COMPRESSION TEST OF ALUMINIUM ALLOY AT DIFFERENT STRAIN RATE

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By

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CERTIFICATE

This is to certify that thesis entitled, "COMPRESSION TEST OF ALUMINIUM ALLOY AT DIFFERENT STRAIN RATE" submitted by RAHUL RAJ in partial fulfilment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology Rourkela is an authentic work carried out by him under my Supervision and guidance. To the best of my knowledge, the matter included in this thesis has not been submitted to any other university or institute for award of any Degree.

Date: 10th may, 2013

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ABSTRACT

Compression test of aluminium alloy at different strain rate were experiments carried out on a universal testing machine at room temperature and under a different strain rate ranging from 0.01/s to 0.15/s using powdered graphite mixed with machine oil as lubricant all over the tests. True Stress and strain values were calculated using the engineering equation which was used to plot the true stress-strain curve for different strain rate, which indicates the mechanical properties of the metal for industrial applications.

Keywords: Compression, True Stress, True Strain, Regression Analysis

CONTENT

Chapter 4

Chapter 5

Chapter 1 Introduction

1. INTRODUCTION

1.1 Compression Test

A compression test determines the characteristics of materials under crushing loads. The sample is compressed and deformation at various loads is noted. Compressive stress and strain was calculated and plotted as a stress-strain diagram which is used to determine elastic limit, proportional limit, yield strength and yield point. Compression Tests are of extremely high importance, because it helps to calculate the different material properties that are applicable to hot as well as cold metal forging employed for different metal forming applications. It becomes important to find the suitable load to carry out the operations. Load depends on the materials and flow stress. Flow behaviour of aluminium at different strain rate can be determined by establishing a relationship between flow stress, strain and strain rate. When a compressive load is applied on a specimen, the deformation may take place: for brittle materials it may be crushing or fracture and for ductile material it may be due to elastic or plastic.

1.2 Effect of Different Parameters on Compression

Effect of strain rate

The rate at which strain is applied to a specimen can have an important influence on the flow stress. Strain rate is defined as:

$$\text{strain rate} = \frac{\partial \varepsilon}{\partial t}$$

It is expressed in units of /sec. normally, increasing strain rate increases flow stress.

1.3 Material

Aluminium is a chemical element in the boron group with symbol Al and atomic number is 13. It is silvery white, and it is not soluble in water. After oxygen and silicon, aluminium is the third most abundant element in the Earth's crust. Aluminium has a unique combination of attractive properties. high strength, Low weight, great malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium’s most significant properties. Aluminium is also very easy to recycle. The chief ore of aluminium is bauxite. It is nonmagnetic and does not easily ignite. Commercial purity of aluminium is 99.5 to 99.79%, but pure aluminium is too soft to be of structural value. The primary reason for alloying aluminium is to increase strength without increasing weight and reasons are to improve weldability, machinability, surface appearance and corrosion, resistance. The main alloying elements are magnesium, manganese, copper, silicon and zinc.

Different Properties of Aluminium

Aluminium is unique and unbeatable combination of properties making its use versatile. It is highly usable and attractive construction material.

Weight: Al is the light material compare to other material like steel. Its Density is 2.700 kg/m3

Strength: Aluminium is strong with the tensile strength 70 to 700 MPa. Its strength depends on the alloying materials and manufacture process.
Linear expansion: Aluminium has a relatively large coefficient of linear expansion.
Elasticity: The Young’s modulus of Al is one-third of steel (E = 70,000 MPa).
Formability: Aluminium has a good formability. With the hot metal or cold metal this property is exploited in the rolling of strips and foils.
Machinability: Aluminium is very simple to machine. Aluminium is suitable for forming in both hot and cold process.
Joining: Aluminium can be joined applying all the methods available as the welding, soldering, adhesive bonding and riveting.
Reflectivity: Aluminium is a best reflector of both visible light and heat.

Corrosion resistance: Aluminium generates a protective oxide coating and is highly corrosion resistant. It is useful for application where protection and conservation are required.

Conductivity: Al is an excellent conductor of heat and electricity. Al conductor is only half the weight of an equivalent Cu conductor.

Non-toxic: Aluminium is not poisonous; that's why it is highly suitable for the preparing and storage of the meal.

Non-magnetic material: Aluminium is a non-magnetic material. Al is used in magnet X-ray devices to avoid the interference of magnetic fields.

Different Applications of Aluminium:-

Aluminium alloy are wide range of application. Followings application are some of them.

I. In aircraft and other aerospace structure
II. for boat and shipbuilding, and other marine and salt-water sensitive shore applications
III. for cycling frames and components
IV. for automotive body panels
V. As packaging materials.
VI. In making household components etc.

CHAPTER 2

LITERATURE SURVEY

Literature Survey

Because of many use of aluminium in electrical conductors, air conditioning units, optical and light reflectors the strain rate behaviour of aluminium is need to know. Out of them some important literatures are discussed here:

At small strain rate the true stress–true strain curves exhibit a peak stress after that the flow stresses decrease monotonically until high strains. The stress decreases with increasing deformation temperature and decreasing strain rate [1].

The deformed structures demonstrate elongated grains with serrations developed in the grain boundaries dynamic recovery and recrystallization are the main reasons for the flow softening [2].

Investigation showed that when the peak stress level increased then strain rate decrease. The geometrical dynamic recrystallization Occurred at temperatures below 520℃ [3].

The stress level decreases with increasing temperature and decreasing strain rate, which can be represented by the Zener–Hollomon parameter Z in the hyperbolic sine equation [4].

The homogenized aluminium alloy when temperature increased or the strain rate decreased. The main softening mechanism of 7050 aluminum alloy is dynamic recovery [5].

The strain has shown an effect on the material constants, and true stress–true strain curves have showed that the flow stress was sensitive to the deformation strain rate and temperature for the 7050 aluminium alloy [6].

