BULGING TEST OF ALUMINIUM AT ROOM TEMPERATURE

A Thesis submitted to the

National Institute of Technology, Rourkela

In partial fulfillment of the requirements

of

Bachelor of Technology (Mechanical Engineering)

By

Vaibhav Dash

Roll No. 10603024

Under the guidance of

Prof. Susanta Kumar Sahoo

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ORISSA -769008, INDIA

2010

CERTIFICATE

This is to certify that thesis entitled, "BULGING TEST OF ALUMINIUM AT ROOM TEMPERATURE" submitted by Mr. VAIBHAV DASH in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any other Degree or Diploma.

Date: 13th May, 2010

Place: Rourkela

Prof. Susanta Kumar Sahoo

Dept. of Mechanical Engineering
National Institute of Technology
Rourkela-769008

ACKNOWLEDGEMENT

It is with a feeling of great pleasure that I would like to express my most sincere heartfelt gratitude to Prof.S.K.Sahoo, Professor, Department of Mechanical Engineering, NIT Rourkela for his ready and able guidance throughout the course of my project work. I am greatly indebted to him for his constructive suggestions and criticism from time to time during the course of progress of my work.

I express my sincere thanks to Prof. R.K.Sahoo, Head of the Department of Mechanical Engineering, NIT Rourkela for providing me the necessary facilities in the department.

I express my sincere gratitude to Prof. K.P.Maity, coordinator of Mechanical Engineering course for his timely help during the course of work.

I would also like to thank all the faculty of Mechanical Engineering department who have been extremely helpful in the course of this project work.

Finally, I would like to deeply thank my parents, and my friends who were indeed a great help, and who lend me great support during this project.

Date:13th May, 2010 **Vaibhav Dash**

Place: Rourkela 10603024

Mechanical engineering

ABSTRACT

During Compression Testing, a solid specimen (Hexagonal in Cross-Section) is compressed axially between the punch and the bottom plates. As a result of this, the work piece material undergoes deformation which basically is ***Bulging*** at its centre position. This test can further be carried out at different temperatures to record the nature of compression for different ranges of temperatures.

In ***Compression or Upsetting***, the presence of frictional constraints between the dies and the work piece directly affects the plastic deformation of the work piece. The friction at the faces of contact retards the plastic flow of metals around the surface and in its vicinity. A conical wedge of a relatively undeformed metal is formed directly below it while the rest of the cylindrical metal suffers high strain hardening and subsequently bulges out. However, in practice, the use of lubricants greatly reduces the degree of bulging to a great extent. Hence it is necessary to apply a correction factor for the purpose of bulging design of die.

For a ductile material like Aluminium used here lateral distortion takes place and due to restraining influence of friction of the load faces, the cross section becomes greater at the centre, the test piece taking up a barrel shape. Hence this is also termed as ***Barreling***.

In this particular experimentation the behavior of Aluminium specimen under different loading conditions and at room temperature is recorded and the data thus generated is utilized in predicting the behavior of Aluminium and other metals under cold loading conditions.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Fig 1: Hydraulic Compression Test

A numerous and varied range of metals and alloys are being used worldwide for a large number of operations depending upon their special characteristics and properties. These materials before being used in any specific operations need to be tested out for the various parameters pertaining to them. These parameters need to be analyzed properly and the corresponding behavior of the materials and resulting properties for such operating conditions need to be properly reviewed. Usually these alloys are to be processed through various thermo-mechanical treatments before being fabricated into final products. Determination of the load to carry out these operations is of paramount importance. Load depends on the flow stress of materials besides the geometry of the die and friction at the tool-work piece interface. Therefore, prediction of hot deformation behavior linking process variable such as strain, strain rate and temperature to the flow stress of the deforming materials is necessary.

For predicting various temperatures flow behavior of different alloys there is a necessity to establish the relationship between flow stress, strain, strain rate and temperature. Towards this end, bulging test at different temperatures more commonly known as compression tests need to be conducted for a wide range of strain rates and temperatures. The experimental stress strain data can then be employed to relate flow stress, strain rate & temperature. This relation can then be crosschecked with other experimental data generated.

Compression Tests are of extremely high commercial importance because it helps determines different material properties pertaining to hot as well as cold metal forging employed in a number of metal forming applications. Another major aspect of axisymmetric compression from the standpoint of testing the mechanical manufacturing properties of metals is its estimation of their forming limits up to plastic instability and subsequently fracture.

When a simple compressive load is applied on a particular specimen, the following types of deformation may take place: elastic or plastic shortening as in the case of ductile materials, crushing and fracture in brittle materials, or a sudden bending deformation called buckling in long, slender bars, or a combination of these. Ductile materials, such as aluminium, have no meaningful compressive strength. Lateral expansion and thus an increasing cross-sectional area along with axial shortening. The specimen won’t break: excessive deformation rather than loss of strength demonstrate failure characteristics.

1.2 Brief Description of Work:

Compression Tests are basically performed to understand and properly predict the flow behavior of different specimens by establishing a relationship between flow stress, strain, strain rate and temperature. The experimental data obtained from this test would subsequently be utilized to form a constitutive equation relating various flow parameters and deformation parameters. The equation is subsequently used to determine the behavior of the metal and alloy, in this case mild steel, under different conditions of temperature, loading, lubrication and putting it to appropriate usage.

The work basically involves the following steps:

- Sample preparation of Aluminium specimen in the form of billets (Cross Section: Hexagon).
- Characteristic study of Aluminium specimen.
- Performing compressive testing under different loading conditions and high temperatures on the prepared Aluminium specimens.

1.3 Tension and Compression Testing:

Description of Technique:

Fig 2: Tensile and Compression Testing Apparatus

The evaluation of the mechanical behavior of a particular sample under various conditions of tension and compression can be performed so as to provide basic material property data which is critical for component design and also service performance assessment.

The requirements for tensile and compression strength values and the methods for testing these significant properties are specified in various standards for a vivid range of materials. Testing can be performed on machined material samples or also on full-size or scale models of the actual components. These tests are usually performed using a universal mechanical testing instrument.

Fig 3: Tensile Test Specimens

A tensile test is basically a method for determining behavior of materials under axial tensile loading. This test is conducted by fixturing the specimen into the test apparatus and then subsequently applying a force to the specimen by separating the testing machine crossheads. The crosshead speed can be varied in order to control the rate of strain in the test specimen. Data from the test are then used to determine tensile strength, yield strength, and the modulus of elasticity. Measurement of specimen dimensions after testing also provides reduction of area and elongation values to characterize the ductility of the material. Tensile tests can be performed on a variety of materials, including metals, plastics, fibers, adhesives, and rubbers. Testing can be performed at subambient as well as elevated temperatures.

A compression test is used for determining the behavior of materials under a compressive load. Compression tests are basically conducted by loading the test specimen between two plates, and after that applying a force to the specimen by moving the crossheads together. During the test, the specimen gets compressed, and deformation versus the applied load is plotted. The compression test is used for the purpose of determining elastic limit, proportional limit, yield point, yield strength, and (for certain materials) compressive strength.

ANALYTICAL INFORMATION:

Compressive Strength:

The compressive strength can be defined as the maximum compressive stress a material is capable of withstanding without fracture. Brittle materials fracture during testing and have a definite compressive strength value. The compressive strength of ductile materials can be determined by their degree of distortion during testing.

