ε p is the plastic contribution and εe is the elastic contribution (and still related to the stress by Eq 2.3).

It is tempting to define an *elastic limit* as the stress at which plastic deformation first occurs and a *proportional limit* as the stress at which the stress-strain curve first deviates from linearity. However, neither definition is very useful, because measurement of the stress at which plastic deformation first occurs or the first deviation from linearity is observed depends on how accurately strain can be measured. The smaller the plastic strains that can be sensed and the smaller the deviations from linearity can be detected, the smaller the elastic and proportional limits [3].

To avoid this problem, the onset of the plasticity is usually described by an offset *yield strength,* which can be measured with greater reproducibility. It can be found by constructing a straight line parallel to the initial linear portion of the stress-strain curve, but offset by ε= 0.002 or 0.2%. The yield strength is the stress at which this line intersects the stress-strain curve (Fig 2.5). The rationale is that if the material had been loaded to this stress and then unloaded, the unloading path would have been along this offset line and would have resulted in a plastic strain of ε = 0.2% [2].

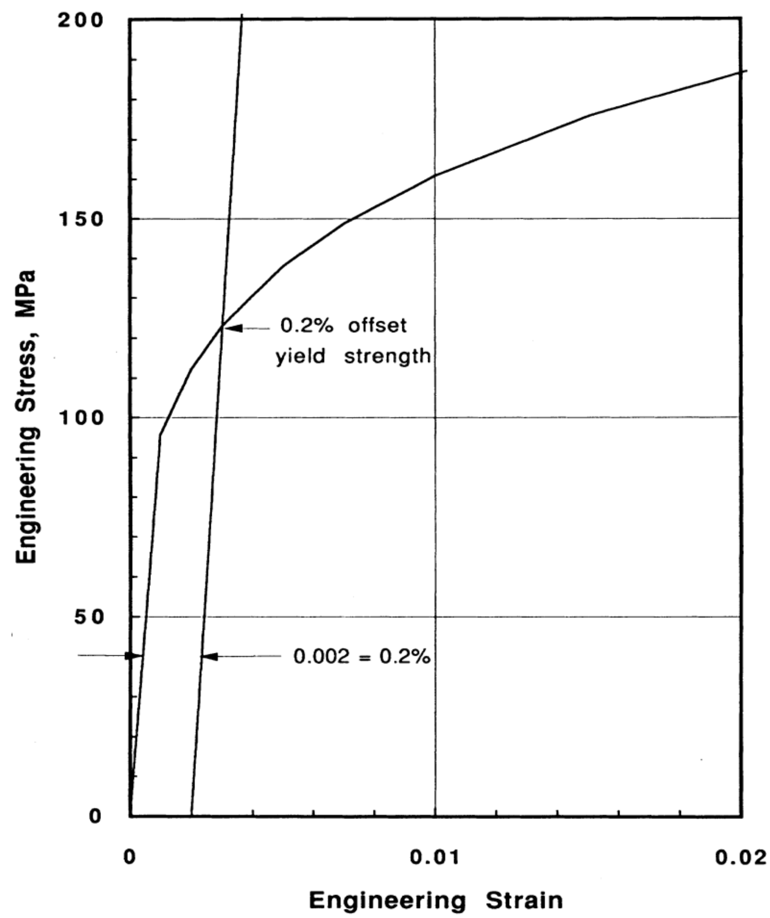


Fig 2.5: The low-strain region of the stress-strain curve for a ductile material [2].

Other offset strains are sometimes used. The advantage of defining yield strength in this way is that such a parameter is easily reproduced and does not depend heavily on the sensitivity of measurement.

Sometimes, for convenience, yielding in metals is defined by the stress required to achieve a specified total strain (e.g., ε T = .005 or 0.5% elongation) instead of a specified offset strain. In any case, the criterion should be made clear to the user of the data.

2.3.3 Yield Point

For some materials (e.g., low carbon steels and many linear polymers), the stress-strain curves have initial maxima followed by lower stresses, as shown in Fig 2.6(a) and 2.6(b). After the initial maximum, all the deformation at any instant is occurring within a relatively small region of the specimen. Continued elongation of the specimen occurs by propagation of the deforming region (Luders band in the case of steels) along the gage section rather than by increased strain within the deforming region. Only after the entire gage section has been traversed by the band does the stress rise again. In the case of linear polymers, yield strength is often defined as the initial maximum stress [6].

For steels, the subsequent *lower* yield strength is used to describe yielding. This is because measurements of the initial maximum or *upper* yield strength are extremely sensitive to how axially the load is applied during the tensile test. Some laboratories cite the minimum, whereas others cite a mean stress during this discontinuous yielding [6].

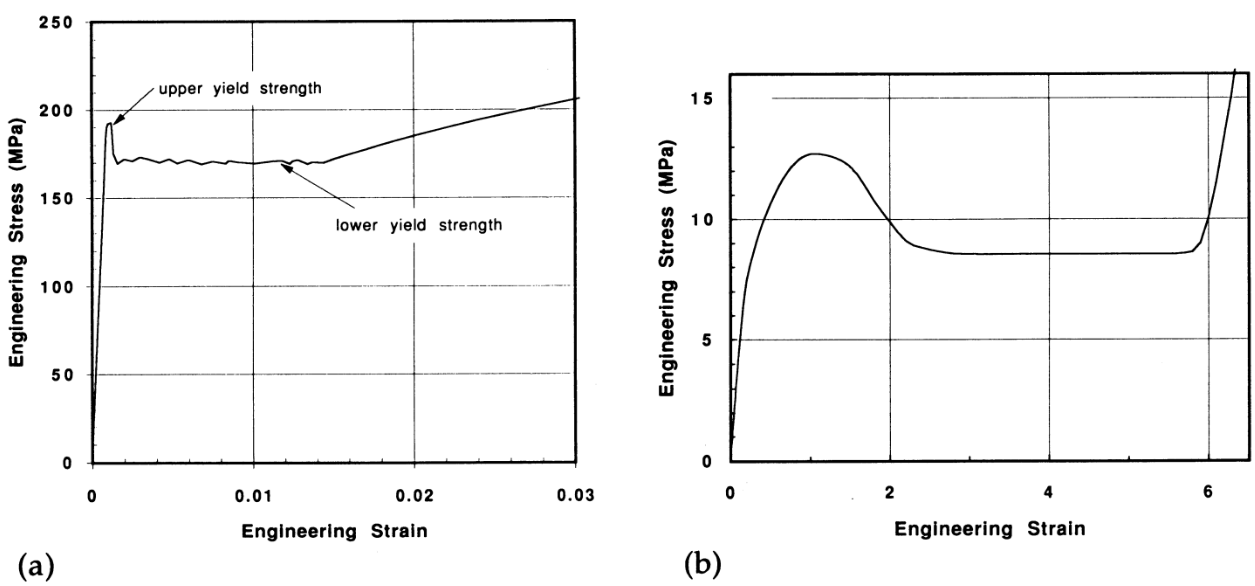


Fig 2.6: Inhomogeneous yielding of low-carbon steel (a) and a linear polymer (b). After the initial stress maxima, the deformation occurs within a narrow band, which propagates along the entire length of the gage section before the stress rises again [6].

The tensile strength (ultimate strength) is defined as the highest value of engineering stress (Fig2.7). Up to the maximum load, the deformation should be uniform along the gage section. With ductile materials, the tensile strength corresponds to the point at which the deformation starts to localize, forming a neck (Fig 2.7a). Less ductile materials fracture before they neck (Fig 2.7b). In this case, the fracture strength is the tensile strength. Indeed, very brittle materials (e.g., glass at room temperature) do not yield before fracture (Fig 2.7c). Such materials have tensile strengths but not yield strengths [6].

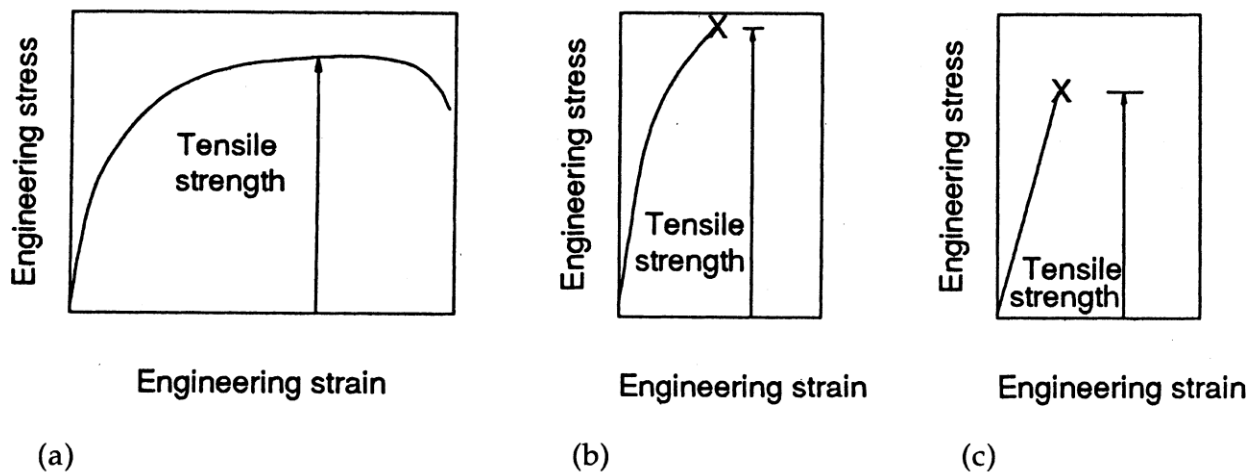


Fig 2.7: Stress-strain curves showing that the tensile strength is the maximum engineering stress regardless of whether the specimen necks (a) or fractures before necking (b and c), [6].

2.3.4 Ductility

There are two common measures used to describe the ductility of a material. One is the percent elongation, which is defined simply as.

$$\%El = [\frac{(Lf - Lo)}{Lo}] * 100 \quad (2.5)$$

Where *L*o is the initial gage length and *L*f is the length of the gage section at fracture. Measurements may be made on the broken pieces or under load. For most materials, the amount of elastic elongation is so small that the two are equivalent. When this is not so (as with brittle metals or rubber), the results should state whether or not the elongation includes an elastic contribution. The other common measure of ductility is percent reduction of area, which is defined as [6].

$$\%RA = [\frac{Ao - Af}{Ao}] * 100 \quad (2.6)$$

Where *A*o and *A*f are the initial cross-sectional area and the cross-sectional area at fracture, respectively. If failure occurs without necking, one can be calculated from the other:

$$\%El = \frac{\%RA}{(100 - \%RA)} \quad (2.7)$$

After a neck has developed, the two are no longer related. Percent elongation, as a measure of ductility, has the disadvantage that it is really composed of two parts: the uniform elongation that occurs before necking, and the localized elongation that occurs during necking. The second part is sensitive to the specimen shape [6].

When a gage section that is very long (relative to its diameter), the necking elongation converted to percent is very small. In contrast, with a gage section that is short (relative to its diameter), the necking elongation can account for most of the total elongation.

For round bars, this problem has been remedied by standardizing the ratio of gage length to diameter to 4:1. Within a series of bars, all with the same gage-length-to-diameter ratio, the necking elongation will be the same fraction of the total elongation. However, there is no simple way to make meaningful comparisons of percent elongation from such standardized bars with that measured on sheet tensile specimens or wire. With sheet tensile specimens, a portion of the elongation occurs during diffuse necking, and this could be standardized by maintaining the same ratio of width to gage length. However, a portion of the elongation also occurs during what is called localized necking, and this depends on the sheet thickness. For tensile testing of wire, it is impractical to have a reduced section, and so the ratio of gage length to diameter is necessarily very large. Necking elongation Contributes very little to the total elongation [6].

Percent reduction of area, as a measure of ductility, has the disadvantage that with very ductile materials it is often difficult to measure the final cross-sectional area at fracture. This is particularly true of sheet specimens.

2.4 True Stress and Strain

If the results of tensile testing are to be used to predict how a metal will behave under other forms of loading, it is desirable to plot the data in terms of true stress and true strain. True stress, σ, is defined as:

$$\sigma = \frac{F}{A} \quad (2.8)$$

Where A is the cross-sectional area at the time that the applied force is F. Up to the point at which necking starts, true strain, ε, is defined as:

$$\varepsilon = \ln \frac{L}{Lo} \quad (2.9)$$

This definition arises from taking an increment of true strain, de, as the incremental change in length, dL, divided by the length, L, at the time, $d\,\varepsilon = dL/L$, and integrating. As long as the deformation is uniform along the gage section, the true stress and strain can be calculated from the engineering quantities. With constant volume and uniform deformation [1], $L*A = L_0*A_0$:

$$\frac{Ao}{A} = \frac{L}{Lo} \quad (2.10)$$

And, with substitution for A_0/A *and* F/A_0, as:

$$\sigma = \varepsilon\,(1 + e) \quad (2.11)$$

Substitution of $L/L_0=1+e$ into the expression for true strain (Eq 2.9) gives:

$$\varepsilon = \ln(1 + e) \quad (2.12)$$

At very low strains, the differences between true and engineering stress and strain are very small. It does not really matter whether Young's modulus is defined in terms of engineering or true stress strain [2].

It must be emphasized that these expressions are valid only as long as the deformation is uniform. Once necking starts, Eq. 2.7 for true stress is still valid, but the cross-sectional area at the base of the neck must be measured directly rather than being inferred from the length measurements. Because the true stress, thus calculated, is the true stress at the base of the neck, the corresponding true strain should also be at the base of the neck. Eq. 2.8 could still be used if the L and Lo values were known for an extremely short gage section centered on the middle of the neck (one so short that variations of area along it would be negligible). Of course, there will be no such gage section, but if there were [2]. Eq. 2.10 would be valid. Thus the true strain can be calculated as:

$$\varepsilon = \ln\left(\frac{Ao}{A}\right) \quad (2.13)$$

Figure 2.8 shows a comparison of engineering and true stress-strain curves for the same material.

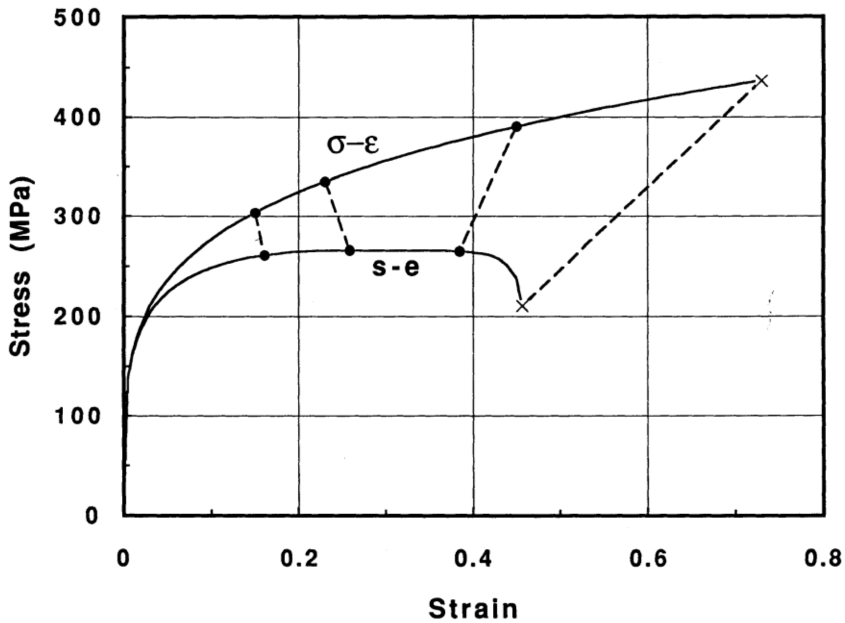


Fig 2.8: Comparison of engineering and true stress-strain curves. Prior to necking, a point on the σ-ε curve can be constructed from a point on the *s*-*e* curve using Eq. 11 and 12. Subsequently, the cross section must be measured to find true stress and strain [6].