The flow stress increases with increasing the strain rate or decreasing the deformation temperature, which can be described by a hyperbolic-sine constitutive equation [7].

When the z value decrease the main softening mechanism of the al alloy transforms from dynamic recovery to dynamic recrystallization. And the subgrain size increase and the dislocation density decrease [8].

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CHAPTER-3
Experimental Details

Experiment details

3.1 Experimental Setup

The experiments were carried out in the universal testing machine of INSTRON SATEC 600 KN. 600 KN Models of INSTRON are ideal for high capacity tension, compression, flex and shear testing. This design offers the ultimate versatility by accommodating a large variety of specimen sizes, grips, fixtures and extensometers. These models feature an ultra large, single test space and so user friendly (easily and safely) load and unload specimens. Models include**:** 300KN, and 600KN, 1200KN, 1500KN, 2000KN and 3500K

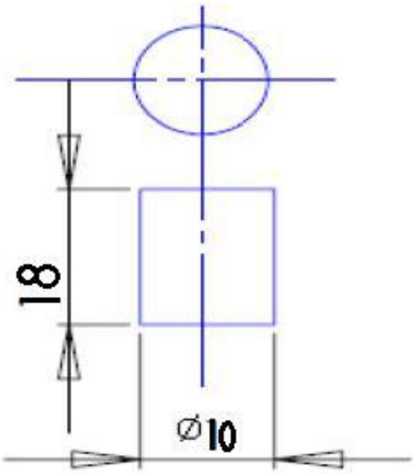
Table 3.2 Specifications of INSTRON SATEC 600 KN

maker	Instron,UK
Software	Bluehill EM Console
type	hydraulic
Max. Loading capacity	600 KN
Max. Vertical test opening	1625 mm
Actuator stroke	508 mm
Load accuracy	±0.5% of reading down to 1/500 of Load cell capacity
Strain accuracy	±0.5 of reading down to 1/50 of Full range

Figure 3.1 INSTRON SATEC

Figure 3.2 temperature controller

3.3 Preparation of sample



Compression Test to be conducted requires the testing of 15 Specimens prepared from the raw aluminium rod.

Specimen Specifications:

L/Deff ≈ 1.6 for to assure a geometrical dimensional factor and homogeneous deformation

L = Length of the Specimen

Deff = Effective Diameter of the Cross Section of the Specimen

Hence if Deff =10 mm, L should be approximately 15 mm

In the current experiment, L has been taken as 18 mm

Specimens of the required dimensions were cut from the aluminium

Alloy bar using hacksaw and facing operation was carried out to

Make the two ends parallel by the lathe machine.

3.4 Graphite use as a lubricant:

Graphite powder and machine oil in a proper ratio were mixed properly to form the lubricant for the test. Graphite is one of the allotropes of carbon. Graphite has one carbon atom covalently bonded to three other carbon atoms, forming a hexagonal molecular structure with layers held by weak Van der Waal forces. As the Van der Waals forces between the layers are less strong, the layers can easily slide over each other.. Thus, it can be used as a lubricant. The distance of carbon atoms between planes is longer and therefore the bonding is weaker. Graphite is best for lubrication in a regular atmosphere. Graphite mainly classified into two main categories that is natural and synthetic. Natural Graphite is a generally mineral consisting of graphitic carbon. Natural graphite is an excellent conductor of heat and electricity. It is stable for a wide range of temperatures. Synthetic graphite can be produced from coke and pitch. Graphite as a lubricant is used as dry powder or mixed with water or oil. When mixed with water, it is called 'aqua-dag' and when mixed with oil, it is called 'oil dag'.

Graphite lubrication is taken so that the specimen does not get forged to the anvil and ram at high temperature.

3.5 Description

After applying graphite lubricant coating on both the sides of the specimens, they are placed in between the top and bottom plate of the setup such that the axis of the specimen is concentric with the axis of the ram. Then the hydraulic load is applied on the test specimen and test is carried out at room temperature. For each test, one specimen was taken and deformed to different strain rates. The loads used during each deformation were recorded automatically by the BLUEHILL software incorporated with the UTM machine. Compressive test was carried out by giving a deformation of 10 mm, at fifteen strain rate from 0.01/s to 0.15/s. At the end of each experiment time taken (sec), compressive extension (mm), compressive load (N), compressive stress (Pa), compressive strain (%), true stress (Pa) and true strain (%) were recorded automatically in the database of the computer(system), which was further used by the software to generate True stress vs. True strain graph.

Chapter 4

Results and Discussions

4.1 Result and Discussion

True stress and true strain curves obtained during compression of aluminium alloy at a strain rate of 0.01 to 0.15/s. The peak stress and flow stress increase with increasing strain rate. If the true stress based on the actual cross-sectional area of the specimen is used, it is found that stress-strain curve increases continuously until plastic deformation occurs. If the strain measurement is also based on instantaneous measurement, the curve is called true stress-strain curve. Many attempts have been made to fit mathematical equations to this curve. The most common is a power expression of in the form

$$\sigma = A \times \in^{n}$$

Where, σ = true stress, A is strength coefficient, n is the strain hardening exponent.

BLUEHILL software incorporated with the UTM machine automatically generates the flow curve for each specimen instantaneously after the experiment using the true stress and true strain data saved in computer's database. It uses the engineering equation to generate the flow curves.