Elastic Limit:

Elastic limit is defined as the maximum stress that a material is capable of sustaining without permanent deformation after removal of the stress.

Elongation:

Elongation is defined as the amount of permanent extension of a specimen that has been fractured while in a tensile test.

Modules of Elasticity:

The modulus of elasticity is described as the ratio of stress (below the proportional limit) to strain, i.e., the slope of the stress-strain graph. It is considered as the measure of rigidity or stiffness of a metal.

Proportional Limit:

The proportional limit is defined as the greatest amount of stress a material is capable of reaching without any deviation from the linear relation of the stress-strain curve, i.e. without plastic deformation.

Reduction in Area:

The reduction in area is given by the difference between the original cross-sectional area of a tensile specimen and the smallest area of cross sectionat the after fracture following the test.

Strain:

Strain is defined as the amount of change in the shape or size of a material due to force.

Yield Point:

The yield point is given by the stress in a material (usually less than the maximum attainable stress) at which an increase in the strain occurs without an increase in stress. Only few metals have a yield point.

Yield Strength:

The yield strength is defined as the stress at which a material undergoes a specified deviation from a linear stress-strain relationship.

Ultimate Tensile Strength:

Ultimate tensile strength, or UTS, is defined as the maximum tensile stress a material is capable of sustaining without fracture. It is obtained by dividing the maximum load applied during the tensile test by the original cross sectional area of the sample.

TYPICAL APPLICATIONS

- Tensile as well as compression properties of various raw material for comparison to product specifications.
- For obtaining material property data for finite-element modeling or other product design for desired mechanical behavior and service performance
- Simulations of component mechanical performance in service industry.

1.4 Sample Requirements:

The most common specimen which is used for compression testing is a right circular cylinder with flat ends. Other shapes may also be used; however, they require special fixtures to avoid the occurrence of buckling. Special configurations for component testing or service simulations are also dependent upon the specific test machine which is to be used. The sample which is used in this particular experiment is of Hexagonal cross-section.

Standard tensile tests on metals and plastics are usually conducted on specially prepared test specimens. These specimens can either be machined cylindrical samples or flat plate samples (dogbone). Test samples must always have a specific ratio of length to width or diameter in the test area (gauge) to produce repeatable results and also comply with standard test method requirements. Tubular products, fibers, and wires can be put to tensile tests at full size using special fixtures which promote optimal gripping and failure location.

CHAPTER 2

LITERATURE SURVEY

LITERATURE SURVEY:

Due to its relevance in metal forming applications many investigators have carried out a series of investigations on cold upset forging of solid cylindrical specimens. Comprehensive review of literature has been published by Johnson and Mellor [1]. Another major aspect of axisymmetric compression from the standpoint of testing the mechanical manufacturing properties of metals is its estimation of their forming limits up to plastic instability and subsequently fractures [2]. In upsetting the presence of frictional constrains between the dies and the work-piece has a direct effect on the plastic deformation of the later. When a solid cylinder undergoes axial compression between the punch and bottom platen, the work-piece material which is in contact with the surfaces undergoes heterogeneous deformation which results in the “barreling” of the cylinder. Friction at the faces of contact causes a retarding effect on the plastic flow of metal on the surface and in its vicinity. As a result, a conical wedge of a relatively undeformed metal is formed directly below it while the rest of the cylinder suffers high strains and bulges out in the form of a barrel. This demonstrates that the metal goes easily towards the nearest free surface which is said as the point of least resistance, a well-known principle of plastic deformation. However, the use of lubricants greatly reduces the degree of bulging and under the condition of proper lubrication, bulging can be brought down to zero. However, the friction cannot be eliminated during upset forging and it is extremely necessary to go for a correction factor for the bulging during the design of a die.

Kulkarni and Kalpakjian having examined the arc of barrel, led an assumption that it may be circular or parabolic. In the meantime, Schey et al presented a comprehensive report on the different geometrical factors that affect the shape of the barrel [3, 4]. Banerjee and Narayanasamy et al. showed theoretically that the barrel radius can also be expressed as a function of axial strain and subsequently confirmed the same through experimental verification [5, 6]. Yang et al. developed an upper bound solution for determination of forging load and also deformed bulged profile during upset forging of cylindrical billets under the dissimilar frictional conditions at flat die surfaces [7]. Fuh-Kuo Chen et al. has developed a theoretical solution for the prediction of flow stresses during the upsetting operation with an apt consideration of the barreling effect [8]. Gokler et al. made a study of taper upset forging using elastic plastic finite element analysis [9]. Narayanasamy and Pandey studied the effect of barreling in aluminium solid cylinders during cold upsetting which most significantly pertains to the work to be done in this particular experimentation [10]. Malayappan and Narayanasamy studied the effect of barreling during cold upsetting of solid cylinder with the introduction of conical die constraint at one end at both ends of the work-piece in un-lubricated as well as lubricated conditions [11–13]. They also have experimentally studied the barreling phenomenon under varying frictional conditions at the flat die surface and with the introduction of an extrusion die constraint at one end of the work-piece [14, 15].

CHAPTER 3

MATERIALS & METHOD

3.1Material Used: Aluminium

Aluminium:

Fig 4: Aluminium

Aluminium (or **aluminum** ;) is a silvery white and ductile member belonging to the boron group of chemical elements. Its symbol is **Al** and its atomic number is 13. It is insoluble in water under normal circumstances. Aluminium is the most abundant metal in the Earth's crust, and the third most abundant element overall, after oxygen and silicon. It makes up for about 8% by weight of the Earth's solid surface. Aluminium is highly reactive chemically to occur in nature as a free metal. Instead, it is found combined in more than 270 different minerals. The primary source of aluminium is bauxite ore.

Aluminium is remarkable for the metal's ability to resist corrosion due to the phenomenon of passivation and also for its low density. Structural components which are made from aluminium and its alloys are of extreme utility to the aerospace industry and are a major contributor in other areas of transportation and building. Its reactive nature makes it useful as an additive or catalyst in chemical mixtures, including ammonium nitrate explosives, to enhance blast power.

Properties of Aluminium:

Light Weight

Aluminium is an extremely light metal with a specific weight of just 2.7 g/cm^3, which is about a third that of steel. As an example, the use of aluminium in vehicles reduces dead-weight and energy consumption while simultaneously increasing load capacity. Its strength can be adapted to the application desired by modifying the composition of its alloys.

Corrosion Resistance

Aluminium generates a protective oxide coating and is highly resistant to corrosion. Different types of surface treatment such as anodizing, painting or lacquering can further improve upon this property. It is mostly useful in applications where protection and conservation are required.

Electrical and Thermal Conductivity

Aluminium is an excellent conductor of heat and electricity and in relation to its weight is almost twice as good a conductor as copper. This has made aluminium one of the most commonly used materials in major power transmission lines.

Reflectivity

Aluminium is a good reflector of both visible light as well as heat, and that adding up to its low weight, makes it an ideal material for all kind of reflectors in, for example, light fittings or rescue blanket

Ductility

Aluminium is highly ductile and has a low melting point and density. In a molten condition it can be processed in various ways. Its ductility allows products of aluminium to be basically formed in close range to the end of the product's design.