Other Factors Influencing the Stress-Strain Curve

There are a number of factors not previously discussed in this chapter that have an effect on the shape of the stress-strain curve. These include strain rate, temperature, and anisotropy [3].

CHAPTER 3

Static Analysis for Computerized Hydraulic Tensile Test Machine

3.1 Introduction.

In this chapter we will discuss the static analysis for Computerized Hydraulic Tensile Test Machine, which include machine model, static analysis of mechanical structure, and static analysis of the specimen.

3.2 Model for machine mechanical structure.

The mechanical structure of the machine was existed in the university, but it was missed some parts.

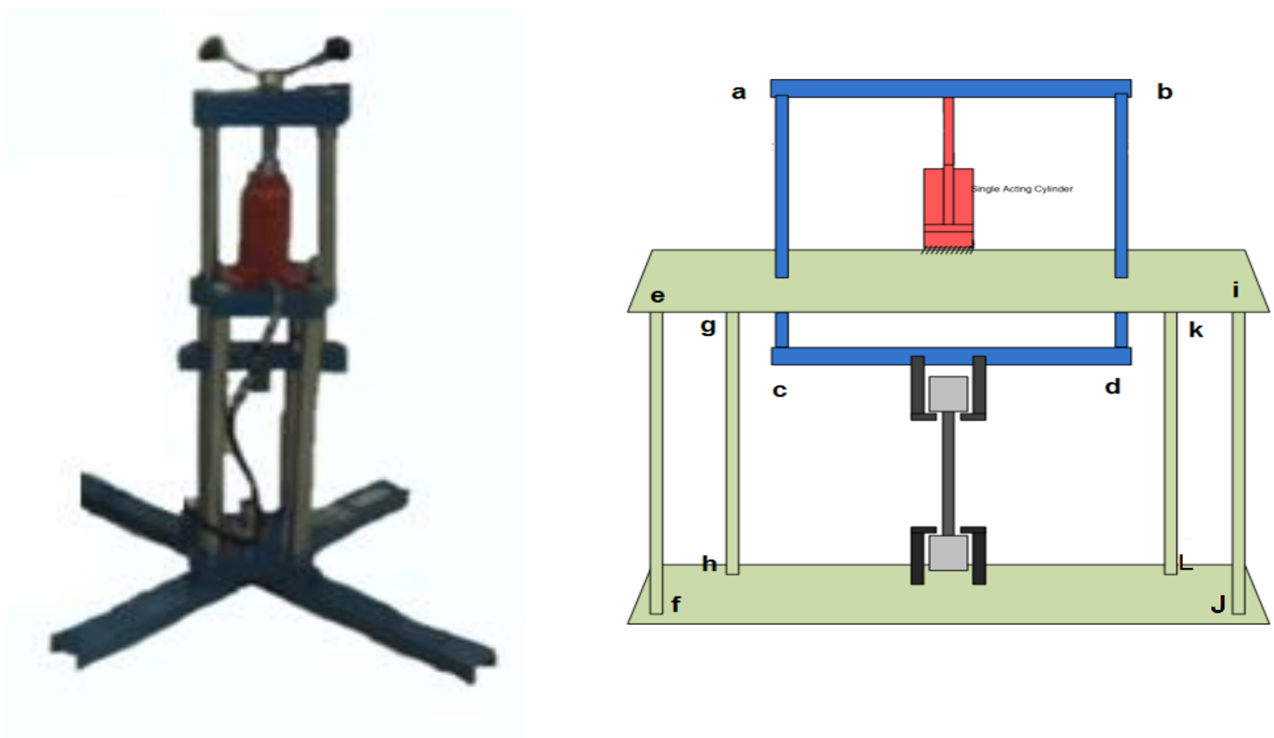


Fig 3.1: Model for machine mechanical structure

The applied force by the cylinder -F1- pushes the frame (abcd) upward, which pulls the specimen upward until its fracture.

The dimensions of the mechanical structure are as follows in table 3.1.

Table 3.1: Dimensions table for the parts in mechanical model structure.

Part Name	Part Length [mm]	Cross Sectional Dimensions [mm]	Cross Sectional Area [m^2]	Second Moment of Area [m^4]
Link ab	267	75x63.3	4.7475 E -3	1.5852 E−6
Link ac	535	Ø =33.5	8.8141 E -4	6.1823 E−8
Link bd	535	Ø =33.5	8.8141 E -4	6.1823 E−8
Link cd	267	75x63.3	4.7475 E -3	1.5852 E−6
Link ef	690	Ø =38.3	1.1521 E -3	1.0562 E-7
Link gh	690	Ø =38.3	1.1521 E -3	1.0562 E-7
Link ij	690	Ø =38.3	1.1521 E -3	1.0562 E-7
Link kl	690	Ø =38.3	1.1521 E -3	1.0562 E-7
Link ei	267	190x50	9.5000 E-3	1.9792 E−6
Cylinder's rod	250	Ø=40.0	1.2566 E-3	1.2566 E−7

The machine part's material is Carbon Steel. And so, the Modulus of elasticity equals 207 [GPa].

To find the force applied to specimen F_1 we use fig 3.2.

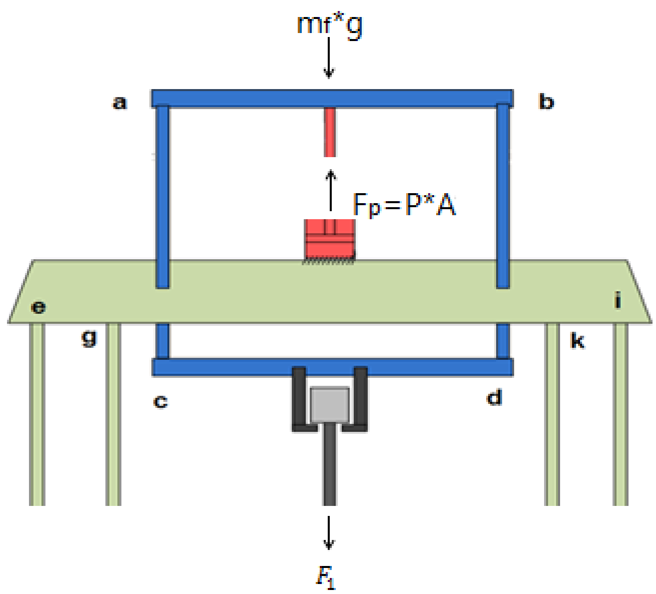


Fig 3.2: Model for find the force applied to specimen.

From fig 3.2 the mass of frame 'abcd' is m_f , and equals (16 Kg) ,so the net force of this frame is equals $F_f = m_f * g$; where g is gravity acceleration .The piston force (F_p) equals oil pressure multiplied by the piston's area , so the net force applied to specimen equals (F_1); where $F_1 = P * A - mf * g$,and this equations will be used to find the stress in specimen at software programming .

The system will be designed so the maximum force applied to specimen $F_1 = 75{,}000\ [N]$, so that the factor of safety = 1.7 (max. force from piston =43kN = $P*A_p$).The free body diagram and the internal forces in each member are expressed in each next section.

3.3 Static analysis for machine mechanical structure.

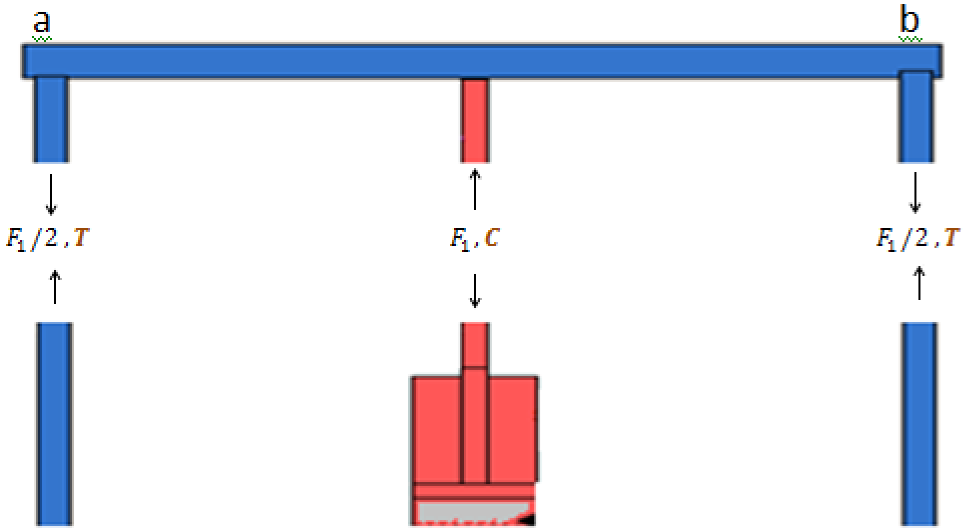


Fig 3.3: Free body Model for machine mechanical structure –first section.

Where, "**T**"denotes tension in the link, and "**C**"denotes compression in the link [4], [5].

Due to symmetry,

$$F_a = F_b = \frac{1}{2} F_1 = 37{,}500 \ [N] \tag{3.1}$$

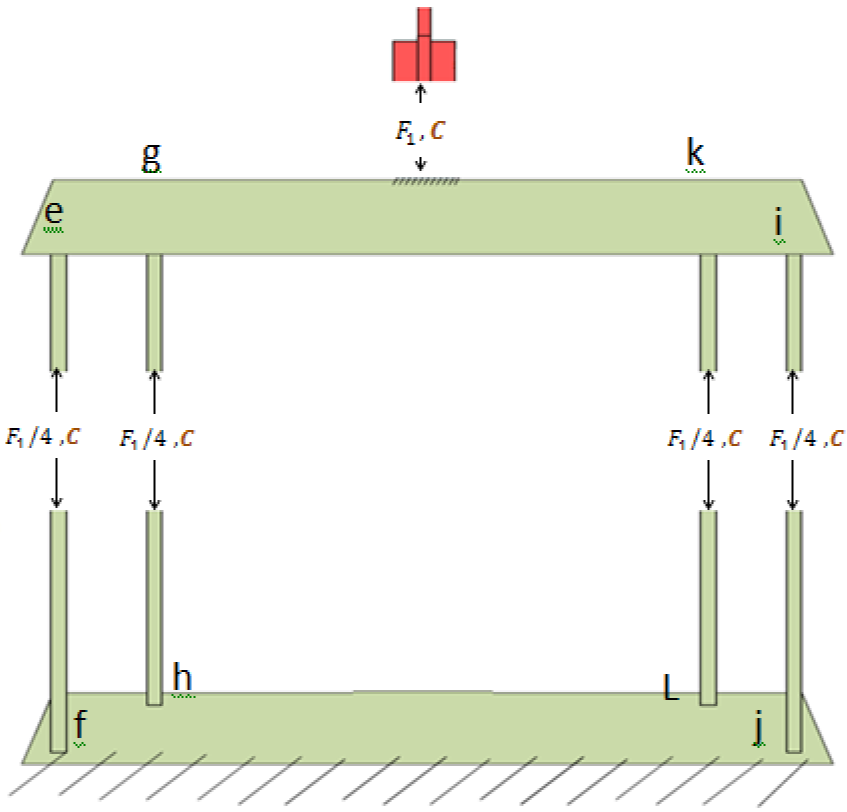


Fig 3.4: Free body Model for machine mechanical structure –second section.

Due to symmetry,

$$F_{ef} = F_{gh} = F_{ij} = F_{kL} = \frac{1}{4}F_1 = 18{,}750 \ [N] \qquad (3.2)$$

For the beam 'ab':

The shear, moment and deflection diagrams of the beam are as follows:

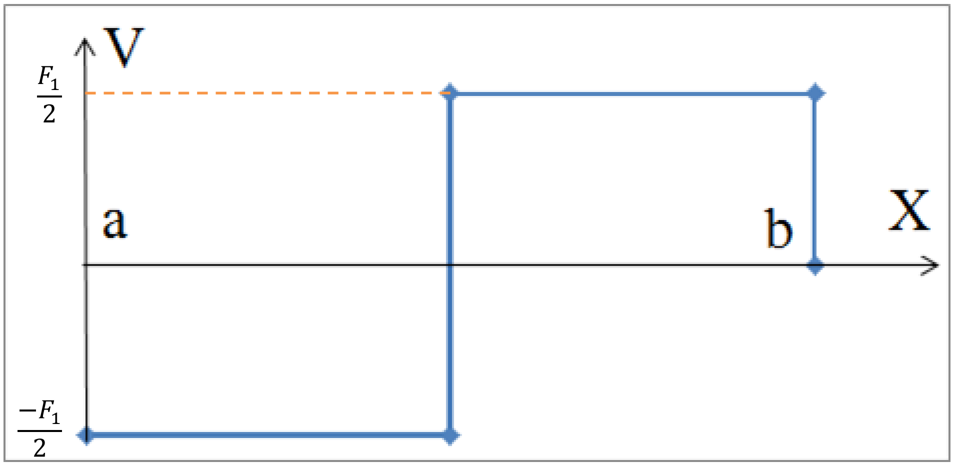


Fig 3.5: Shear diagram of beam ab [4], [5].