Flow curve

- For strain rate 0.01/s

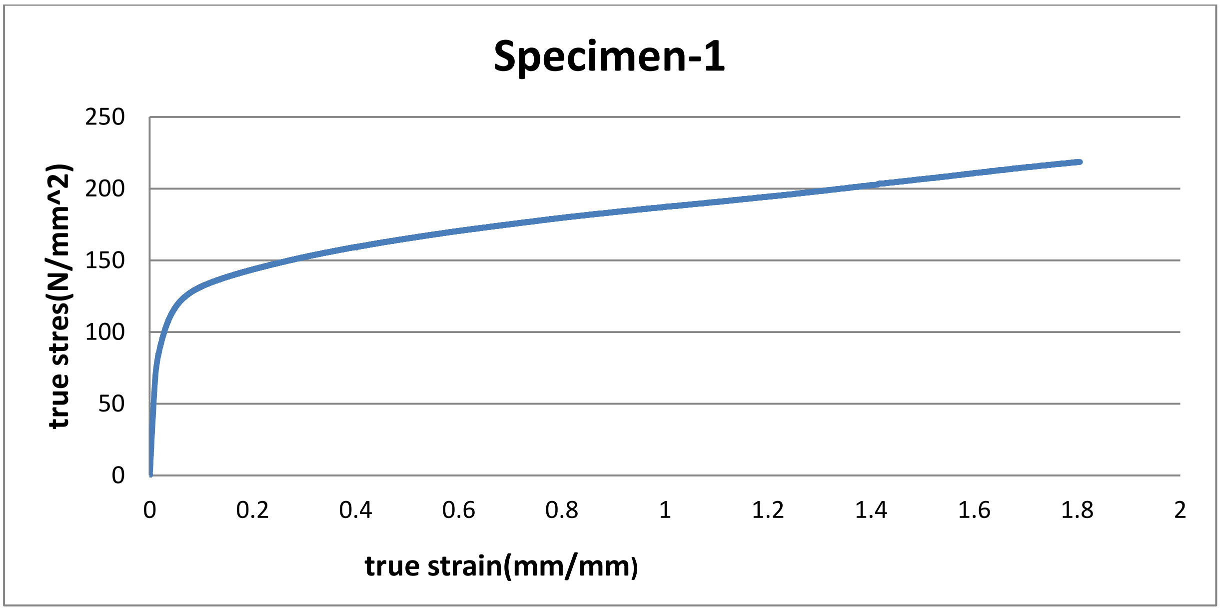


Figure 4.1 Variation of true stress with true strain at 0.01 strain rate

- <u>For strain rate 0.02/s</u>

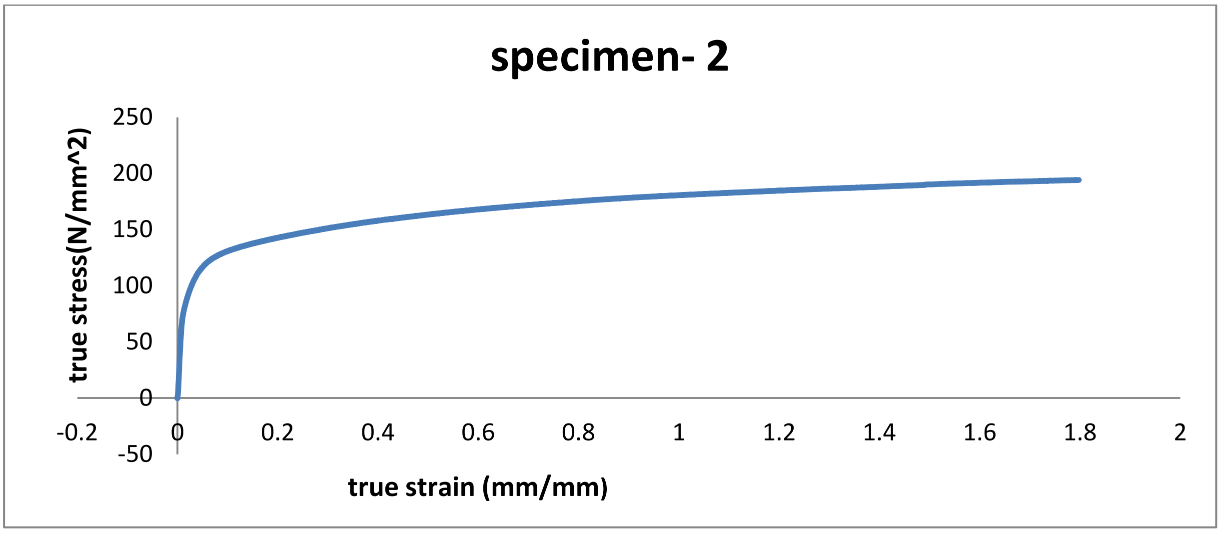


Figure 4.2 Variation of true stress with true strain at 0.02 strain rate

- <u>For strain rate 0.03/s</u>

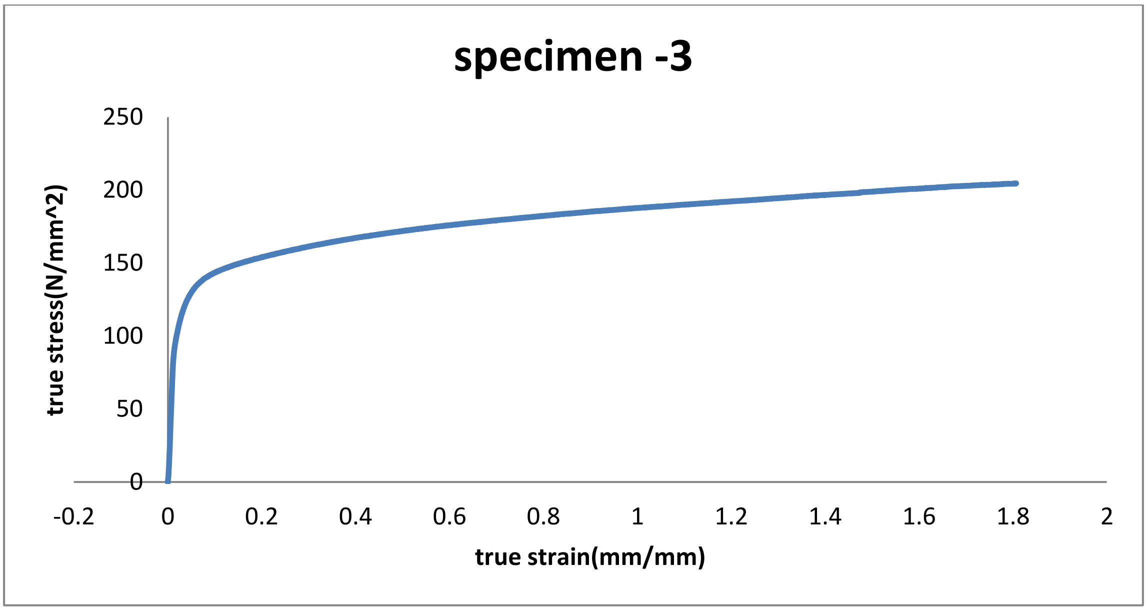