Recyclability

Aluminium is completely recyclable with no downgrading of its qualities. The re-melting of aluminium requires minimum energy: just about 5 percent of the energy needed to produce the primary metal initially is needed during the recycling process.

3.2Machine Used : Universal Testing Machine

Universal Testing Machine

Fig 5: Universal Testing Machine

A **Universal Testing Machine** also known as materials testing machine/ test frame is used in order to test the tensile and compressive properties of materials. The Universal Testing machine is named so as it can perform all the tests such as compression, bending, tension, etc. to examine the material and all its mechanical properties Such machines usually have two columns but single column types are also available. Load cells and extensometers are used to measure the key parameters of force and deformation as the sample is tested. These machines are widely used worldwide and are common in any materials testing laboratory.

A typical testing system basically consists of a materials testing machine/test frame, control and analysis software, and critically, the test fixtures, accessories, parts and devices which are used to hold and support the test specimen.

A tension test is a destructive test in the sense that the specimen is finally fractured into two pieces. In order to perform the tensile test, the UTM must be capable of applying that load which is required to break or fracture the specimen material.

The test piece or specimen of the material is mostly a straight piece, uniform in the cross-section over the test length and often with enlarged ends for it to be held in the machine grips. However, the machine is capable of holding the specimen without enlarged ends also.

Many decades ago before the birth of digital sensor arm or non-contact extensometers, two fine marks were made near to the end of uniform test section of the specimen and the distance between these two points was termed as the "gauge length".

The gauge length is that length which is under study or observation when the experiment on the particular specimen is performed. The gauge length of a specimen bears a constant standardized ratio to the dimension of the cross-sectional for certain reasons.

The specimen is placed in the machine held by the grips and an extensometer if required which is used to automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can also record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but along with it also of all other elastic components of the testing machine and its drive systems including any type of slipping of the specimen in the grips.

Once the machine is started it begins to gradually apply an increasing load on specimen. Throughout the tests the control system and its associated software are used to record the load and extension of the specimen. Finally, a plot between the gradual increase in load (Y-axis) to that of the increase in displacement (X-axis) of the specimen is obtained. For compression Testing depending upon the desired decrease in the specimen length the experiment is continued till the desired reduction is obtained

3.3Lubricant Used: Lithium Based White Grease

Composition:

Ingredient	Formula	content
LIQUEFIED PETROLEUM GAS (LPG)	$C_3H_8/C_3H_6/C_4H_{10}$	10-30%
MINERAL OIL - ACID TREATED HEAVY NAPHTHENIC (SEVERE SOLVENT-REFINING AND/OR HYDROTREATMENT)	Not Available	10-30%
ZINC OXIDE	Zn-O	<10%
ISOHEXANE	C6-14	30-60%

Appearance: Viscous off-white Liquid

Specific Gravity: 0.663

3.4 Specimen Preparation:

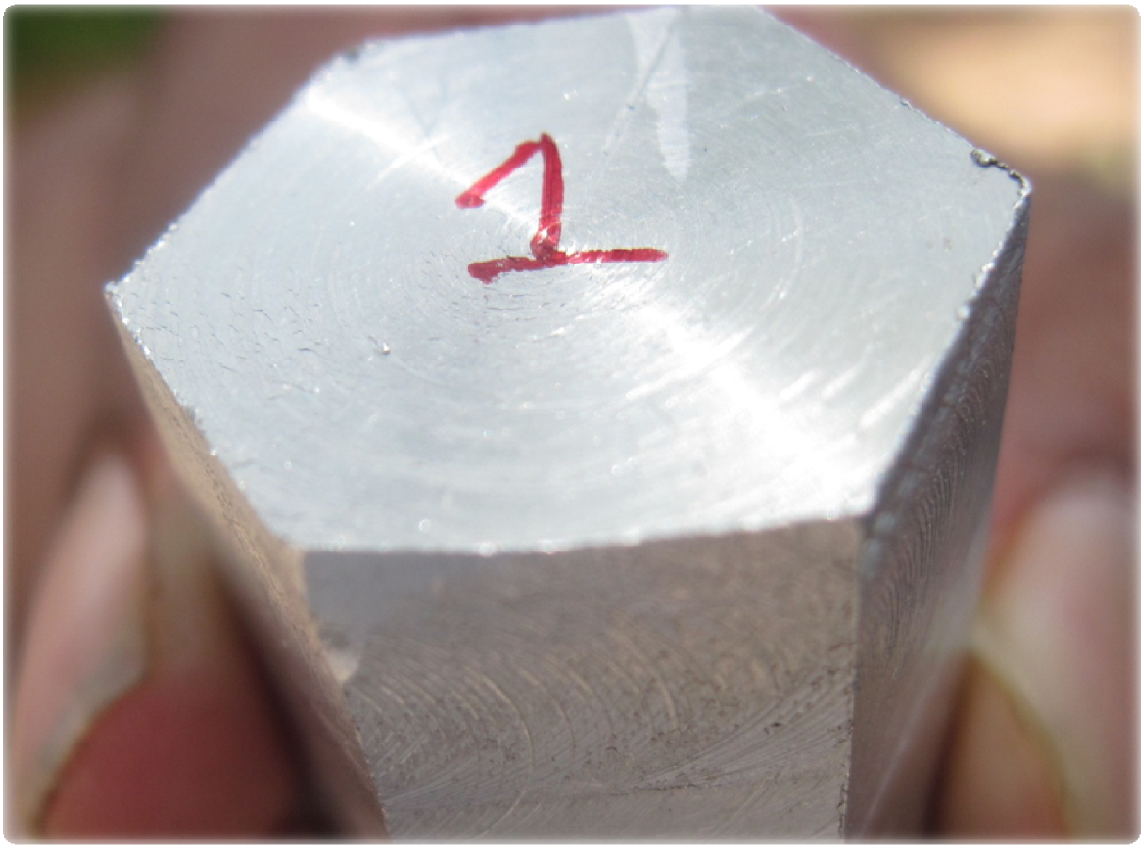


Fig 6: Specimen

Compression Test to be conducted subsequently during the course of this experimental analysis requires the testing of five specimens prepared from the raw aluminium sample.

Specimen Specifications:

L/D_{eff} = 1.5(approximately)

L = Length of the Specimen

D_{eff} = Effective Diameter of the Cross Section of the Specimen

Hence if D_{eff} = 22 mm

Edge Length of the Hexagon (E_l) = 12 mm (approx.)

Length (L) = 33 mm (approx.)

Procedure:

The raw aluminium sample is in the form of a solid cylinder having a diameter of 30mm and a length of 250mm.We are required to obtain five specimen of length 33mm(approx.) each and a hexagonal edge length of 12mm(approx.)

Step 1: Turning operation is performed on the given aluminium sample and its diameter is subsequently reduced to 25mm (diameter of the circumscribed circle of the desired hexagon). Turning is performed on a lathe machine in which the tool is stationary and the part is rotated. The figure below illustrates an engine lathe. Lathes are designed solely for the purpose of turning operations, so that precise control of the cutting yields tight tolerances. The work piece is mounted on the chuck, which rotates in relation to the stationary tool.