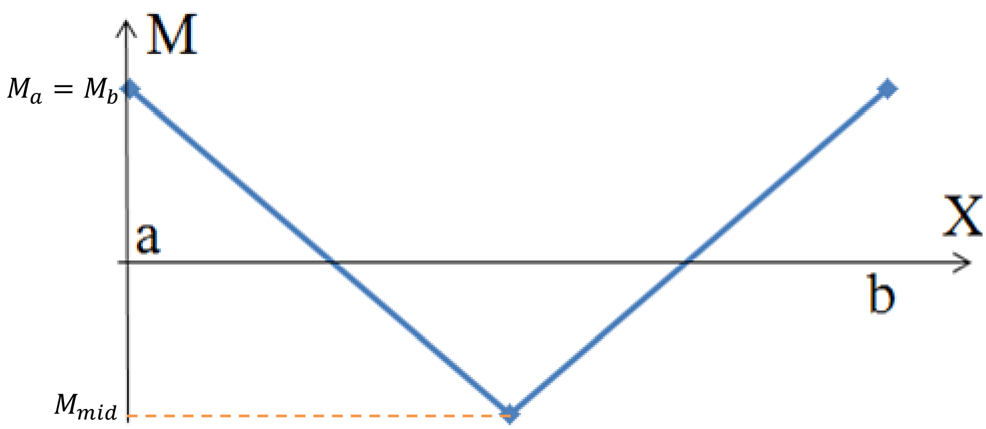


Fig 3.6: Moment diagram of beam ab [4], [5].

$$M_a = M_b = \frac{F\ l}{8} = \frac{\frac{F_1}{2} * l}{8} \tag{3.3}$$

$$= \frac{37{,}500 * 0.267}{8} = 1{,}251\ [N.m]$$

$$M_{mid} = \frac{F\ l}{8} = \frac{\frac{F_1}{4} * l}{8} = 625.8\ \ [N.m] \tag{3.4}$$

$$\sigma = \frac{M\,c}{I} \tag{3.5}$$

$$= \frac{1{,}168.1 * 31.65 * 10^{-3}}{1.5852 * 10^{-6}} = 23.32 \quad [MPa]$$

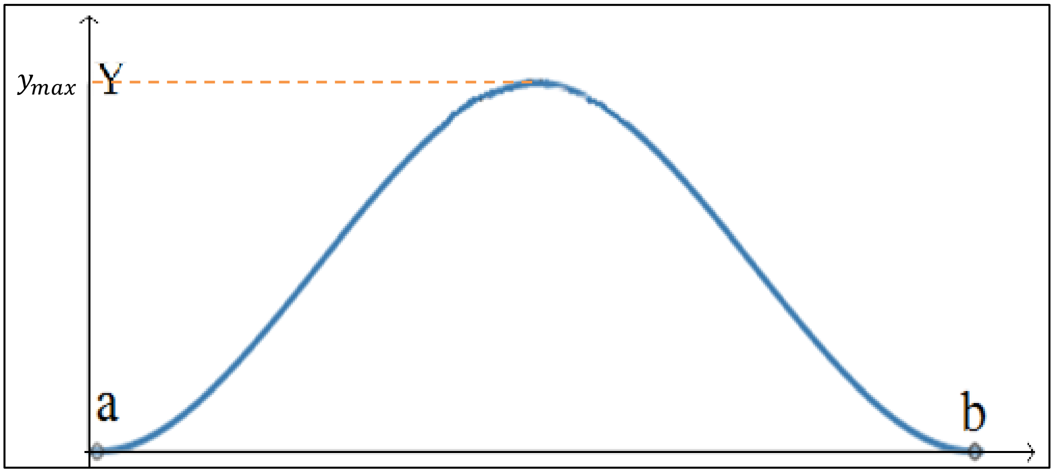


Fig 3.7: Deflection diagram of beam ab [4], [5].

$$y_{max} = \frac{Fl^3}{192\,EI} \tag{3.6}$$

$$= \frac{75{,}000*0.267}{192*207*10^9*1.5852*10^{-6}} = 3.178*10^{-4} \quad [m] \qquad \text{(Accepted)}^1$$

For the hydraulic cylinder rod:

The critical force that may cause buckling in the cylinder rod is [4], [5]:

$$F_{crt} = \frac{C\,\pi^2\,E\,I}{L^2} \tag{3.7}$$

For the compressed column, type fixed-fixed, the end condition's constant 'C' equals 4.

[1] The deflection is very small so that the body is to be considered as rigid.

Here we have:

$$F_{crt} = \frac{4\,\pi^2\, I\;E}{L^2} = 16{,}430{,}361 \quad [\mathrm{N}] \tag{3.8}$$

i.e. Assumed maximum load capacity of the machine is $F_{max} = 75{,}000\ [N]$

$$F_{max} \ll \ F_{crt} \tag{3.9}$$

∴ The design is safe in this point of view, buckling is not possible under the assumed working loads.

The cylinder's rod lies under compression; therefore, in addition to buckling, the compressive normal stresses should be checked [4], [5]:

$$\sigma_{comp} = \frac{F}{A} \tag{3.10}$$

$$\sigma_{comp} = \frac{75{,}000}{\frac{\pi}{4}*(40*10^{-3})^2} = 59.68\ [MPa] \tag{3.11}$$

For cylinder's rod axial deflection [4] , [5] :

$$\delta = \frac{\mathrm{FL}}{\mathrm{AE}} = \frac{\sigma\, L}{E} \tag{3.12}$$

$$= \frac{(59.68*10^{6})*(250*10^{-3})}{207*10^{9}} = 7.21 * 10^{-5}\ [m] \quad \text{(Accepted)}$$

For link ‘ac’ and ‘bd’:

Links ‘ac’ and ‘bd’ are subjected to tension force of magnitude:

$$F_{ac} = F_{bd} = \frac{F_1}{2} = \frac{75,000}{2} = 37.5\ [kN] \tag{3.13}$$

Normal tensile stress in links ‘ac’ and ‘bd’ is:

$$\sigma_{ac} = \sigma_{bd} = \frac{F}{A} = \frac{37,500}{\frac{\pi}{4}*(33.5*10^{-3})^2} = 42.54\ [MPa] \tag{3.14}$$

The axial deflection in links ‘ac’ and ‘bd’ is:

$$\delta_{ac} = \delta_{bd} = \frac{FL}{AE} = \frac{\sigma_{ac} L_{ac}}{E} = \frac{(42.54*10^6)*(535*10^{-3})}{207*10^9}$$

$$= 1.099 * 10^{-4}\ [m]\ \text{(Accepted)} \tag{3.15}$$

Stress analysis for beam ‘ei’

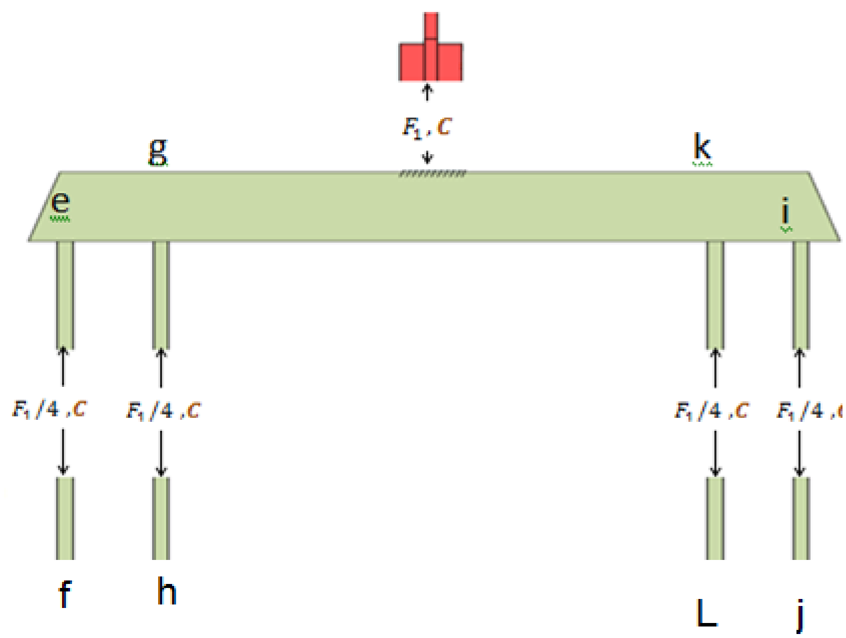


Fig 3.8: Free body Model for machine mechanical structure –third section.

$$F_{ef} = F_{ij} = \frac{F_1}{4} = 18{,}750\ [N] \qquad (3.16)$$

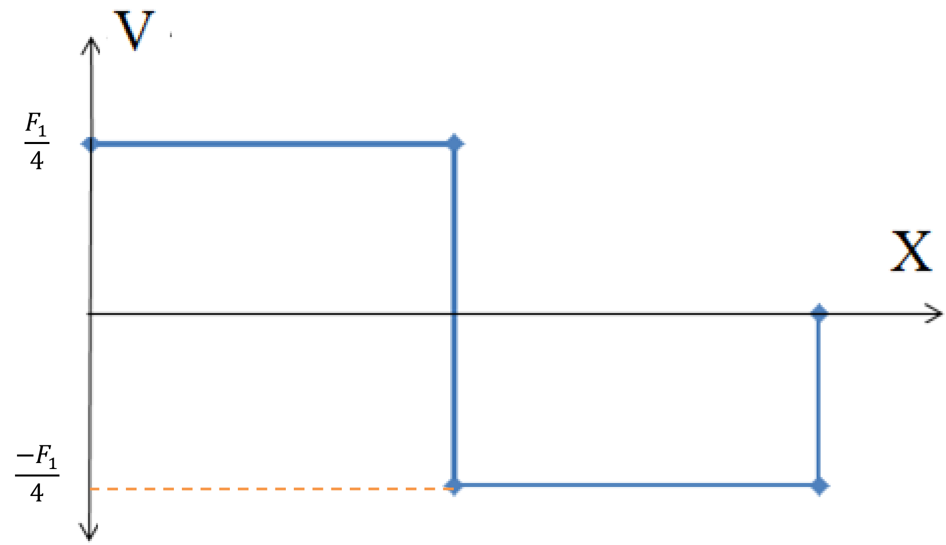


Fig 3.9: Shear diagram of beam (ei) [4], [5].

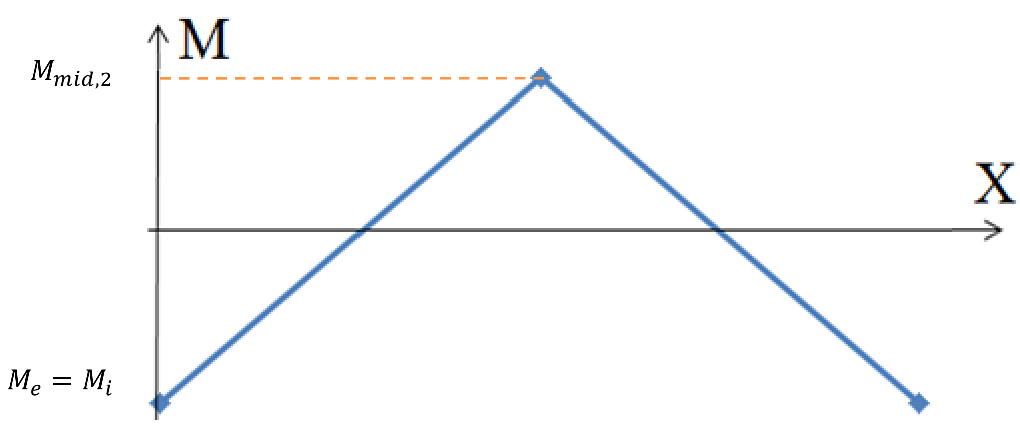


Fig 3.10: Moment diagram of beam (ei) [4], [5].

$$M_e = M_i = \frac{F\ l}{8} = \frac{\frac{F_1}{4} * l}{8} \qquad (3.16)$$

$$= \frac{18{,}750 * 0.267}{8} = 625.8\ [N.m]$$

$$M_{mid,2} = \frac{F\ l}{8} = \frac{\frac{F_1}{4} * l}{8} = 625.8\ [N.m] \tag{3.17}$$

$$\sigma_{ei} = \frac{M_{max}\ c}{I} = \frac{625.8 * 25 * 10^{-3}}{1.9792 * 10^{-6}} = 7.905 \quad [MPa] \tag{3.18}$$

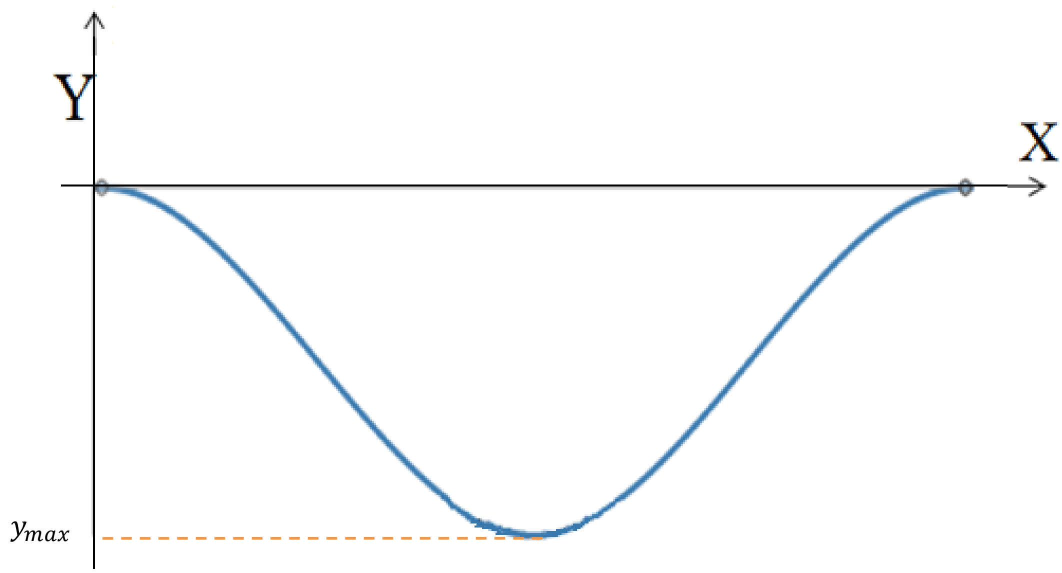


Fig 3.11: Deflection diagram of beam (ei) [4], [5].

$$y_{max} = \frac{Fl^3}{192\ EI} \tag{3.19}$$

$$= \frac{18{,}750 * 0.267^3}{192 * 207 * 10^9 * 1.9792 * 10^{-6}}$$

$=4.537 * 10^{-6}$ [m] (Accepted)

The link ‘ef’ is under compression

For the buckling in cylinder rod:

$$F_{crt} = \frac{4\,\pi^2\,I\;E}{L^2} \tag{3.20}$$

$$F_{crt} = 1{,}812{,}917 \qquad [N]$$

While, $F_{max} = 37{,}500 \quad [N]$ (3.21)

$$F_{max} \ll \;\; F_{crt}$$

∴ The design is safe in this point of view, buckling is not possible under the assumed working loads.