Figure 4.3 Variation of true stress with true strain at 0.03 strain rate

- For strain rate 0.04/s

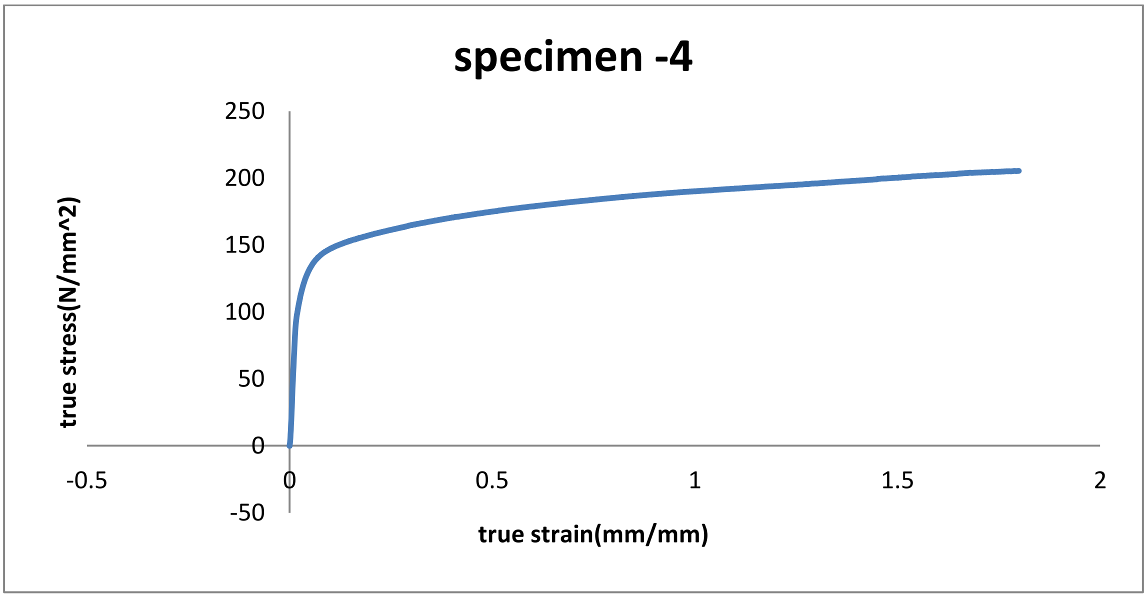


Figure 4.4 Variation of true stress with true strain at 0.04 strain rate

- For strain rate 0.05/s

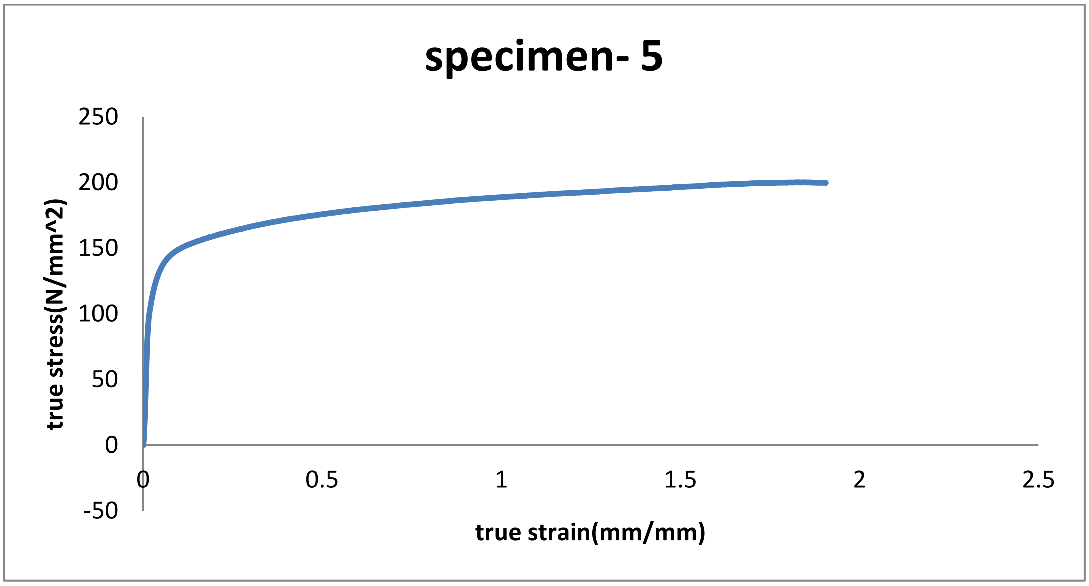


Figure 4.5 Variation of true stress with true strain at 0.05 strain rate