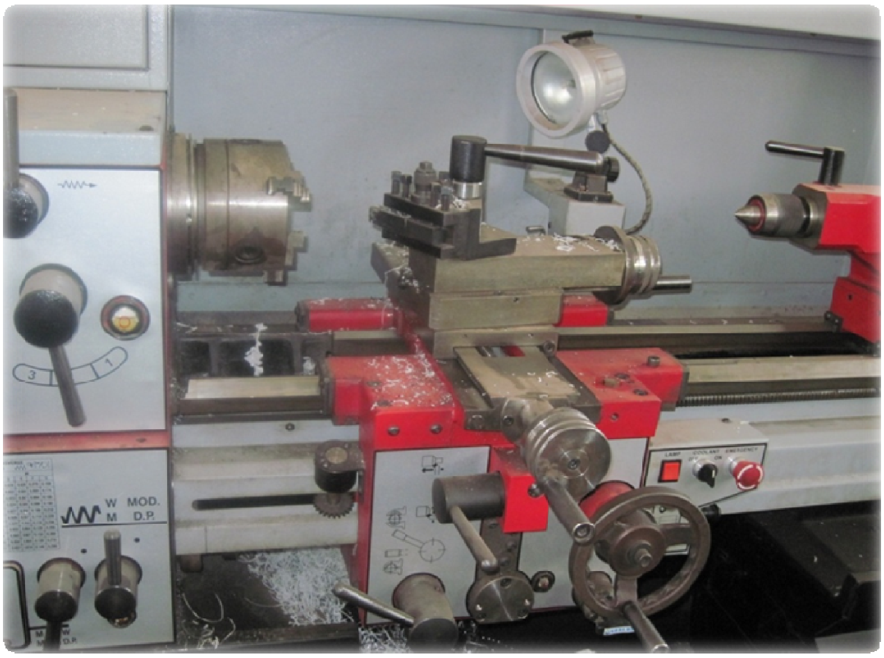


Fig 7: Lathe

Step 2: After reducing the diameter of the raw sample, milling operation is performed on the sample so as to obtain a hexagonal cross section. This particular operation is carried out in a CNC Milling Machine so as to get an accurate Hexagonal Cross Section. A **milling machine** is a machine tool which is used to machine solid materials. Milling machines exist in two basic forms: horizontal and vertical, in which the terms refer to the orientation of the cutting tool spindle. Unlike a drill press, in which the workpiece is held stationary and there is vertical movement of the drill to penetrate the material, milling also involves movement of the workpiece simultaneously against the rotating cutter, the latter of which is thus able to cut on its flanks as well as its tip. Workpiece and cutter movement are precisely controlled to less than 0.001 in (0.025 mm), mostly by means of precision ground slides and leadscrews or analogous technology. Milling machines can be manually operated, mechanically automated, or digitally automated via computer numerical control (CNC).

Fig 8: CNC Milling Machine

Step 3: On obtaining the desired cross section five specimens are then cut from the sample given as per the required lengths of the specimen. Cutting operation is performed using a Hack Saw. The desired lengths are marked through a Marker which is then cut through after fixing them in a clamp. A **hacksaw** is a fine-tooth saw having a blade under tension in a frame, mostly used for the purpose of cutting materials such as metal or bone. Hand-held hacksaws consist of a metal arch with a handle, usually a pistol grip, with pins for the attachment of a narrow disposable blade. A screw or other mechanism is used so as to put the thin blade under tension. The blade can be mounted with either the teeth facing toward or away from the handle, resulting in cutting action on either the push or else the pull stroke. On the push stroke, the arch will flex by a slight amount, decreasing the tension on the blade.

Fig 9: Hacksaw

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Experimental Procedure & Data Generated:

Aluminium Specimens (Hexagonal in cross-section) of effective diameter 22mm and height 33 mm (approx.) were compressed in the Universal Testing Machine (UTM) in the presence of the lubricant Lithium based White Grease. The following experiments are all conducted under constant conditions of friction with the friction factor given by m=0.35 as determined from previously performed Ring Compression Testing using the same aluminium sample on the specified Machine .A total of 5 different specimens were made to undergo a range of percentage reduction in height and a corresponding plot between the load v/s displacements was obtained and a series of data was generated.

Initial Specimen Dimensions:

	Specimen 1	**Specimen 2**	**Specimen 3**	**Specimen 4**	**Specimen 5**
Edge Length(E_l)(mm)	12.04	12.12	12.35	12.33	12.07
Circumscribed Circle Diameter (D)(mm)	24.08	24.25	24.70	24.66	24.14
Height (H)(mm)	34.38	32.84	34.03	32.67	33.81
% reduction in Height during Compression Testing (in %)	40	50	60	70	80
New Height after compression (H_{new})(mm)	20.63	16.42	14.10	10.84	7.57

During Compression Testing of the above mentioned specimens following data was recorded and then which was subsequently utilized to make a Load (Y-axis) V/s Displacement (X-axis) plot for all the five percentages of Height Reduction.

4.2 OBSERVATIONS:

Table 1:

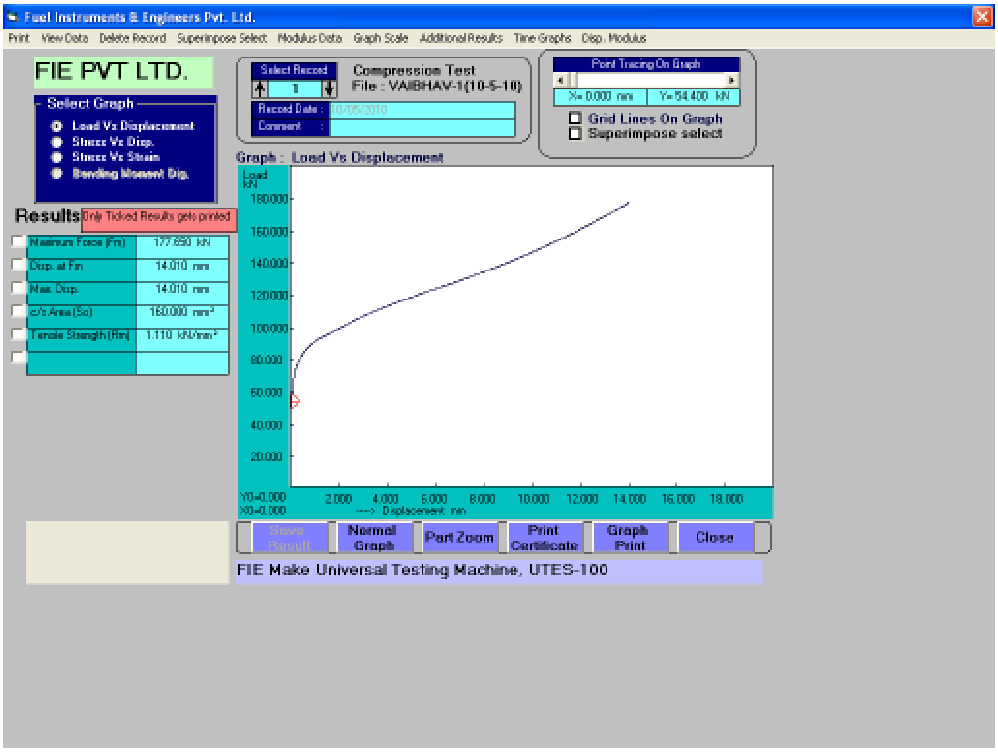
Deflection(mm)	Specimen 1 (40% red^n) Load(in kN)	Specimen 2 (50% red^n) Load(in kN)	Specimen 3 (60% red^n) Load(in kN)	Specimen 4 (70% red^n) Load(in kN)	Specimen 5 (80% red^n) Load(in kN)
Dead Load	54.4	60.15	56.3	56.2	19.0
0.5	83.9	93.8	97.0	96.7	92.95
1.0	91.6	100.6	104.65	105.0	100.2
1.5	95.7	104.9	109.55	109.95	104.85
2.0	99.7	107.95	113.05	113.50	107.95
2.5	103.6	110.05	115.60	116.15	110.10
3.0	107.25	112.00	117.55	118.20	112.10
3.5	110.4	114.00	119.5	120.2	114.0
4.0	113.4	116.00	121.5	122.3	116.0
4.5	116.25	118.00	123.5	124.5	117.9
5.0	118.85	119.95	125.45	126.55	119.75
5.5	121.7	122.25	127.8	129.0	121.95
6.0	124.25	124.40	130.0	131.3	124.0
6.5	126.7	126.5	132.15	133.6	126.05
7.0	129.25	128.9	134.65	136.3	128.35
7.5	131.95	131.6	137.35	139.15	130.8
8.0	134.7	134.2	139.8	141.95	133.25
8.5	137.55	137.2	142.6	145.05	135.95
9.0	140.55	140.35	145.55	148.4	138.75