The link ‘ef’ lies under compression; therefore, in addition to buckling, the compressive normal stresses should be checked:

For axial stress:

From equation (3.10)

$$\sigma_{comp} = \frac{F}{A} = \frac{37{,}500}{1.1521 * 10^{-3}} = 32.55\ [MPa] \tag{3.22}$$

For link ‘ef’ deflection,

$$\delta_{bd} = \frac{FL}{AE} = \frac{\sigma_{comp}\,L_{ef}}{E} \quad [4]\,,[5] \tag{3.23}$$

$$= \frac{32.55 * 10^6 \;\; * 690 \; * \; 10^{-3}}{207 * 10^9}$$

$= 1.085 \; * \; 10^{-4} \;\; [m]$ (Accepted)

- **The other similar links (‘gh’, ‘ij’ and ‘kL’) have same analysis and results of link ‘ef’.**

For screw inside piston:

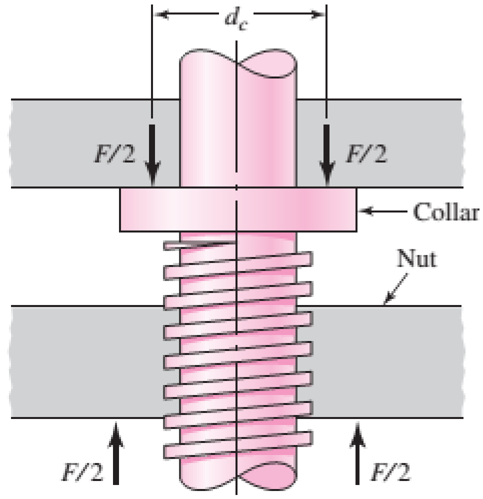


Fig 3.12: Cross section of the threaded piston rod

1) Shear stress

A=$(\pi * d_r * t)$ *n (3.24)

$= \pi * .022 * .002 * 4) = 5.53 * 10^{-4}$ [m²]

$\tau = \frac{F}{A} = \frac{75000}{5.53*10^{-4}} = 135.6$ [MPa] (3.25)

$\tau < Sy$; $Sy = 220$ $[MPa]$ $(1018\ Steel)$

F.S. = $\frac{Sy}{\tau}$ = $\frac{220}{135.6} = 1.62$ (3.26)

∴ Safe Design

2) Compression Stress

$\sigma = \frac{F}{A_r} = \frac{75000}{\frac{\pi}{4}*0.022^2} = 197.3$ [MPa] $,\sigma < S_y$ (3.27)

∴ Safe Design

3) Buckling Analysis

$$I = \frac{\pi * {d_r}^4}{64} = \frac{\pi * 0.022^4}{64} = 2.3758 * 10^{-5}\ [m^4]$$

$$k = \sqrt{\frac{I}{A}} = \sqrt{\frac{2.3758*10^{-5}}{\frac{\pi}{4}*0.022^2}} = 0.25 \quad (3.28)$$

$$\frac{l}{k} = \frac{0.14}{0.25} = 0.56 \quad (3.29)$$

$$\left(\frac{l}{k}\right)_1 = \sqrt{\frac{2*\pi^2*C*E}{S_y}} = \sqrt{\frac{2*\pi^2*4*207*10^9}{220*10^6}} = 272.56 \quad , \frac{l}{k} < \left(\frac{l}{k}\right)_1 \quad (3.30)$$

∴ Short column

$$p_{crt} = A * S_y - A * \left(\frac{S_y}{2\pi} * \frac{l}{k}\right)^2 * \frac{1}{C*E} = 83.629\ [KN] \quad (3.31)$$

$$p_{crt} > p_{max}$$

∴ No buckling

3.4 Static analysis for specimen

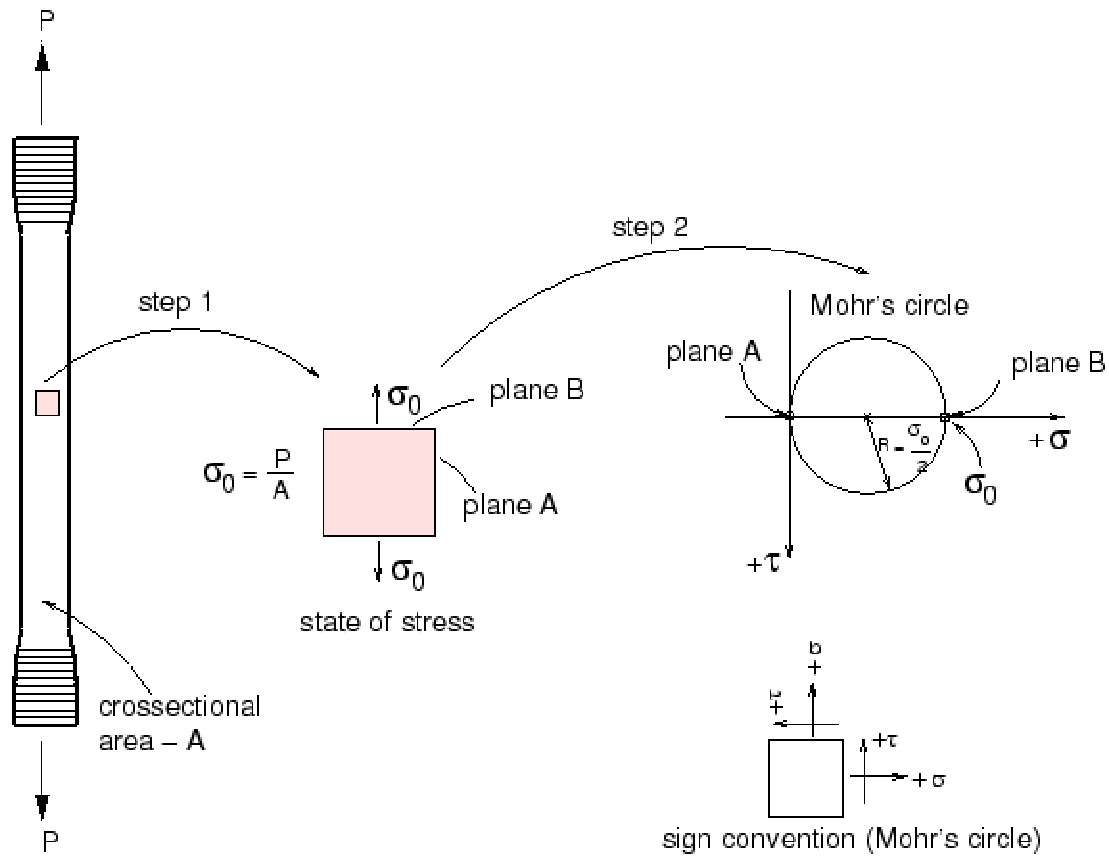


Fig 3.13: State of stress for the tensile test specimen [6].

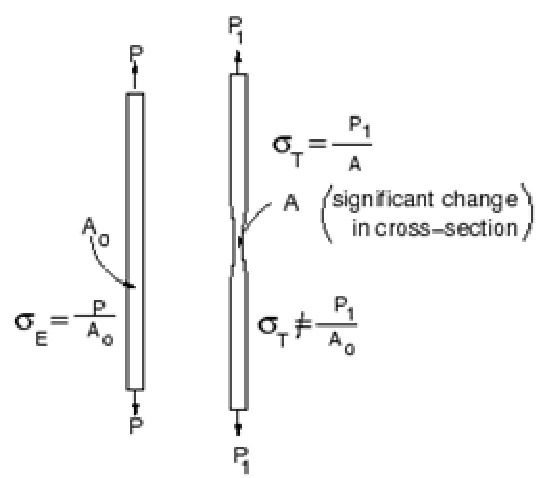


Fig3.14: Engineering stress measures vs. true stress measures for specimen [6].

From the Fig (3.12) we have this equation [4], [5].

$$\sigma_E = \frac{P}{A_0} \tag{3.32}$$

$$\epsilon_E = \frac{\Delta l}{l_0} \tag{3.33}$$

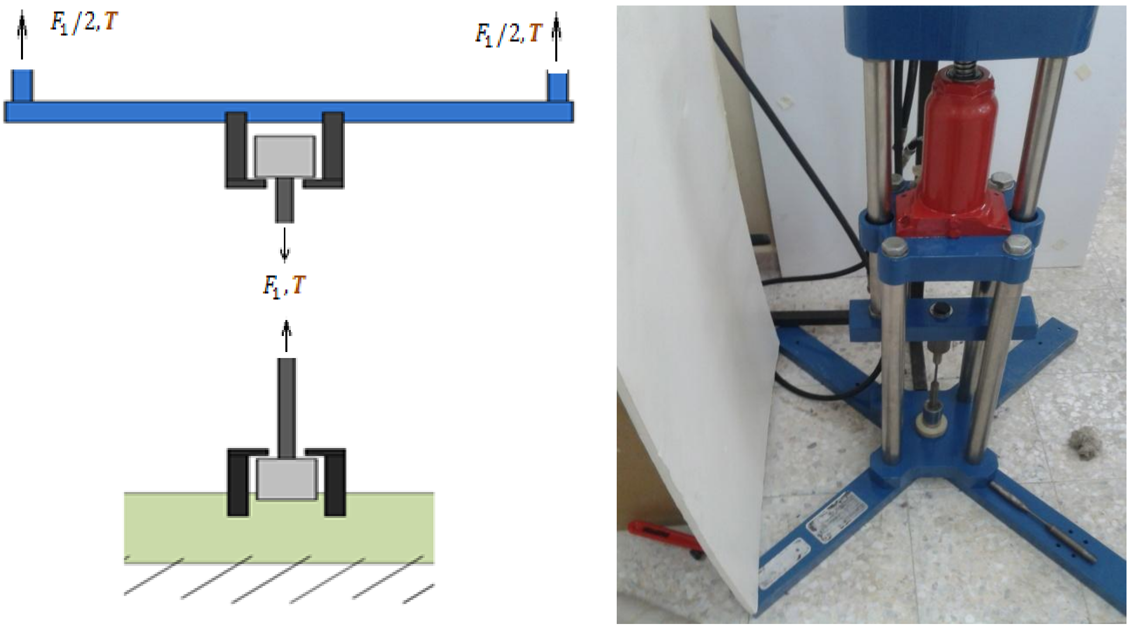


Fig3.15: The specimen static analysis [4], [5].

To find the maximum cross section area of the specimen:

Let the specimen's material is Steel 1045 Q&T [4], [5].