- <u>For strain rate 0.06/s</u>

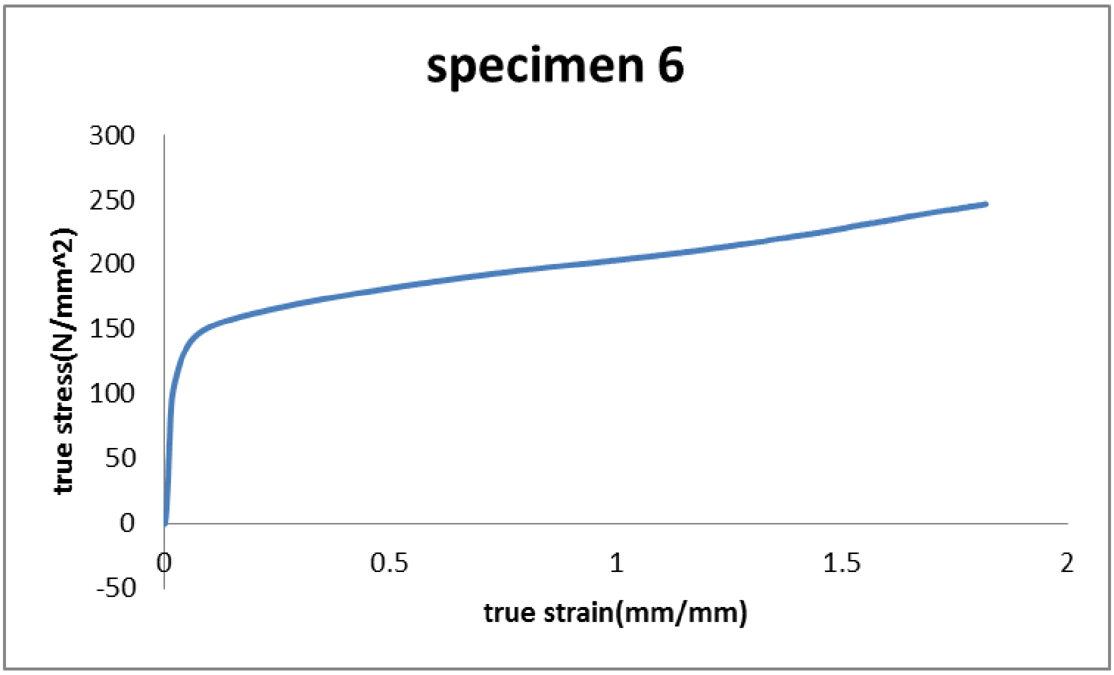


Figure 4.6 Variation of true stress with true strain at 0.06 strain rate

- <u>For strain rate 0.07/s</u>

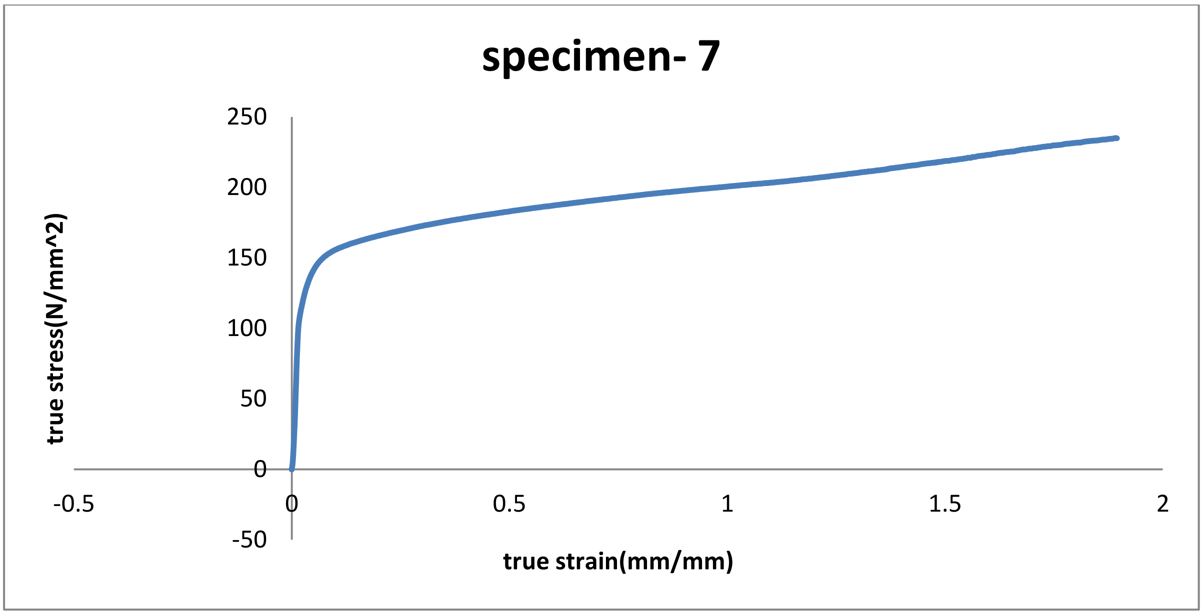


Figure 4.7 Variation of true stress with true strain at 0.07 strain rate

- <u>For strain rate 0.08/s</u>

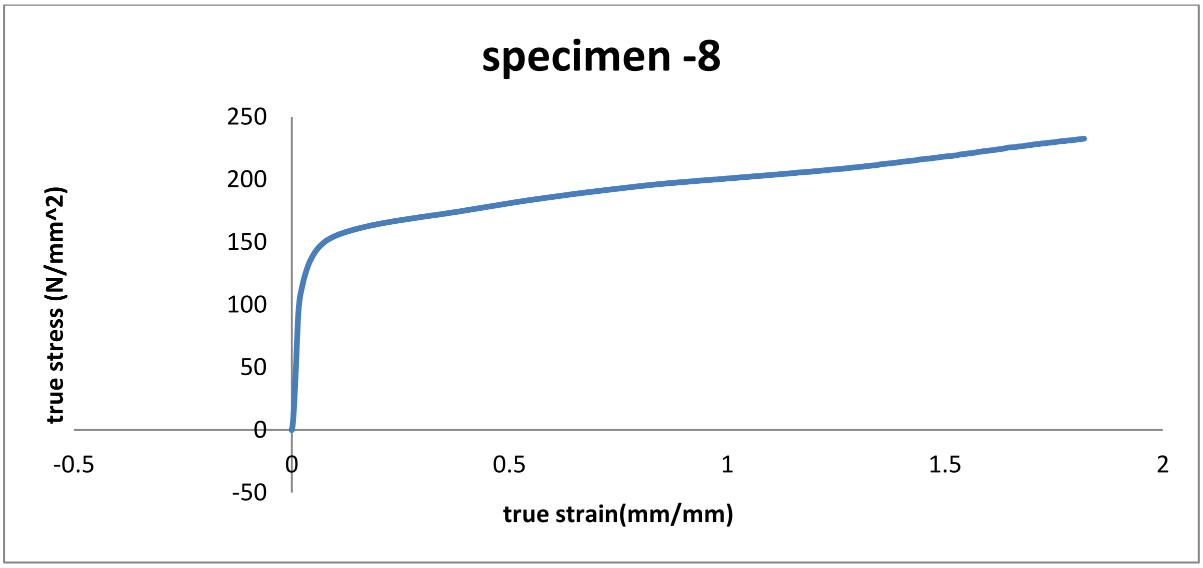