9.5	143.6	143.55	148.55	151.9	141.75
10.0	146.9	146.85	151.8	155.5	144.9
10.5	150.15	150.4	155.0	159.5	148.2
11.0	153.8	154.3	158.5	163.65	159.8
11.5	157.2	157.9	162.0	167.7	155.3
12.0	161.15	162.1	165.8	172.3	159.35
12.5	165.05	166.2	169.35	176.75	163.2
13.0	168.05	170.5	173.05	181.4	167.15
13.5	172.95	174.9	177.05	186.25	171.35
14.0	177.6	180.05	182.35	191.8	176.10
14.5		185.55	187.55	197.85	181.15
15.0		191.15	193.1	204.15	186.35
15.5		197.50	199.1	211.10	192.05
16.0		204.20	205.5	218.5	198.05
16.5		210.95	212.1	225.55	204.4
17.0		217.7	219.05	233.95	211.75
17.5			226.35	242.65	218.80
18.0			233.75	251.25	225.5
18.5			241.75	260.65	233.95
19.0			251.35	272.15	242.65
19.5			260.25	283.65	252
20.0			269.75	295.45	260.9
20.5			280.35	309.55	272.0
21.0			292.35	325.55	284.1
21.5				342.35	296.9
22.0				361.35	312
22.5				382.95	329.1
23.0				407.15	347.8
23.5				434.3	368.9
24.0					392.4

24.5					416.0
25.0					443.2
25.5					474.95
26.0					506.95
26.5					547.45
27.0					585.2
-					

4.3 GRAPHS OBTAINED:

Load V/s Displacement:



Select Record: 1

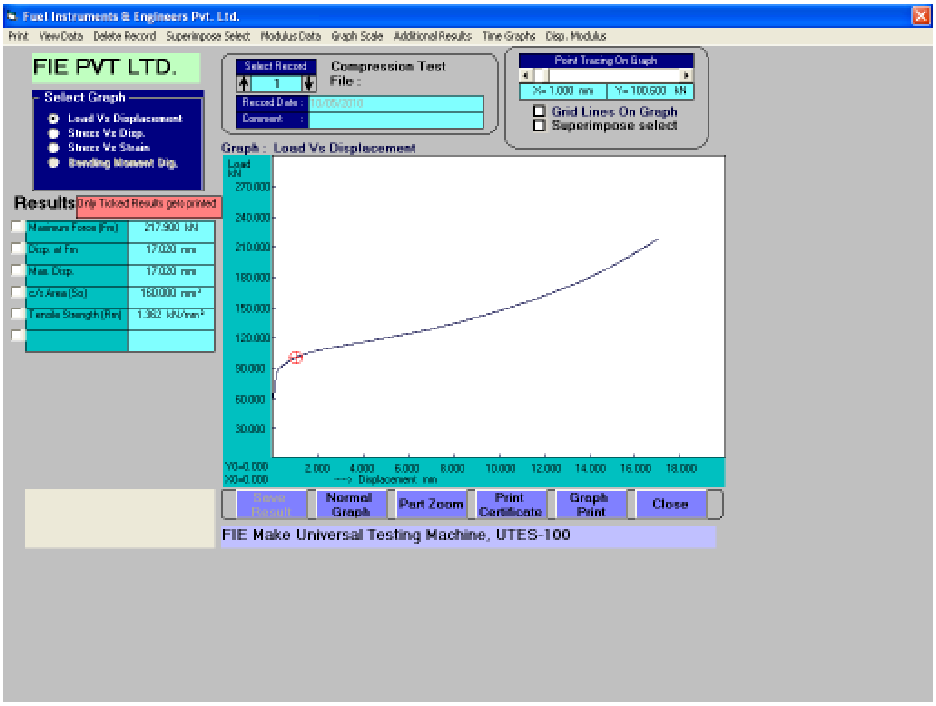
Compression Test
File : VAIBHAV-1(10-5-10)

Record Date : 10/05/2010
Comment :

X= 0.000 mm
Y= 54.400 kN

☐	Maximum Force (Fm)	177.850 kN
☐	Disp. at Fm	14.010 mm
☐	Max. Disp.	14.010 mm
☐	c/s Area(So)	160.000 mm²
☐	Tensile Strength(Rm)	1.110 kN/mm²
☐		

Fig 10: Load v/s Displacement: (Specimen 1: Reduction in Height: 40%)



● Load Vs Displacement

Select Record: 1

Compression Test

File :

Record Date : 10/05/2010

Comment :