$\sigma_f = 2380\ [MPa]$

$F_{applied} = 75{,}000\ [N]$

$$A_{max} = \frac{F_{applied}}{\sigma_f} \tag{3.34}$$

$$= \frac{75{,}000}{2380 * 10^6} = 3.1513 * 10^{-5}\ [m^2]$$

This is corresponded to specimen diameter $\emptyset = 6.33\ [mm]$

3.5 Isometric View of the machine

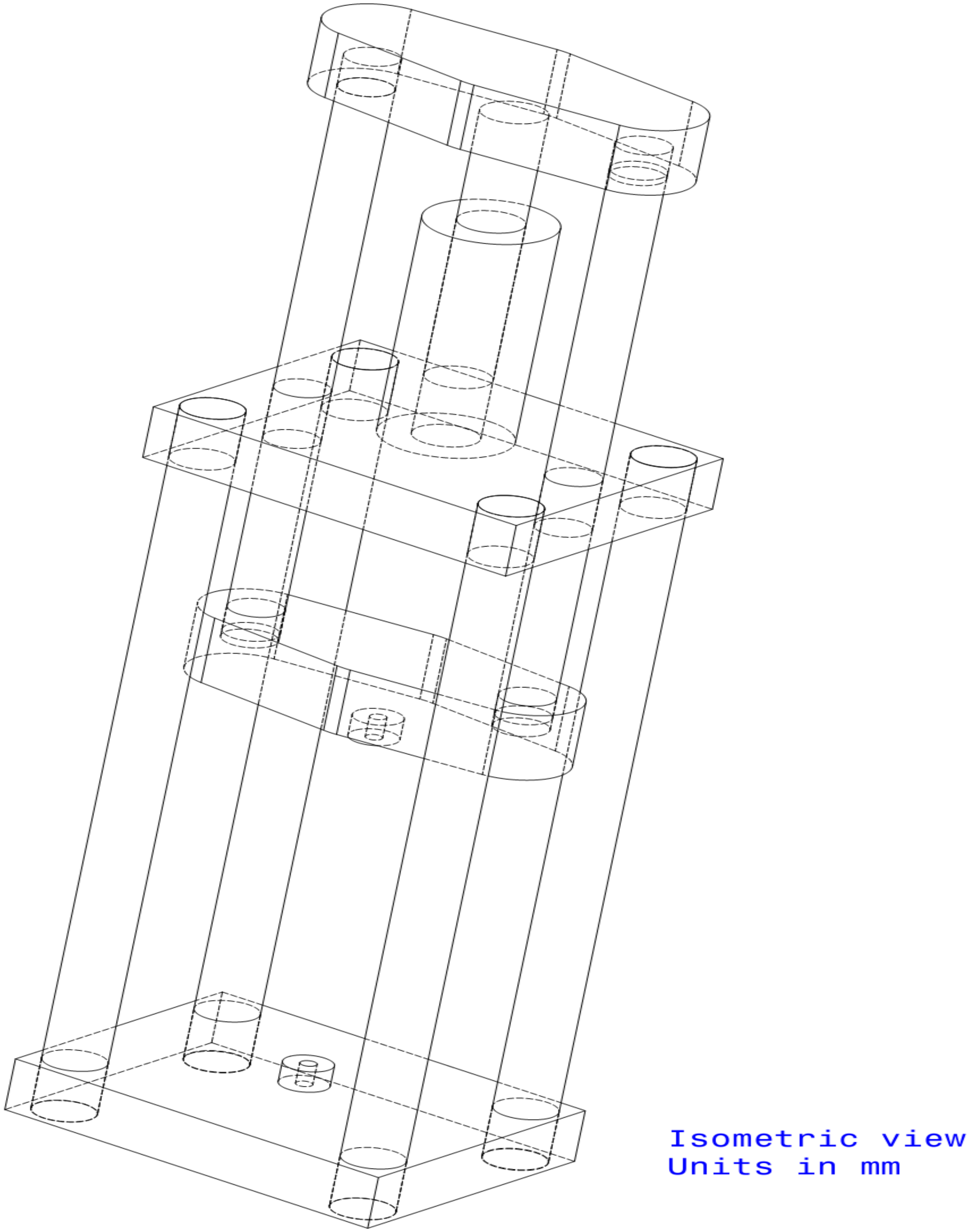


Fig3.16: Isometric view for mechanical structure

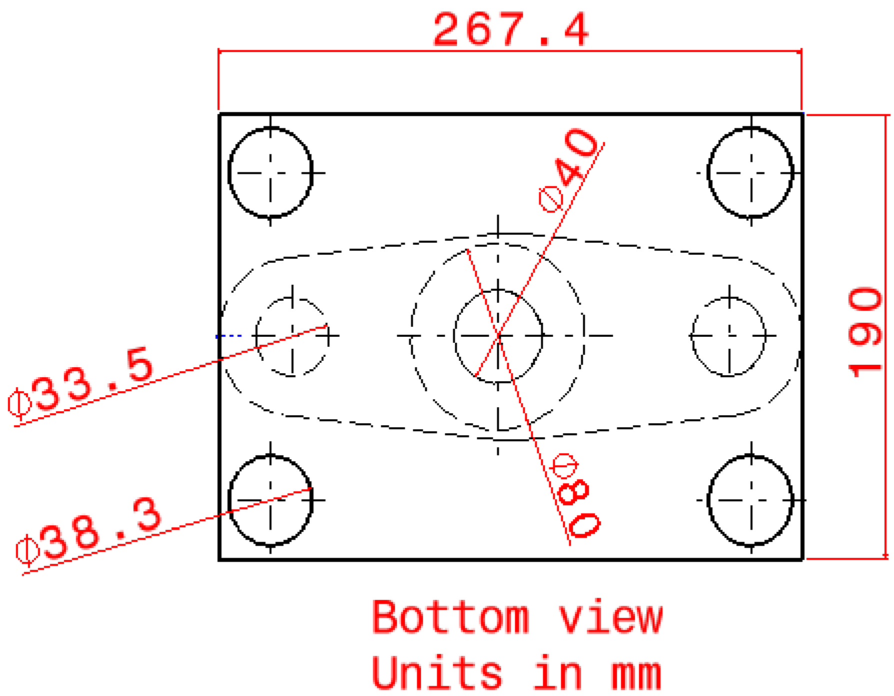


Fig3.17: Bottom view for mechanical structure

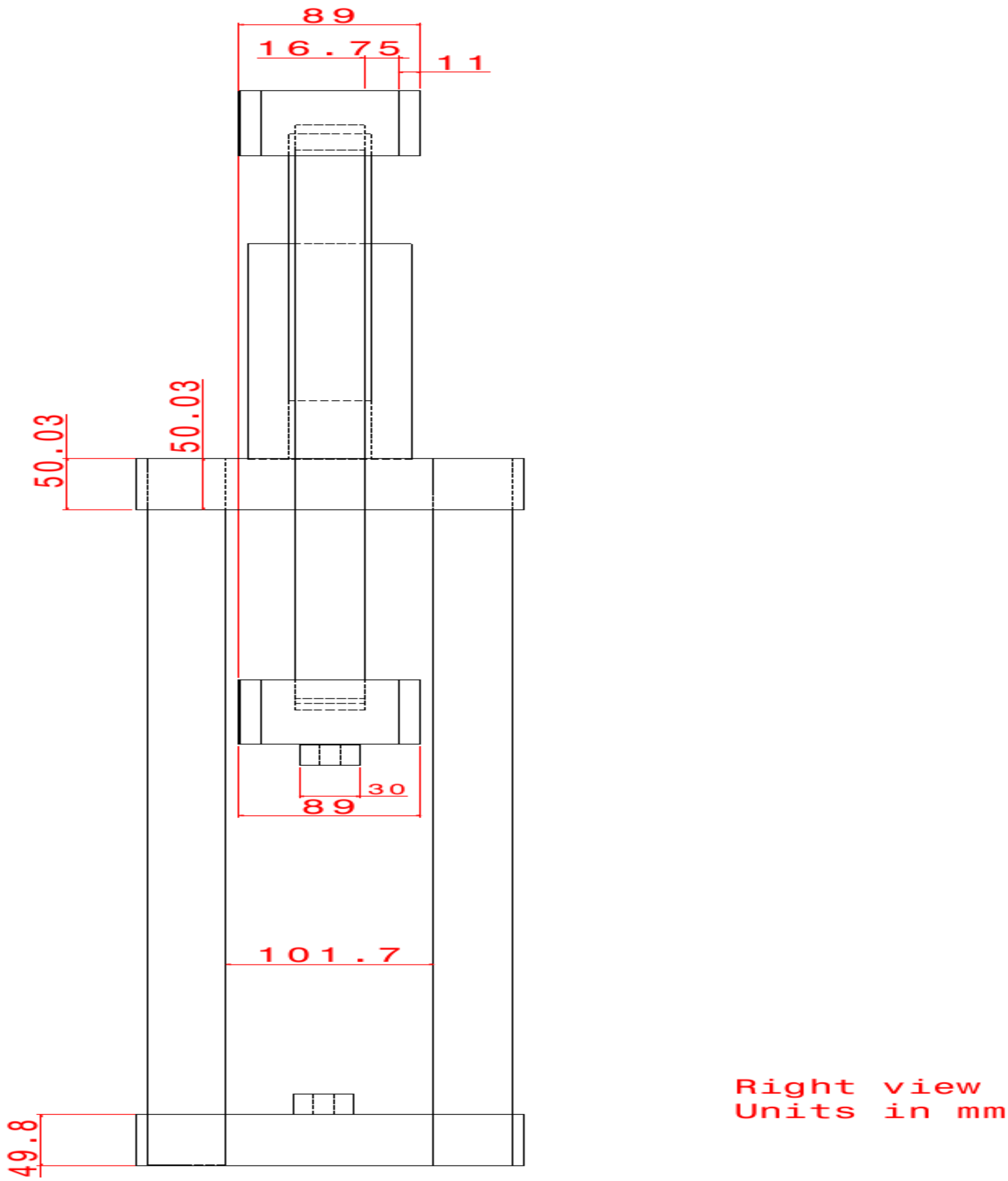


Fig3.18: Right view for mechanical structure

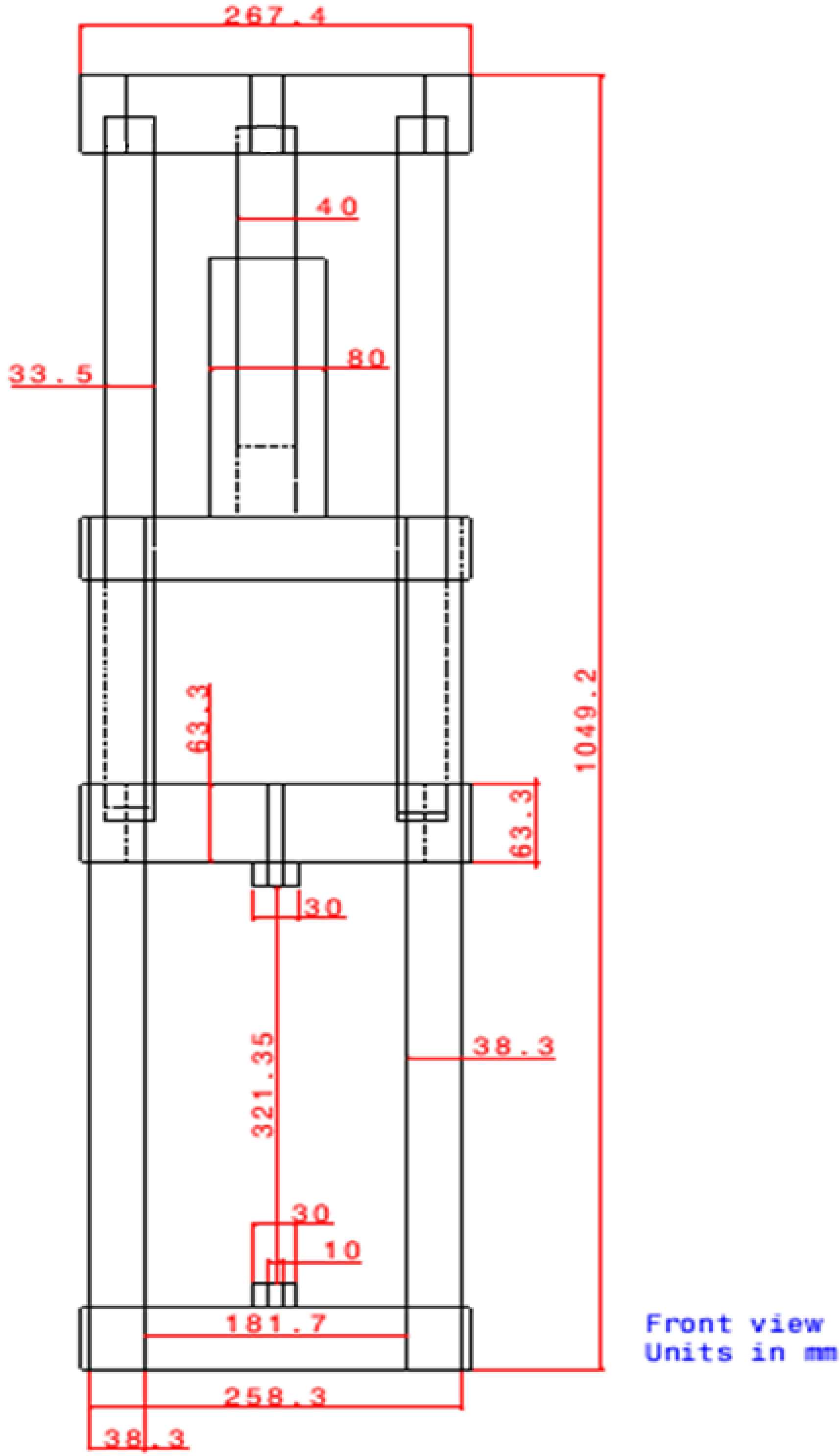


Fig3.19: Front view for mechanical structure

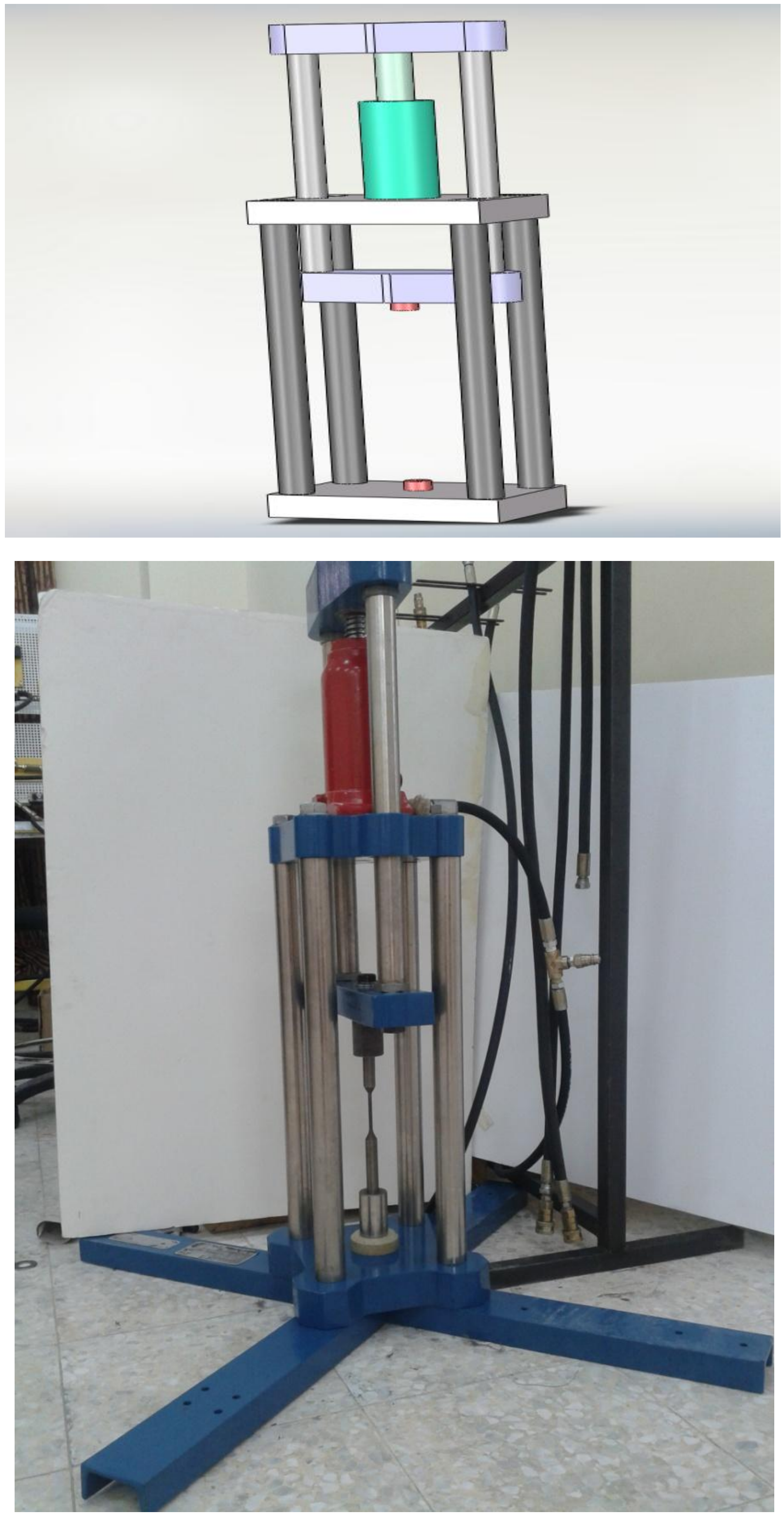


Fig3.20: 3D Isometric view for mechanical structure.

CHAPTER 4

System's Control Architecture for Computerized Hydraulic Tensile Test Machine

4.1 Introduction

In this chapter, the block diagram for all components in the machine is to be shown, the integration of all components, and the electrical parts: the data acquisition card (DAC), linear displacement sensor, and Electro-Hydraulic part, the pressure sensor.

4.2 Computerized Hydraulic Tensile Test Machine block diagram

The block diagram in Fig4.1 shows all components in Computerized Hydraulic Tensile Test Machine, which include the hydraulic parts and electrical parts. The block diagram describes the processes in the machine.

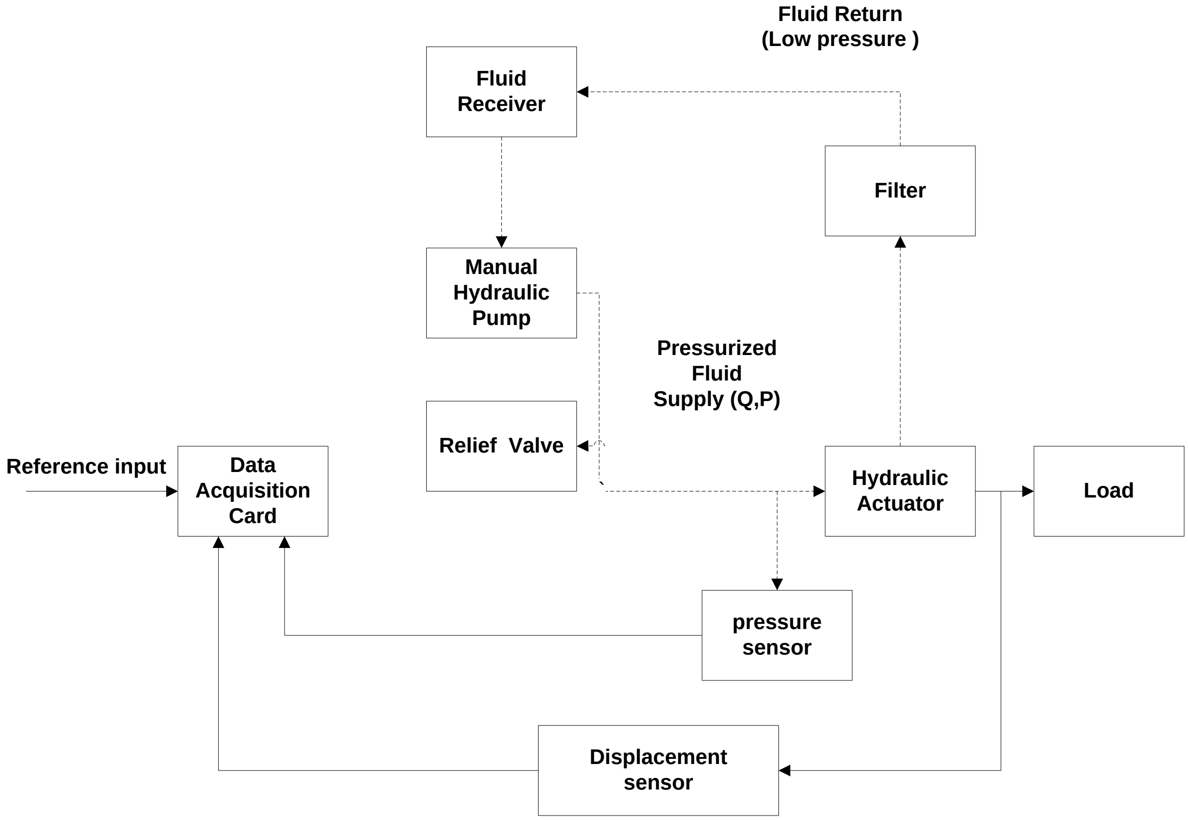


Fig4.1: Block diagram for Computerized Hydraulic Tensile Test Machine [7].

From the block diagram, the hydraulic pump produce pressurized fluid with (Q, P), and this pressurized fluid entered into the piston, which is used to produced force to make tension in specimen. Next, the displacement sensor measures the elongation in specimen. At the end, we plot the tensile test curve.

4.3 System's Control Architecture

In the System control Architecture we explain and describe the parts of machine, each one separately.

The Fig 4.2 shows the hydraulic control for Computerized Hydraulic Tensile Test Machine, which includes single acting cylinder (piston), pressure sensor and the relief valve.