Figure 4.8 Variation of true stress with true strain at 0.08 strain rate

- <u>For strain rate 0.09/s</u>

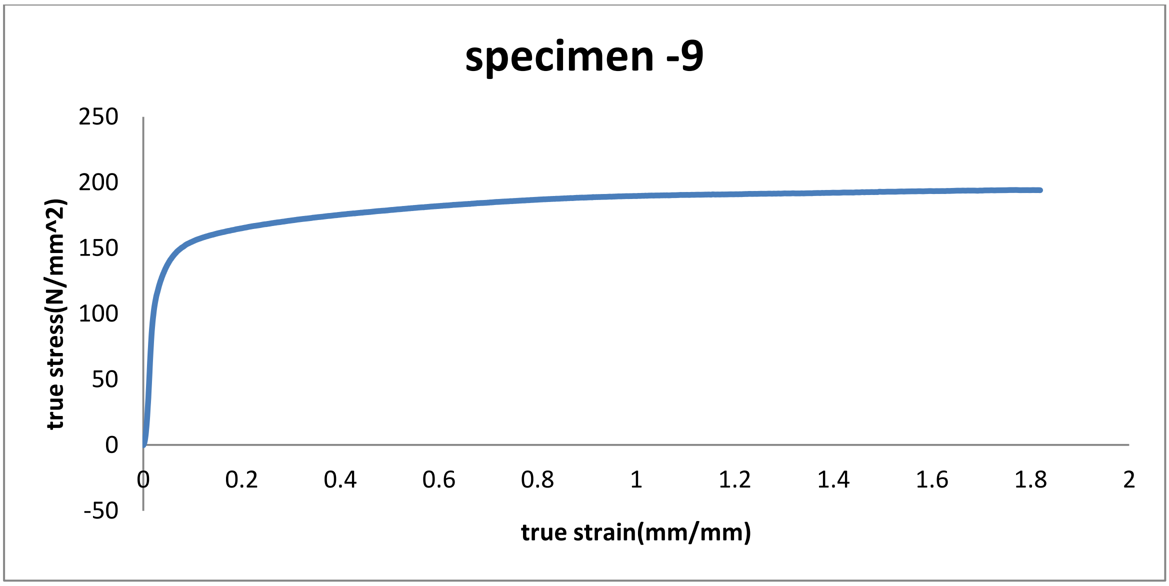


Figure 4.9 Variation of true stress with true strain at 0.09 strain rate

- For strain rate 0.10/s

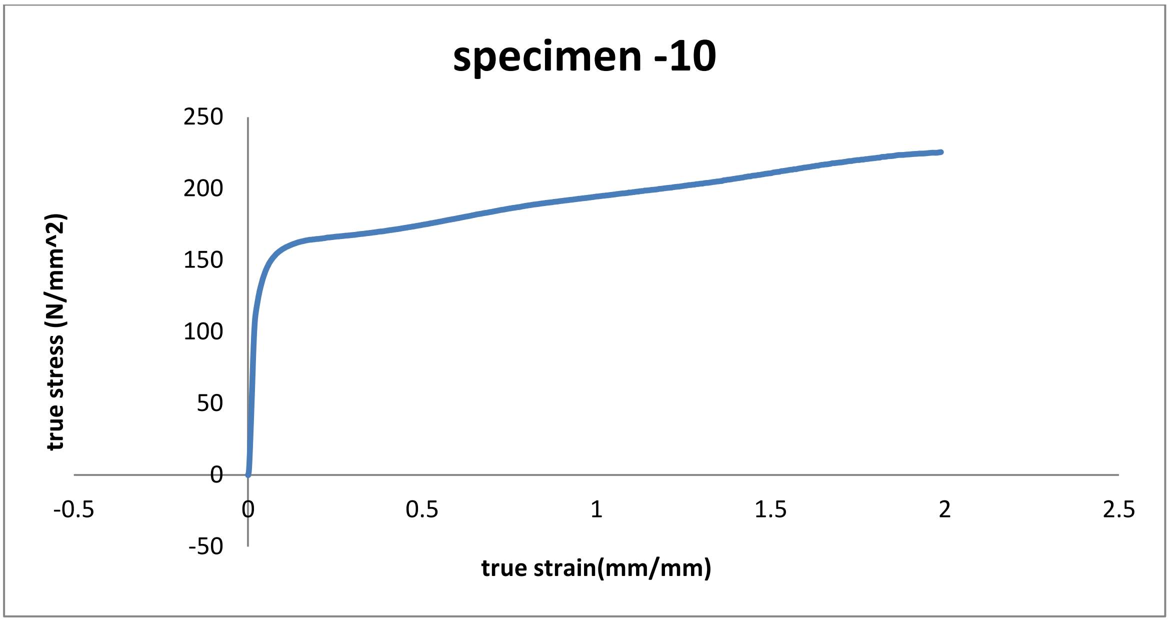


Figure 4.10 Variation of true stress with true strain at 0.10 strain rate