X= 1.000 mm Y= 100.600 kN

☐ Grid Lines On Graph
☐ Superimpose select

Graph : Load Vs Displacement

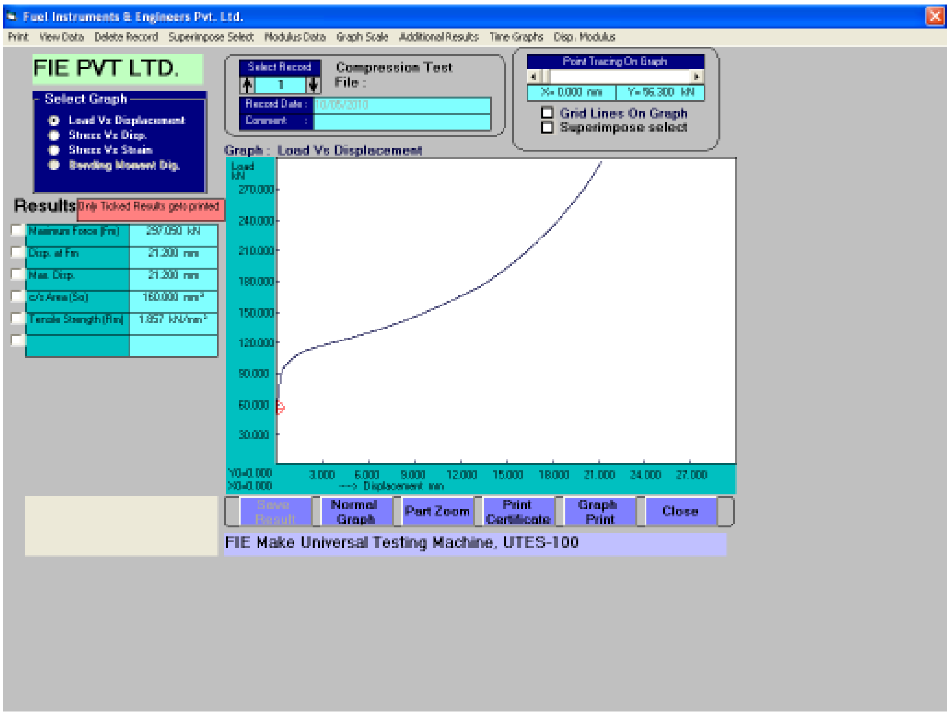
Y0=0.000
X0=0.000

Results Only Ticked Results gets printed

☐	Maximum Force (Fm)	217.900 kN
☐	Disp. at Fm	17.020 mm
☐	Max. Disp.	17.020 mm
☐	c/s Area (So)	160.000 mm²
☐	Tensile Strength (Rm)	1.362 kN/mm²
☐		

FIE Make Universal Testing Machine, UTES-100

Fig 11: Load v/s Displacement: (Specimen 2: Reduction in Height: 50%)



● Load Vs Displacement

Select Record: 1

Compression Test

File :

Record Date : 10/05/2010

Comment :

X= 0.000 mm Y= 56.300 kN

☐ Grid Lines On Graph
☐ Superimpose select

Graph : Load Vs Displacement

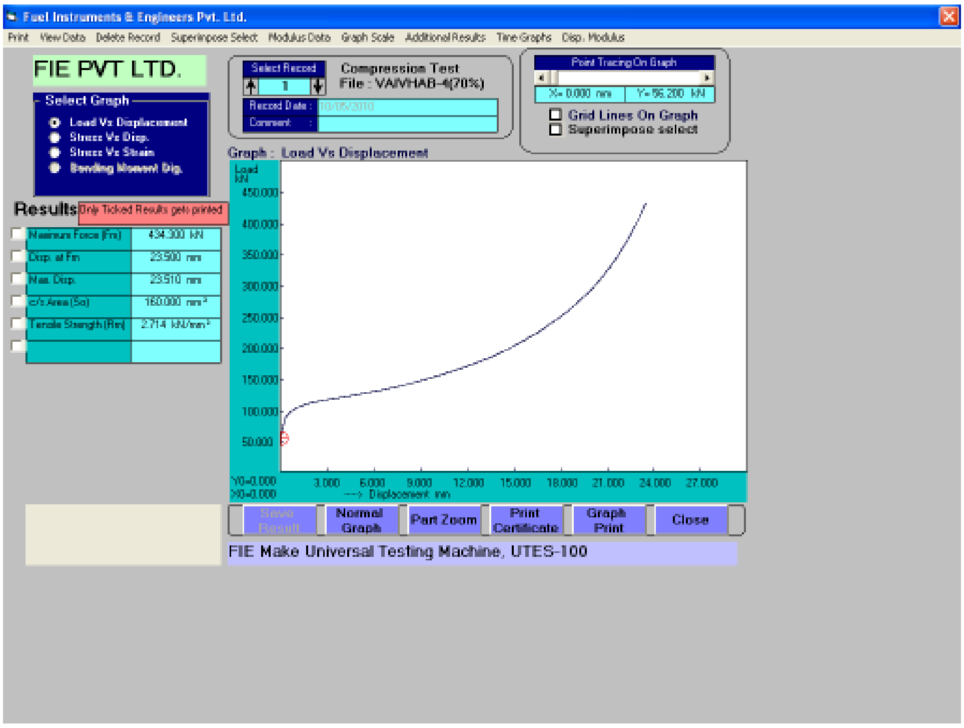
Y0=0.000
X0=0.000

Results Only Ticked Results gets printed

☐	Maximum Force (Fm)	297.050 kN
☐	Disp. at Fm	21.200 mm
☐	Max. Disp.	21.200 mm
☐	c/s Area (So)	160.000 mm²
☐	Tensile Strength (Rm)	1.857 kN/mm²
☐		

FIE Make Universal Testing Machine, UTES-100

Fig 12: Load v/s Displacement: (Specimen 3: Reduction in Height: 60%)



Select Record: 1

Compression Test
File : VAIVHAB-4(70%)

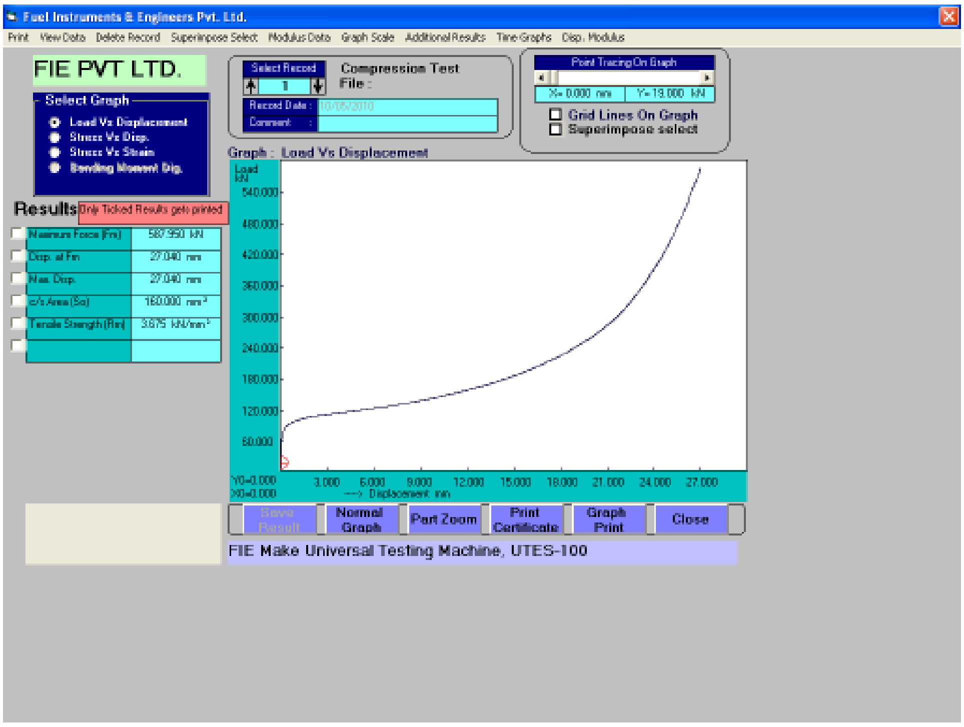
Record Date : 10/05/2010
Comment :

X= 0.000 mm | Y= 56.200 kN

Graph : Load Vs Displacement

☐	Maximum Force (Fm)	434.300 kN
☐	Disp. at Fm	23.500 mm
☐	Max. Disp.	23.510 mm
☐	c/s Area (So)	160.000 mm²
☐	Tensile Strength (Rm)	2.714 kN/mm²
☐		

Fig 13: Load v/s Displacement: (Specimen 4: Reduction in Height: 70%)



Select Record: 1

Compression Test
File :

Record Date : 10/05/2010
Comment :