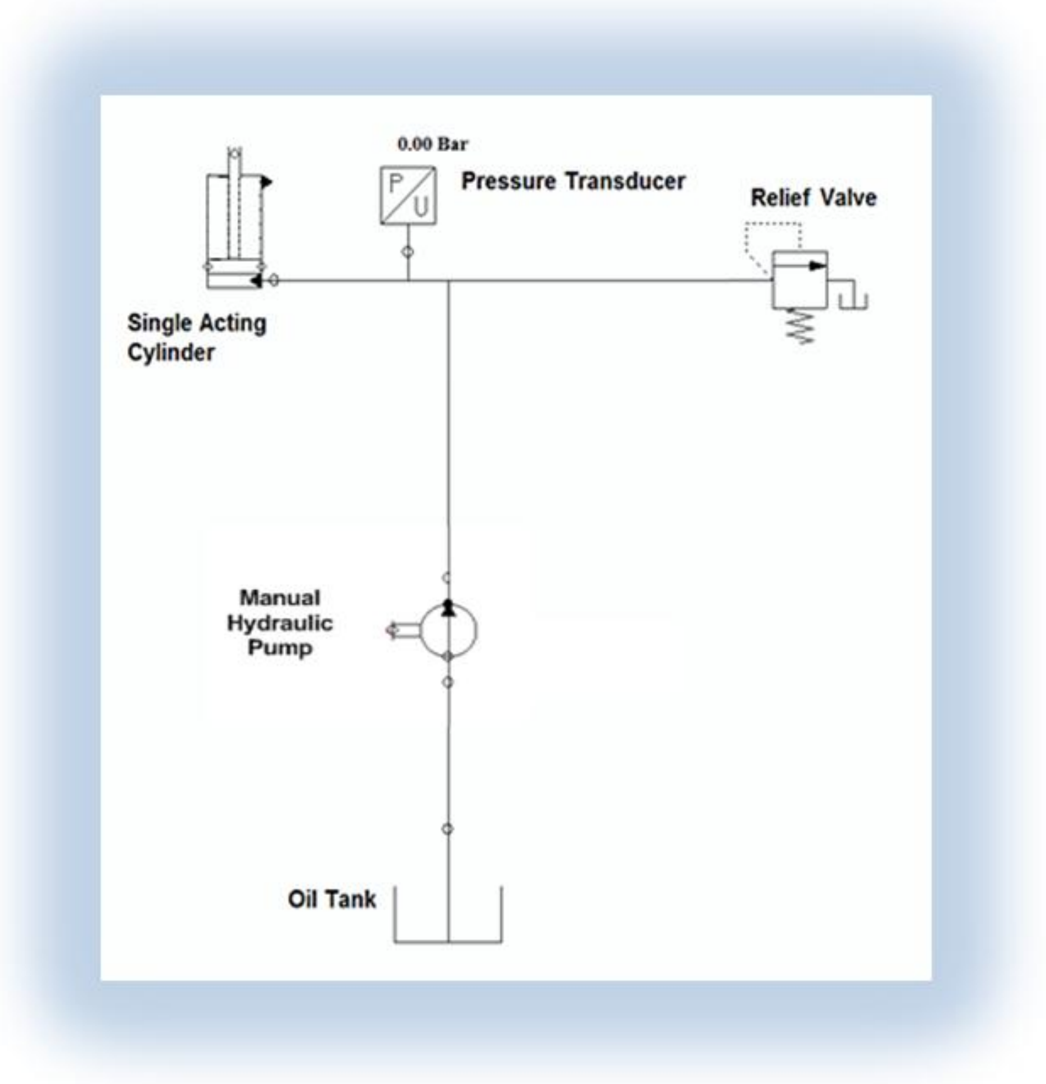


Fig 4.2: Hydraulic circuit for Computerized Hydraulic Tensile [7].

The principle of hydraulic system is as follows:

The oil is pumped from the oil tank using manual hydraulic pump, so it gets highly pressurized. And so, it is enter the single acting cylinder causing a tension load on the specimen.

The pressure is sensed by a pressure transducer. Finally, after fracturing the specimen, the piston is retracted using the relive valve.

4.3.1 Data Acquisition (DAQ) System

Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (abbreviated with the acronym DAS or DAQ) typically convert analog waveforms into digital values for processing [10].

The components of data acquisition systems include:

- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

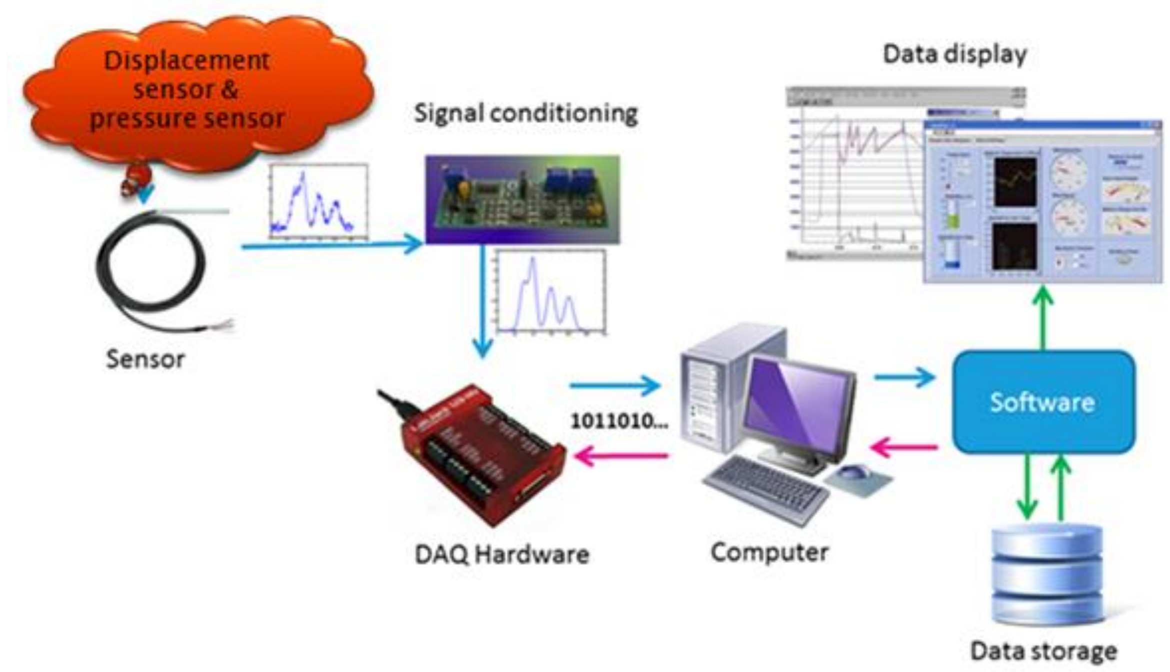


Fig 4.3: Data Acquisition Components.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages such as BASIC, C, Fortran, Java, Lisp, Pascal [10].

Data acquisition begins with the physical phenomenon or physical property to be measured. Examples of this include temperature, light intensity, gas pressure, fluid flow, and force. Regardless of the type of physical property to be measured, the physical state that is to be measured must first be transformed into a unified form that can be sampled by a data acquisition system. The task of performing such transformations falls on devices called sensors [10].

A sensor, which is a type of transducer, is a device that converts a physical property into a corresponding electrical signal (e.g., Strain gauge, thermostat). An acquisition system to measure different properties depends on the sensors that are suited to detect those properties. Signal conditioning may be necessary if the signal from the transducer is not suitable for the DAQ hardware being used [10].

The signal may need to be filtered or amplified in most cases. Various other examples of signal conditioning might be bridge completion, providing current or voltage excitation to the sensor, isolation, and linearization. For transmission purposes, single ended analog signals, which are more susceptible to noise can be converted to differential signals. Once digitized, the signal can be encoded to reduce and correct transmission errors [10].

4.3.1.1 DAQ Hardware

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.) or cards connected to slots (S-100 bus, Apple Bus, ISA, MCA, PCI, PCI-E, etc.) in the motherboard. Usually the space on the back of a PCI card is too small for all the connections needed, so an external breakout box is required. The cable between this box and the PC can be expensive due to the many wires, and the required shielding [10].

DAQ cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM). These are accessible via a bus by a microcontroller, which can run small programs. A controller is more flexible than a hard wired logic, yet cheaper than a CPU so that it is permissible to block it with simple polling loops. For example: Waiting for a trigger, starting the ADC, looking up the time, waiting for the ADC to finish, move value to RAM, switch multiplexer, get TTL input, let DAC proceed with voltage ramp [10].

The DAQ type which has been used in this project is: National Instruments USB-6008, which is shown in figure 4.4, used to get the reading from both sensors (pressure sensor & displacement encoder) and interface them to the computer [11].

Fig 4.4: DAQ National Instruments USB-6008 [11].

4.3.1.2 DAQ Software

DAQ software is needed in order for the DAQ hardware to work with a PC. The device driver performs low-level register writes and reads on the hardware, while exposing a standard API for developing user applications. A standard API such as COMEDI allows the same user applications to run on different operating systems [11].

Fig 4.5: LabVIEW for Data Acquisition.

LabVIEW is a graphical programming environment that makes it easy to take any measurement from any sensor on any bus. When examining the cost of building a data acquisition (DAQ) system, you will find that software development itself often accounts for 25 percent of total system cost. Having easy-to-use driver software with an intuitive application programming interface makes a big impact on completing a project on time, and coming in under budget. NI-DAQmx driver software goes far beyond a basic DAQ driver to deliver increased productivity and performance and is one of the main reasons National Instruments continues to be a global market leader in PC-based data acquisition [11].

The acquired signals from both sensors, which have entered to DAQ, and then to computer should be processed in order to get the stress in the specimen from pressure reading, and the strain value from the displacement reading, as shown in figure 4.7.

Using the following criteria, the stress and strain would be found.

$$Stress\ , \qquad \sigma = \frac{P * A_p}{A_0}$$

Where, P: Hydraulic pressure value

A_p: Piston's area

A_0: Specimen's initial cross section area

$$Strain\ , \qquad \varepsilon = \frac{\Delta \mathrm{L}}{\mathrm{L}_0}$$

Where, ΔL : Displacement reading from linear encoder

L_0: Initial specimen's length

Figure 4.6 shows the data acquisition algorithm, the needed data is entered by the user (specimen diameter & its initial length) the DAC gets the reading from both sensors (pressure & displacement) and plot a pair of pint

The user interface screen, which shown in figure 4.8 consists of: Initial specimen's diameter, Initial specimen's length, hydraulic pressure reading (Pa and psi), Stress, Modulus of Elasticity, and finally the Stress – Strain Curve.

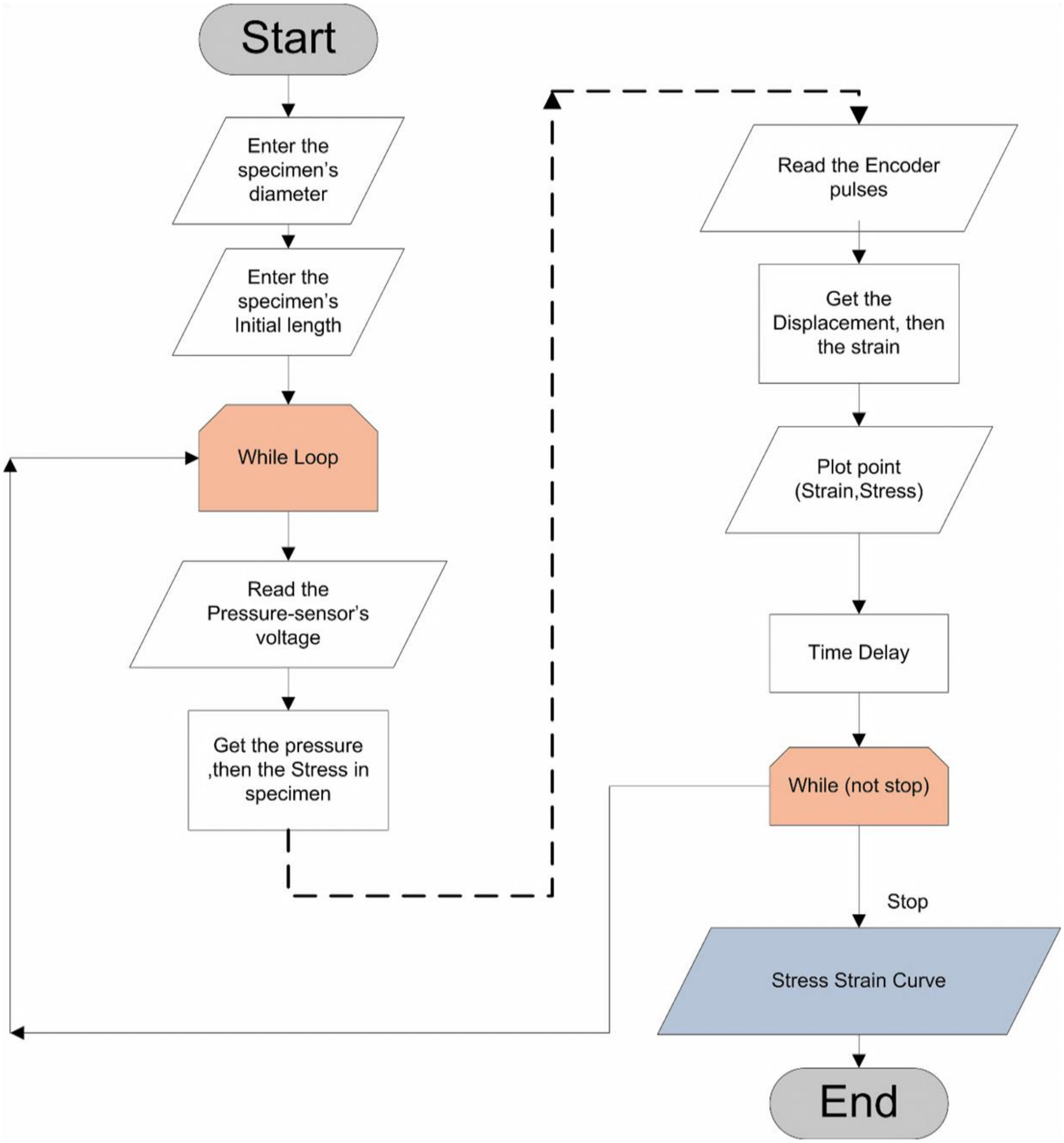


Fig 4.6: Acquisition Algorithm.