- <u>For strain rate 0.11/s</u>

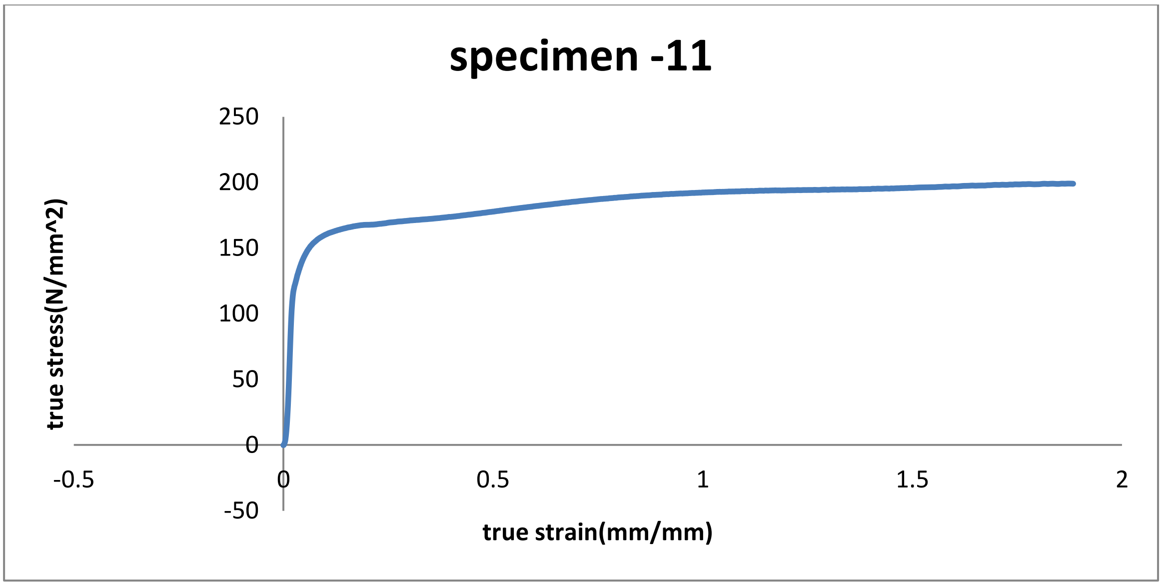


Figure 4.11 Variation of true stress with true strain at 0.11 strain rate

- <u>For strain rate 0.12/s</u>

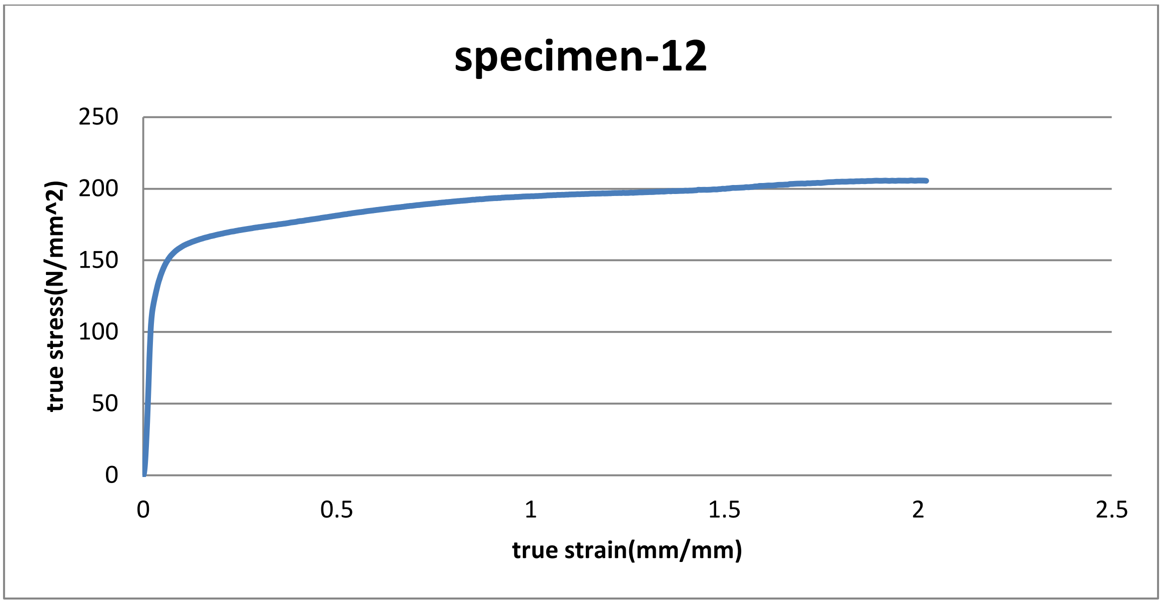


Figure 4.12 Variation of true stress with true strain at 0.12 strain rate

- <u>For strain rate 0.13/s</u>

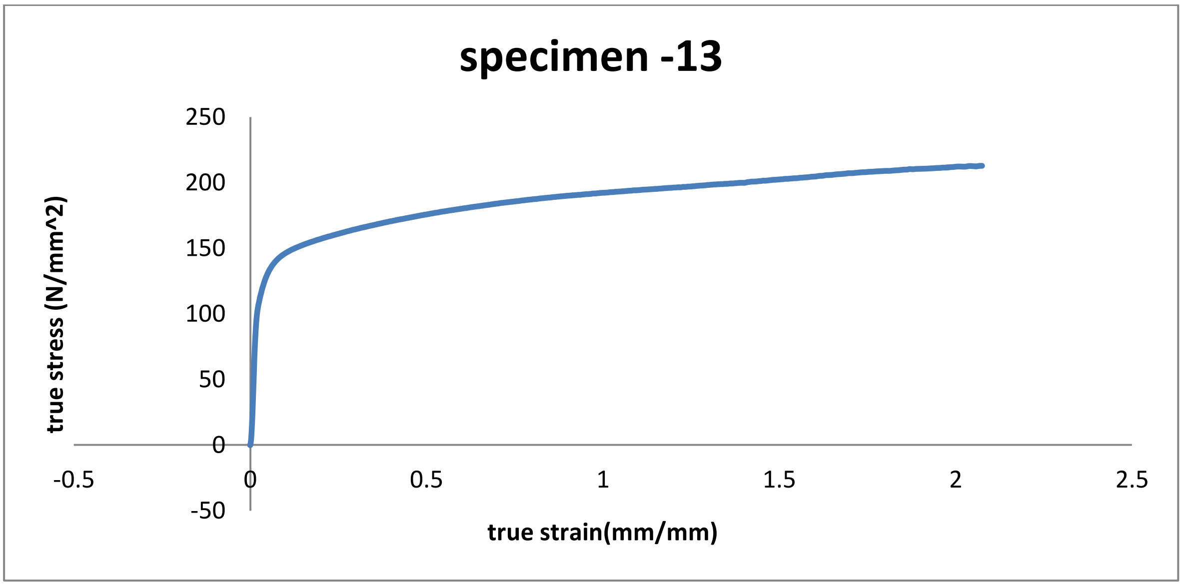