X= 0.000 mm | Y= 19.000 kN

Graph : Load Vs Displacement

☐	Maximum Force (Fm)	587.950 kN
☐	Disp. at Fm	27.040 mm
☐	Max. Disp.	27.040 mm
☐	c/s Area (So)	160.000 mm²
☐	Tensile Strength (Rm)	3.675 kN/mm²
☐		

Fig 14: Load v/s Displacement: (Specimen 5: Reduction in Height: 80%)

4.4 CALCULATIONS:

After Compression Testing:

Table 2: Specimen Specifications

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
% reduction in Height during Compression Testing(in %)	40	50	60	70	80
New Height after compression (H_{new})(mm)	20.63	16.42	14.10	10.84	7.57
Initial Corner to Corner Distance ($D_{c\text{-}c}$)(mm)	24.08	24.12	24.17	24.24	24.11
New Corner to Corner Distance ($D_{c\text{-}c}$)(mm)	31.31	31.48	35.17	39.42	41.39
Average Bulging Diameter(D_{bg})(mm)	7.23	7.36	11.0	15.18	17.28
Min.Barrel diameter($D_{b,min}$)(mm)	31.31	31.48	35.17	39.42	41.39
Max.Barrel Diameter($D_{b,max}$)(mm)	31.84	32.92	38.12	42.90	46.14
Intermediate Barrel Diameter($D_{b,int}$)(mm)	31.57	32.08	36.21	40.73	43.46

BULGING & BARRELING PROFILE:

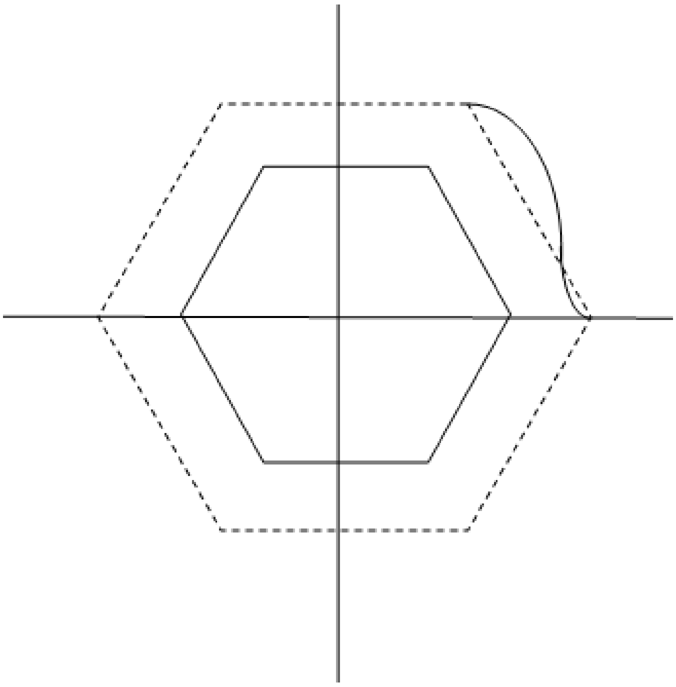


Fig 15: Bulging Profile

BULGING PROFILE

After Compressions of the Aluminium specimens it is observed that the presence of friction causes inhomogenity in the compression process and simultaneous phenomenon of Bulging and Barreling are observed. The Bulge profile of the specimen is as shown in the fig. above. As it can be seen the corners undergo bulging by a larger margin as compared to other points in the Hexagonal Cross Section. The linear Hexagonal edges are deformed to form a curve which hits Maxima approximately in the middle of the edges and also the corner faces. The friction at the faces greatly retards the plastic flow of metal at the surface and its vicinity. Hence the depression near the corners as shown is observed.

The average Bulging diameter is computed from the circumferential Bulging at the corners for each individual specimen. With a gradual increase in the percentage of height reduction it can be observed that there is also a consistent increase in the average Bulging dia. This can be attributed to the Volume Constancy Principle.

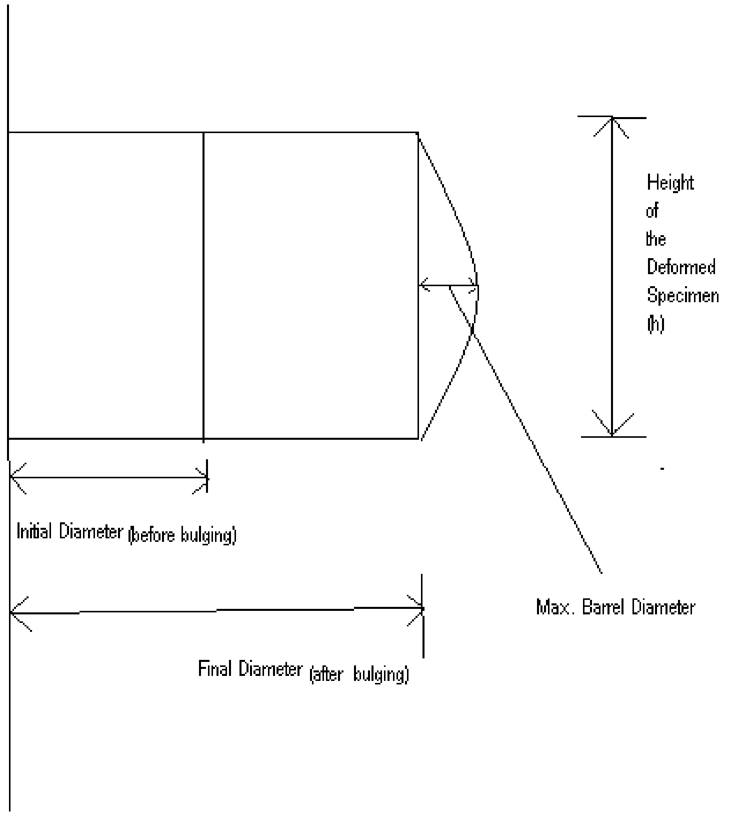


Fig 16: Barreling Profile

BARRELING PROFILE

Barreling is the phenomenon when the circumferential faces under compression get deformed to result in a barrel shaped profile with barrel diameter attending a maximum in the middle of the height of the deformed specimen. The barrel Profile observed in this particular case of Aluminium compression at room temperature bears a close resemblance to the one shown in the above fig.

After compression testing of the Aluminium specimen different coordinates along the barrel Profile are noted down namely those corresponding to maximum Barrel Diameter, Minimum Barrel Diameter as well as an Intermediate Barrel Diameter. Using the so-obtained data the polynomial equation for the each individual specimen is predicted and then the equations thus obtained are utilized to generate a generalized equation for directly determining the barreling curve from given inputs of % reduction and the height of the deformed specimen.

DEFORMED SPECIMEN

Specimen 1(40% ht. Reduction)(Fig.17)

Specimen 2(50% ht. Reduction) (Fig.18)

Specimen 3(60% ht. Reduction) (Fig.19)

Specimen 4(70% ht. Reduction) (Fig.20)

Specimen 5(80% ht. Reduction) (Fig.21)

BARRELING CURVE:

From the Barreling profile obtained after compressive deformation the Barreling Curve equations is given by:

$$X = Ah^2 + Bh + C$$

Where A, B, C are constants

X= Barreling Diameter corresponding to a height h

H= Height of the deformed specimen where the Barreling Diameter is to be Measured.