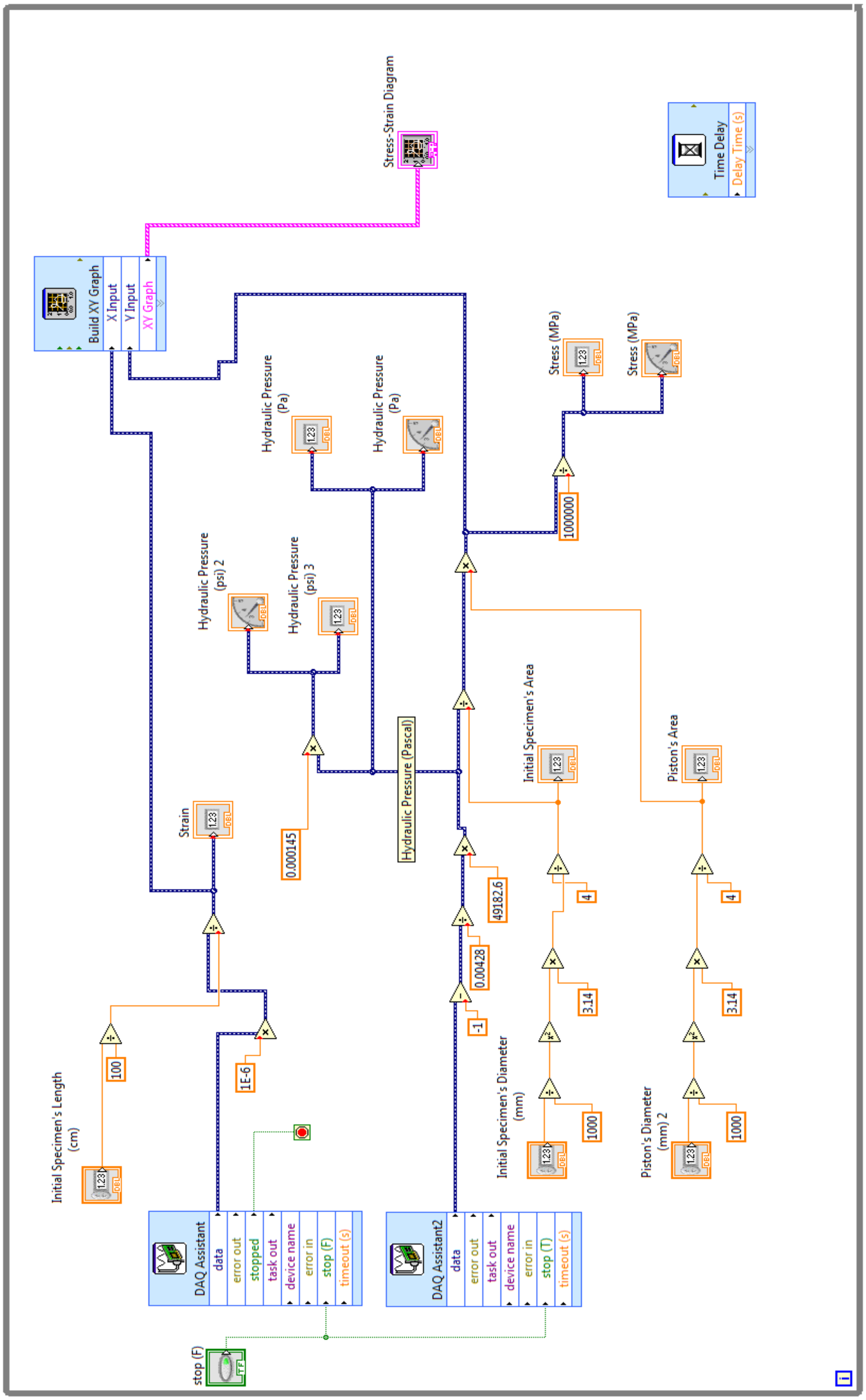


Fig 4.7: Programming in LabVIEW.

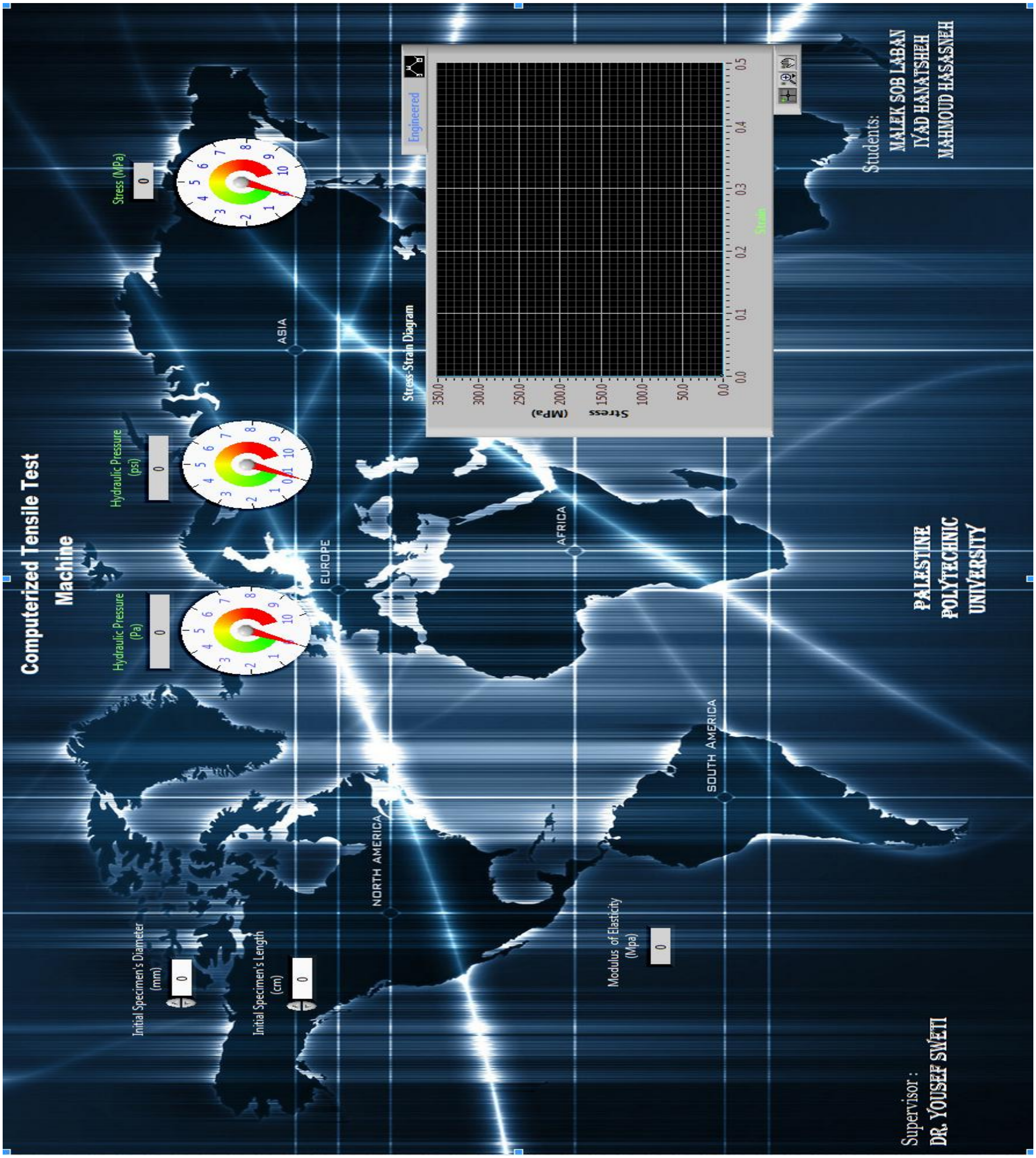


Fig 4.8: User Interface in LabVIEW [11].

4.3.2 Linear displacement sensor

The measuring transducer that converts a linear or angular displacement into an electric, mechanical, pneumatic, or other signal suitable for recording, long-distance transmission, or further conversion. Capacitance sensors, inductance sensors, transformer, resistive, stringed, photoelectric, jet, induction, and electrodynamics' transducers, as well as coding disks, can be used as displacement transducers [10].

A distinction is made between displacement transducers for small displacements (from several microns to several centimeters) and for large displacements (from tens of centimeters to several meters). Greater displacements are measured by means of traveling transducers. The greatest sensitivity for the measurement of small displacements is provided by photoelectric sensors, capacitance sensors, and some types of inductance sensors. Displacements associated with deformations in mechanical components are measured by strain gauges, which usually have amplifiers [10].

A linear encoder is a sensor, transducer or redhead paired with a scale that encodes position. The sensor reads the scale in order to convert the encoded position into an analog or digital signal, which can then be decoded into position by a digital readout (DRO) or motion controller [10].

The encoder can be either incremental or absolute. Motion can be determined by change in position over time. Linear encoder technologies include optical, magnetic, inductive, capacitive and eddy current. Optical technologies include shadow, self-imaging and interferometry. Linear encoders are used in metrology instruments, motion systems and high precision machining tools ranging from digital calipers and coordinate measuring machines to stages, CNC Mills, manufacturing gantry tables and semiconductor steppers [10].

The table 4.1 shows comparison between different linear displacement sensors.

Table 4.1: Comparison between different linear displacement sensors.

Comparison	**Capacitive displacement sensor**	**Laser displacement sensor**	**Linear displacement encoder**
Output Signal	Voltaic signal	Voltaic signal	Digital Pulses
Sensing Range	Low	Medium	High
Displacement Resolution	0.01 mm	0.001 mm	0.001 mm
Price	$ 500	$ 1,200	$ 600
Picture			

The used encoder for displacement measuring in this project shown in figure 4.8 is: *ZS Systems Linear Scale*, and has a resolution of 1micro-meter and gets the signal as digital readout (digital pulses)

Fig 4.9: Linear Encoder.

4.3.3 Pressure sensor

A pressure sensor measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed. For the purposes of this project, such a signal is electrical.

Pressure sensors are used for control and monitoring in thousands of everyday applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called pressure transducers, pressure transmitters, pressure senders, pressure indicators and piezometers, manometers, among other names [10].

What is a pressure transducer? A pressure transducer, sometimes called a pressure transmitter, is a transducer that converts pressure into an analog electrical signal. Although there are various types of pressure transducers, one of the most common is the strain-gage base transducer. The conversion of pressure into an electrical signal is achieved by the physical deformation of strain gages which are bonded into the diaphragm of the pressure transducer and wired into a Wheatstone bridge configuration. Pressure applied to the pressure transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance change proportional to the pressure [10].

The used pressure sensor in this project is: *Honeywell SPT4v5000P*, which is shown in figure 4.9, it can read pressures up to 5000 psi (340 bar) and burst pressure of 10000 psi, it transduce the pressure into voltage signal , it is calibrated and temperature compensated (-10˚C to 85˚C), [10].

Fig 4.10: Honeywell SPT4v5000P pressure sensor.

4.4 General flow chart of the tensile test

Fig 4.10 shows General flow chart of the tensile test. We will use this flow chart to help us to programming all components in the machine by LabVIEW program [6].

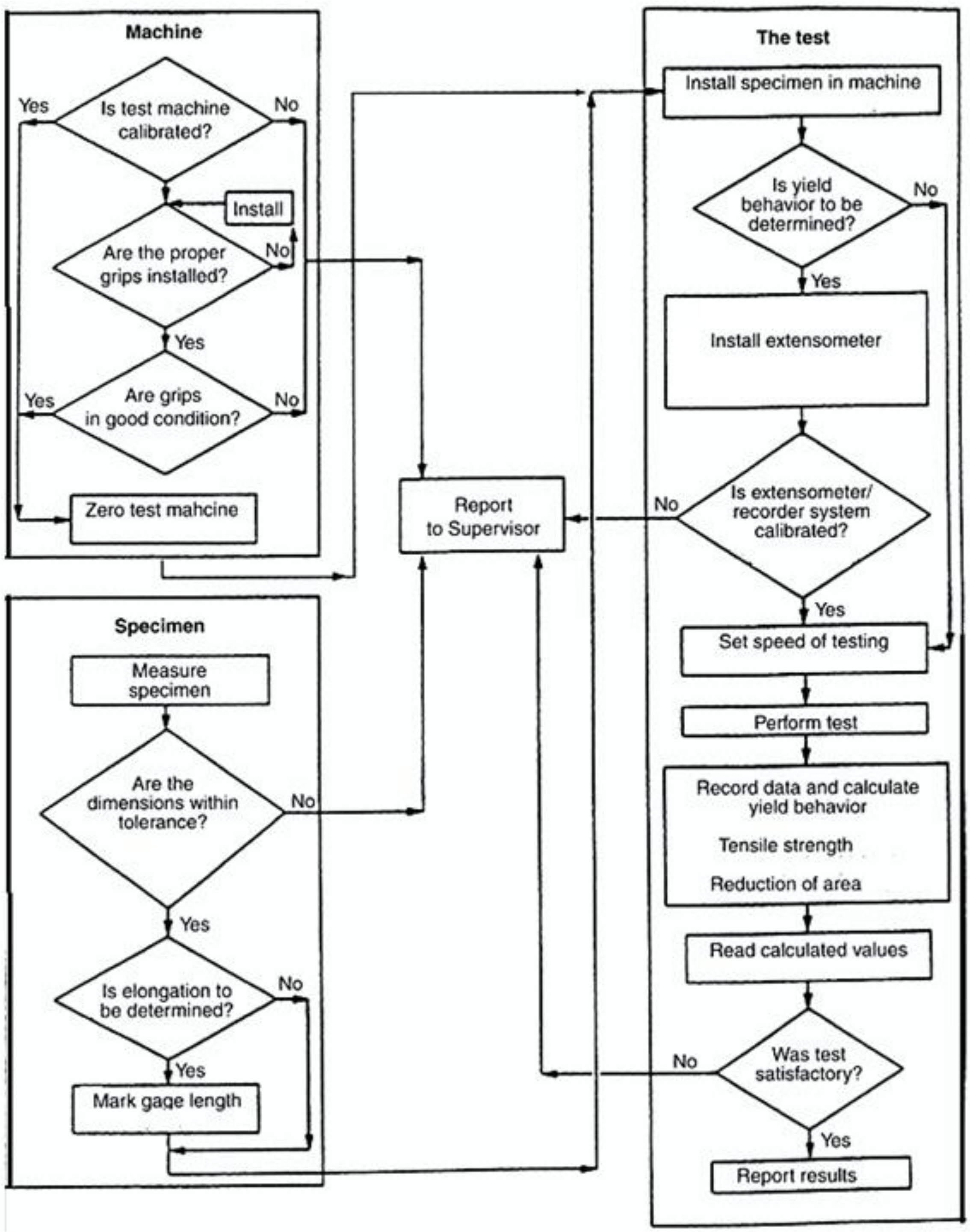


Fig 4.11: General flow chart for tensile test.

CHAPTER 5

Experiment Results and Analysis of

Tensile Test

This chapter provides the Results and Conclusion from Computerized Hydraulic Tensile Test Machine project.

5.1 Introduction

The tensile experiment is the most common mechanical test that reveals several important mechanical properties, such as: modulus of elasticity, yield strength, ultimate tensile strength, ductility, and toughness. The material to be tested is pulled at constant rate until it fractures. The tensile instrument elongates the specimen at a constant rate and has devices to continuously measure and record the applied load and elongation of the specimen. During the stretching of the specimen, changes occur in its physical dimensions and its mechanical properties. The ability to predict the loads that will cause a part to fail depends upon both material properties and the part geometry. This experiment involves testing to determine the relative properties.

5.2 Objective

The main objective of this experiment is to enable the students to derive the most important tensile properties from a stress strain curve. Three common construction materials will be tested.

5.3 Instrument

The equipment to be used is the Computerized Hydraulic Tensile Test Machine with 43 KN loading capacity. The testing machine applies tensile forces by means of a hydraulic force. Digital calipers are available to measure the cross-sectional dimensions and gauge lengths of all specimens before testing. A computer recording system is used to construct a stress-strain curve.

5.4 Materials

A steel alloy; an aluminum alloy; and brass alloy will be tested.

5.5 Experimental Procedure

In order to obtain uniform and accurate results, it is important that all tests have to be conducted under standard conditions. The American Standard for Testing and Materials (ASTM) has set up standards, which should be followed. The standard method of mechanical testing is specified by ASTM E-8M for metals, show in figure 5.1, [14].

a) Identify the material of each specimen used.

b) Record and measure the specimen parameter such as: diameter; length.

c) Mount the specimen in the testing machine and test the specimen to fracture (the lab technician and/or your lab instructor will help with the right procedure).

d) Test data will be appears on the computer screen, so take the data to do the report.

e) When the specimen is removed from the instrument measure all parameters that you have measured earlier.

f) Analyze the fracture surfaces of each specimen and record your observations.