The readings obtained after compression testing of the Barreled Aluminium specimen are then utilized to generate a curve and then the equation of this particular curve is used to generate a generalized Barreling curve depending upon the % reduction and Height of the deformed specimen.

The points under considerations are the points of Max. Barrel Diameter, Min. Barrel Diameter and an Intermediate Barrel Diameter

Considering the centre of the deformed specimen as the origins the coordinates of these points are specified as

Specimen 1:

$A_1(31.31,0)$,$B_1(31.57,5.25)$,$C_1(31.84,10.5)$,$D_1(31.57,15.75)$,$E_1(31.31,21)$

Making a plot of these points and subsequently generating a Barreling equation we have

$$\mathbf{X = -1.411h^2 + 108.9h - 2027, \text{ for } h <= 10.5}$$

$$\mathbf{X = 1.411h^2 - 108.9h + 2027, \text{ for } 10.5 < h <= 21.0}$$

Specimen 2:

$A_2(31.48,0)$,$B_2(32.08,4.2)$,$C_2(32.92,8.4)$,$D_2(32.08,12.6)$,$E_2(31.48,16.8)$

Making a plot of these points and subsequently generating a Barreling equation we have

$$\mathbf{X = -1.388h^2 + 95.27 - 1623, \text{ for } h <= 8.4}$$

$$\mathbf{X = 1.388h^2 - 95.27h + 1623, \text{ for } 8.4 < h <= 16.8}$$

Specimen 3:

A_3(35.17,0),B_3(36.21,2.88),C_3(38.12,5.76),D_3(35.17,8.64),E_3(36.21.11.52)

Making a plot of these points and subsequently generating a Barreling equation we have

$X= -0.427h^2 + 33.29h – 641.9$, for $h<=5.76$

$X= 0.427h^2 – 33.29h +641.9$, for $5.76<h<11.52$

Specimen 4:

A_4(39.42,0),B_4(40.73,2.94),C_4(42.9,5.88),D_4(40.73,8.82),E_4(39.42,11.76)

Making a plot of these points and subsequently generating a Barreling equation we have

$X= -0.255h^2 + 22.72h – 498.8$, for $h<=5.88$

$X= 0.255h^2 – 22.72h + 498.8$, for $5.88<h<11.76$

Specimen 5:

A_5(41.39,0),B_5(43.46,2.14),C_5(46.14,4.28),D_5(43.46,6.42),E_5(41.39,8.56)

Making a plot of these points and subsequently generating a Barreling equation we have

$X= -0.049h^2 + 5.237h – 131.9$, for $h<=4.28$

$X= 0.049h^2 – 5.237h + 131.9$, for $4.28<h<8.556$

Using all those above obtained equations a generalized equation is proposed as:

$X= -1.446h^2r^{-0.074} + 6.284E+01hr^{-0.6} -818.26\ r^{-0.99}$, for $0<=h<=H/2$

$X= 1.446h^2r^{-0.074} - 6.284E+01hr^{-0.6} +818.26\ r^{-0.99}$, for $H/2<=h<=H$

Where,

X=Barreling Diameter

h= height of the deformed specimen where Barreling Diameter is to be measured

r=% reduction in Barreling Height

H= total height of the deformed specimen

CHAPTER 5

CONCLUSION

CONCLUSION:

After conducting compression testing of Aluminium Billets (of Hexagonal Cross-Section) under constant conditions of friction (friction factor m=0.35) and at room temperature with an uniaxial loading in UTM it has been concluded that:

1. With an increase in the percentage of height reduced the Compressive load required shows an increasing trend with a rapid increase toward the end of compression.
2. The Bulging and Barreling Diameter of the Specimen does not only depend on the Height of the deformed specimen but also on the percentage reduction.
3. The Barreling Diameter of an Aluminium specimen under conditions of room temperature and constant friction (m=0.35) is proposed as:

$$\mathbf{X= -1.446h^{2}r^{-0.074} + 6.284E{+}01hr^{-0.6} -818.26\, r^{-0.99}, \text{ for } 0<=h<=H/2}$$

$$\mathbf{X= 1.446h^{2}r^{-0.074} - 6.284E{+}01hr^{-0.6} +818.26\, r^{-0.99}, \text{ for } H/2<=h<=H}$$

Where,

X=Barreling Diameter

h= height of the deformed specimen where Barreling Diameter is to be measured

r=% reduction in Barreling Height

H= total height of the deformed specimen

CHAPTER 6

REFERENCES

REFERENCES

[1]. Johnson W, Mellor PB (1975) Engineering plasticity. Van Nostrand, London, ch 6, pp 110–114

[2]. Shaw C, Avery JP (1980) Forming limits – reliability, stress analysis and failure prevention methods in mechanical design. Century, Chicago, IL, ASME, pp 297–303

[3]. Kulkarni M, Kalpakjian S (1969) A study of barreling as an example of free deformation. ASME J Eng Ind 91:743–754

[4]. Schey A, Venner TR, Takomana SL (1982) Shape changes in the upsetting of slender cylinders. ASME J Eng Ind 104:79–83

[5]. Sowerby R, O'Reilly I, Chandrasekaran N, Dung NL (1984) Materials testing for cold forging. ASME J Eng Mater Tech 106:101–106

[6]. Banerjee Barreling of solid cylinders under axial compression. ASME J Eng Mater Tech 107:138–144 48

[7]. Narayanasamy, Murthy RSN, Viswanatham K, Chary GR, Prediction of the barreling of solid cylinders under axial compressive load. J Mech Work Tech 16:21–30

[8]. Yang Y, Choi Y, Kim JH (1991) Analysis of upset forging of cylindrical billets considering the dissimilar frictional conditions at two flat die surfaces. Int J Mach Tools Manuf 31:397–404

[9]. Gokler MI, Darendeliler H, Elmaskay NE (1999) Analysis of tapered preforms in cold upsetting. Int J Mach Tools Manuf 39:1–16

[10]. Chen, Chen CJ (2000) On the non uniform deformation of the cylinder compression test. J Eng Mater Tech Trans ASME 122:192–197

[11]. Narayanasamy R, Pandey KS (1997) Phenomenon of barreling in Al solid cylinders during cold upset-forging. J Mater Proc Tech 70: 17–27

[12]. Malayappan S, Narayanasamy R (2003) Some aspects of barreling in aluminium solid cylinders during cold upset forging using die with a constraint. J Mater Process Technol 135:18–29

[13]. Malayappan S, Narayanasamy R (2003) Barreling of aluminium solid cylinders during cold upset forging with constraint at one end. J Mater Sci Technol 19:507–511

[14]. Malayappan S, Narayanasamy R (2004) An experimental analysis of upset forging of aluminium cylindrical billets considering the dissimilar frictional conditions at flat die surfaces. Int J Adv Manuf Sci Technol, vol 23, pp636–643

[15]. Malayappan S, Narayanasamy R (in press) Effect of barrelling of aluminium solid cylinders by introducing an extrusion die at one end of the specimen. J Mater Des, available online

[16]. Malayappan S, R.Narayanasamy R (in press) Barrelling of aluminium solid cylinders by introducing die constraints at both ends of the specimen. J Mater Des, available online

[17]. Malayappan S, Narayanasamy R (2003) Observations of barrelling in aluminium solid cylinders during cold upsetting using different lubricants. J Mater Sci Technol 19:1705–1708