In all cases, be sure to write your observations in your notebook for each test. You need to include these observations in your report. The general stress strain curve for a typical metal is shown in Figure 5.2 with all the important properties that can be directly measured. It shows the two most important properties for a wide range of materials: elastic modulus and yield strength.

Analysis of Results

Find the following for the three tested materials:

1. Plot stress versus strain of each test.

2. Determine the following parameters:

a) Modulus of elasticity;

b) Yield strength;

c) Strain at yield strength;

d) Tensile strength;

e) Strain at maximum load;

f) Stress at fracture;

g) True stress at fracture;

h) Modulus of resilience (area under the elastic portion of the stress-strain curve);

i) Modulus of toughness (total area under the stress-strain curve);

Report the above values for all tested specimens in a table format.

Points of Discussion

a) Compare Young's modulus of the three materials tested.

b) Compare the yield strengths and the ultimate strengths of the three materials tested. Did all three materials yield?

c) Comment on the usability of each parameter that you have determined (specify few examples if possible).

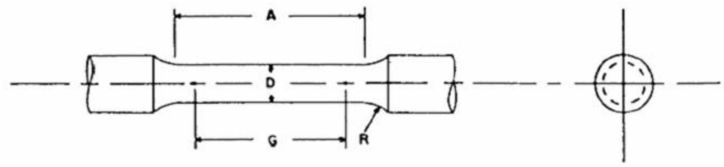
d) Discuss the general shape of the stress–strain curve of each material, especially the region beyond the yield point.

f) Possible sources of error include errors in load cell, cross-sectional dimensions, and gauge measurements. How much error do these factors contribute to the results obtained?

Write your observations and comments whenever possible in your discussion.

5.6 Useful References

ASTM E-8M: "Standard Test Methods for Tension Testing of Metallic Materials."



DIMENSIONS

Nominal Diameter	Standard Specimen				Small-Size Specimens Proportional to Standard					
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
G—Gage length	2.00± 0.005	50.0 ± 0.10	1.400± 0.005	35.0 ± 0.10	1.000± 0.005	25.0 ± 0.10	0.640± 0.005	16.0 ± 0.10	0.450± 0.005	10.0 ± 0.10
D—Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.350± 0.007	8.75 ± 0.18	0.250± 0.005	6.25 ± 0.12	0.160± 0.003	4.00 ± 0.08	0.113± 0.002	2.50 ± 0.05
R—Radius of fillet, min	⅜	10	¼	6	3⁄16	5	5⁄32	4	3⁄32	2
A—Length of reduced section, min (Note 2)	2¼	60	1¾	45	1¼	32	¾	20	⅝	16

Figure5.1: Round tension test specimen (ASTM A-370), [14].

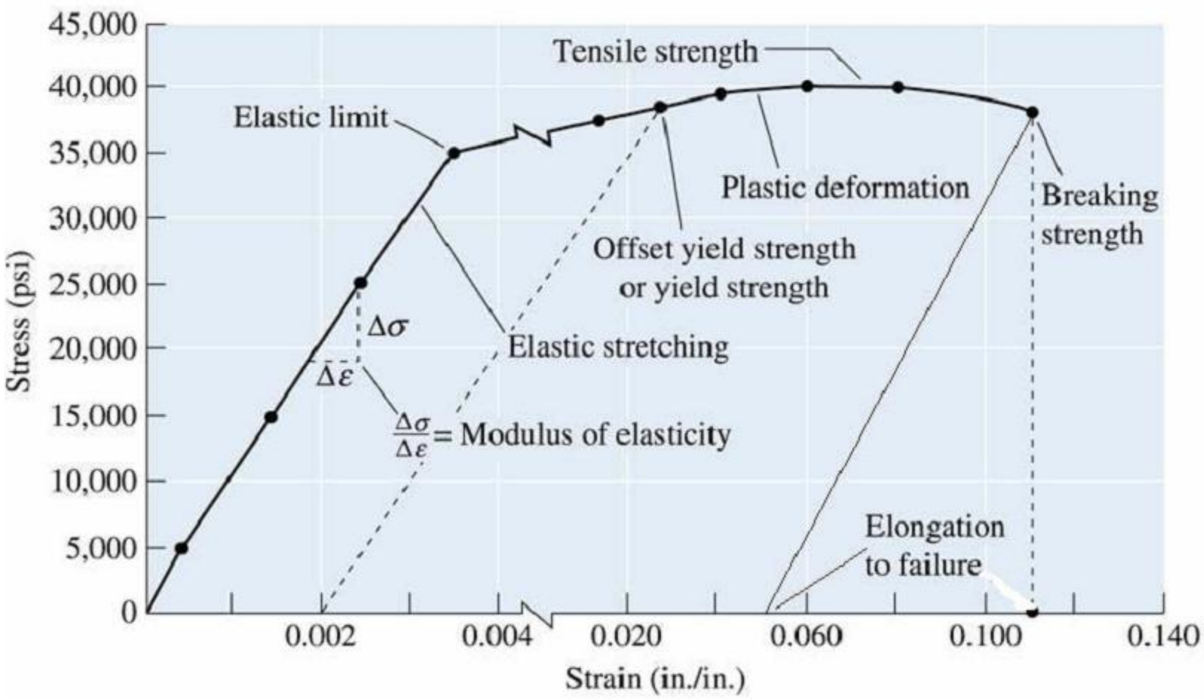


Figure 5.2: A schematic stress strain curve for a metallic alloy [14].

5.7 Real Experiment Results

Due to absence of the digital linear encoder because of Israeli's Objection the entrance of that, a mechanical displacement sensor with resolution of 10[um] is used.

The following geometry parameters are for the specimen and for the piston, this data is to be used for the calculation of both stress & strain.

D piston = 40 [mm]

D specimen = 6 [mm]

L specimen = 5.3 [mm]

Strain, $\epsilon = \frac{\text{Displacement}}{\text{Initial length}}$

Stress, $\sigma = P_{\text{pascal}} * \frac{A_p}{A_0} * 10^{-6}$ [MPa]

5.7.1 Experiment Data Table

Table 5.1: Experiment Data Result.

Displacement (um)	Strain, ϵ	P (psi)	P (kPa)	Stress (MPa)
10	0.000188679	1.450377	413.6854	18.3860187
25	0.000471698	3.625944	689.4757	30.6433644
40	0.000754717	5.80151	1103.161	49.0293831
55	0.001037736	7.977076	1378.951	61.2867289
90	0.001698113	13.0534	1241.056	55.158056
100	0.001886792	14.50377	1310.004	58.2223924
110	0.002075472	15.95415	1378.951	61.2867289
140	0.002641509	20.30528	1516.847	67.4154018

150	0.002830189	21.75566	1723.689	76.6084111
170	0.003207547	24.65642	1792.637	79.6727476
180	0.003396226	26.10679	1999.48	88.8657569
210	0.003962264	30.45793	1916.742	85.1885532
220	0.004150943	31.9083	1682.321	74.7698092
240	0.004528302	34.80906	2330.428	103.574572
250	0.004716981	36.25944	3102.641	137.89514
270	0.00509434	39.16019	2420.06	107.558209
280	0.005283019	40.61057	2371.796	105.413174
300	0.005660377	43.51132	2888.903	128.395697
320	0.006037736	46.41208	2888.903	128.395697
350	0.006603774	50.76321	3206.062	142.491645
360	0.006792453	52.21359	3102.641	137.89514
390	0.007358491	56.56472	3171.588	140.959476
400	0.00754717	58.0151	3068.167	136.362972
420	0.007924528	60.91585	3102.641	137.89514
440	0.008301887	63.81661	3171.588	140.959476
470	0.008867925	68.16774	3309.483	147.088149
500	0.009433962	72.51887	3723.169	165.474168
550	0.010377358	79.77076	3792.116	168.538504
570	0.010754717	82.67151	3998.959	177.731514
600	0.011320755	87.02265	3950.696	175.586478
650	0.012264151	94.27453	4067.907	180.79585
670	0.012641509	97.17529	4295.434	190.90816
700	0.013207547	101.5264	4136.854	183.860187
730	0.013773585	105.8776	5033.173	223.69656
900	0.016981132	130.534	5515.806	245.146916
950	0.017924528	137.7859	5791.596	257.404261
1010	0.019056604	146.4881	6205.281	275.79028
1050	0.019811321	152.2896	6894.757	306.433644
1150	0.021698113	166.7934	7446.338	330.948336
1220	0.023018868	176.946	7660.075	340.447779
1250	0.023584906	181.2972	7997.918	355.463028

1290	0.024339623	187.0987	7722.128	343.205682
1320	0.02490566	191.4498	8618.446	383.042056
1420	0.026792453	205.9536	8963.184	398.363738
1480	0.027924528	214.6559	8273.708	367.720373
1520	0.028679245	220.4574	9307.922	413.68542
1600	0.030188679	232.0604	8335.761	370.478276
1700	0.032075472	246.5642	9652.66	429.007102
1750	0.033018868	253.8161	9997.398	444.328784
1800	0.033962264	261.0679	11721.09	520.937196
1850	0.03490566	268.3198	11927.93	530.130205
2200	0.041509434	319.083	11996.88	533.194541
2970	0.056037736	430.7621	14478.99	643.510653
3250	0.061320755	471.3727	14823.73	658.832336
3400	0.064150943	493.1283	15237.41	677.218354
3550	0.066981132	514.884	14410.04	640.446317
3650	0.068867925	529.3878	14972.65	665.451302
4050	0.076415094	587.4029	13458.57	598.158474
4530	0.085471698	657.021	12280.94	545.819607
4600	0.086792453	667.1736	11355.66	504.696212
5050	0.095283019	732.4406	9505.112	422.449422
5430	0.10245283	787.5549	8327.488	370.110556
6015	0.113490566	872.402	7738.675	343.941123
7000	0.132075472	1015.264	7149.863	317.771689
9050	0.170754717	1312.592	5046.962	224.309428

5.7.2 Stress Strain Curve

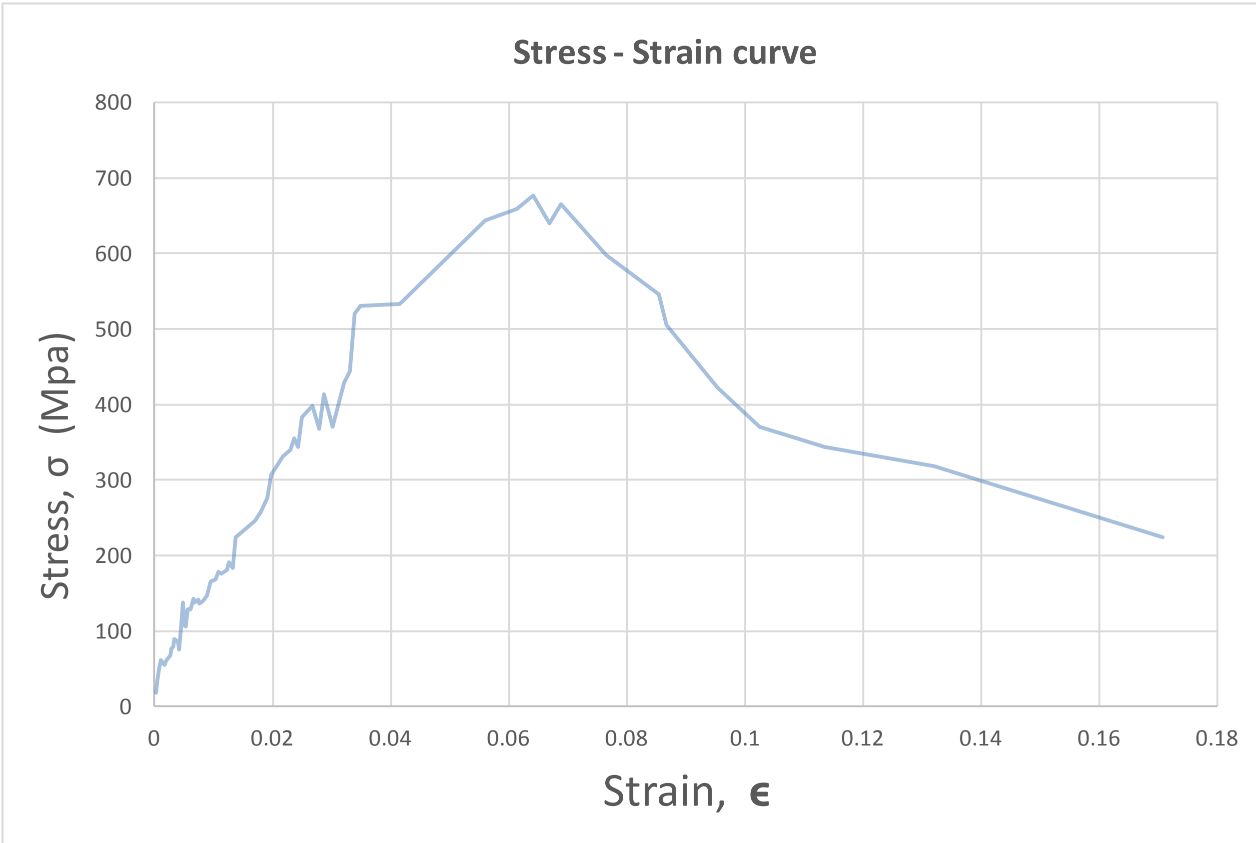


Figure 5.3: Stress Strain Curve.

5.7.3 Data Analysis

From the above stress strain curve, these material properties can be obtained:

Yield Stress, $\sigma_y = \sigma|_{(\epsilon=0.002)} = 60$ [MPa]

Ultimate Stress, $\sigma_u = \sigma_{(max)} = 677$ [MPa]

Fracture Stress, $\sigma_f = \sigma|_{(at\ fracture)} = 225$ [MPa]

Modulus of Elasticity, $E = \frac{\sigma_y}{(\epsilon=0.002)} = 30$ [GPa]

True Strain at Fracture, $\epsilon_{T_f} = \ln(1+\epsilon) = \ln(1+0.1707) = 0.1576$

True Stress at Fracture, $\sigma_{T_f} = \sigma_f(1 + \epsilon) = 225(1 + 0.1707)$

$= 263.4$ [MPa]

Ductility, in terms of either percent elongation $= \frac{l_f - l_0}{l_0} * 100\%$

$= \frac{6.205 - 5.3}{5.3} * 100\% = 17.07\ \%$

5.8 Sources of Errors

1. Reading's errors, which includes:
    a. Non-accurate simultaneous readings (stress to corresponded strain), because of using manual acquisition instead of computer one; due to the use of mechanical displacement sensor.
    b. Sampling time is too small for manual acquisition reading.

2. Low resolution of the displacement sensor.
3. Oil leakage through the relief valve; although it is too small.
4. Geometry reading error for the specimen.
5. Friction inside the piston between the seal and the inner wall of the cylinder.

5.9 Conclusion

- Stress Strain curve presents couple of useful material properties.
- These properties include: modulus of elasticity, yield stress, ultimate stress, fracture stress, Ductility, true stress and true strain.
- True stress is higher than engineered one, but we design using the engineered value; so this explicitly give a safety factored value to design through.
- Elastic region is too narrow compared to plastic one, so the displacement sensor should have a sufficient resolution in order to measure it precisely.
- In order to increase the load capacity of this machine, to parameters should be taken care about: the mechanical structure geometry, and increasing the pistons' area or increasing the hydraulic pressure.

Appendix A: Datasheets

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