Figure 4.13 Variation of true stress with true strain at 0.13 strain rate

- <u>For strain rate 0.14/s</u>

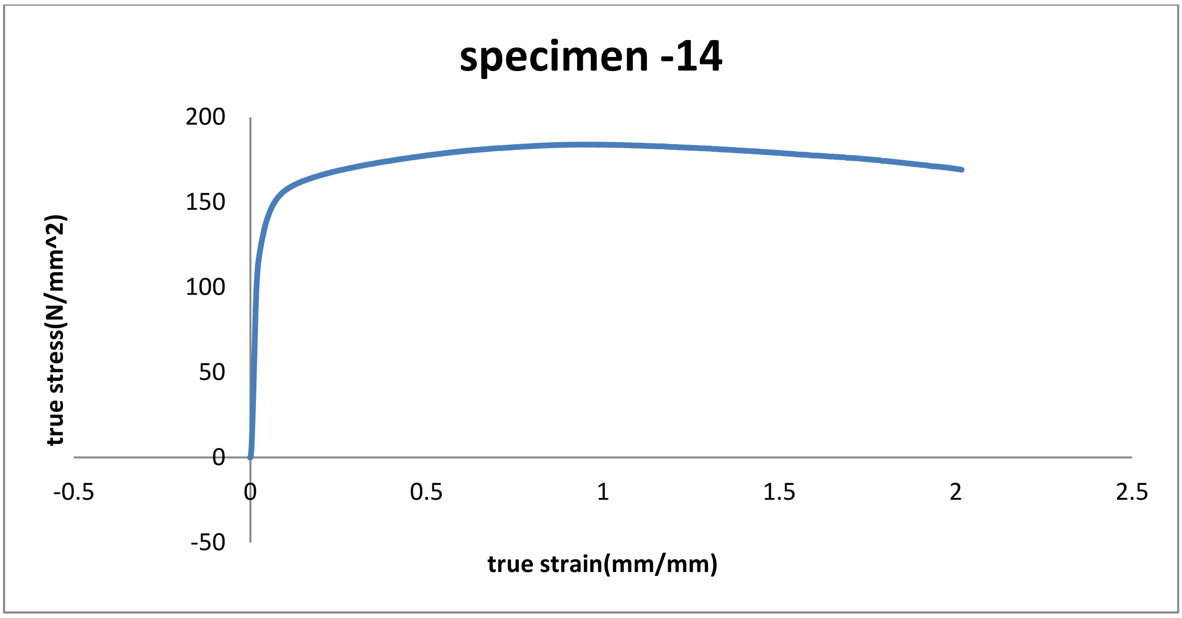


Figure 4.14 Variation of true stress with true strain at 0.14 strain rate

- <u>For strain rate 0.15/s</u>

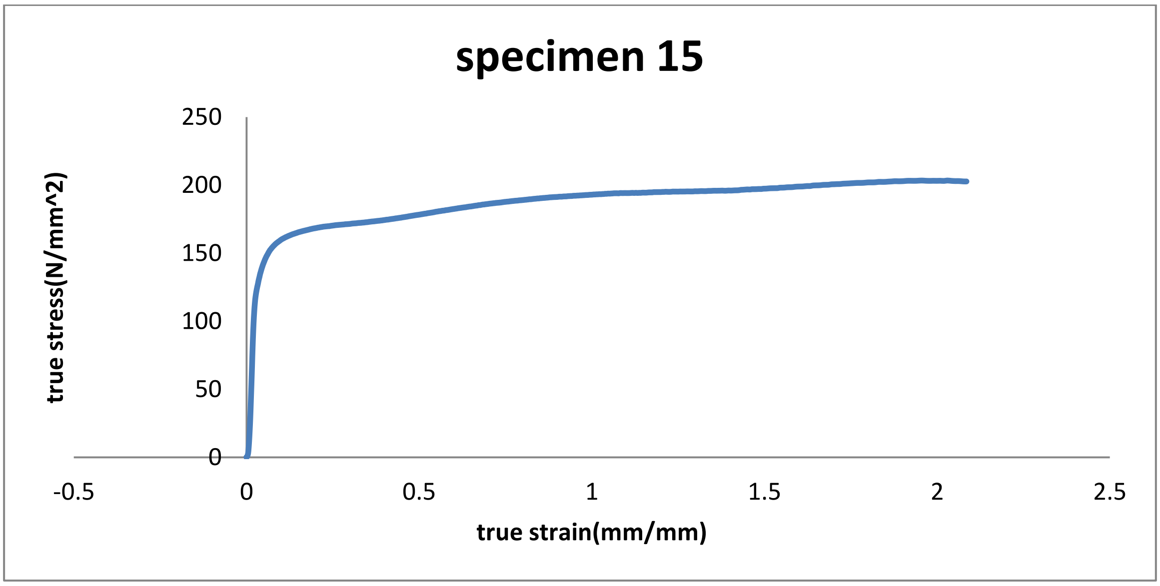


Figure 4.15 Variation of true stress with true strain at 0.15 strain rate

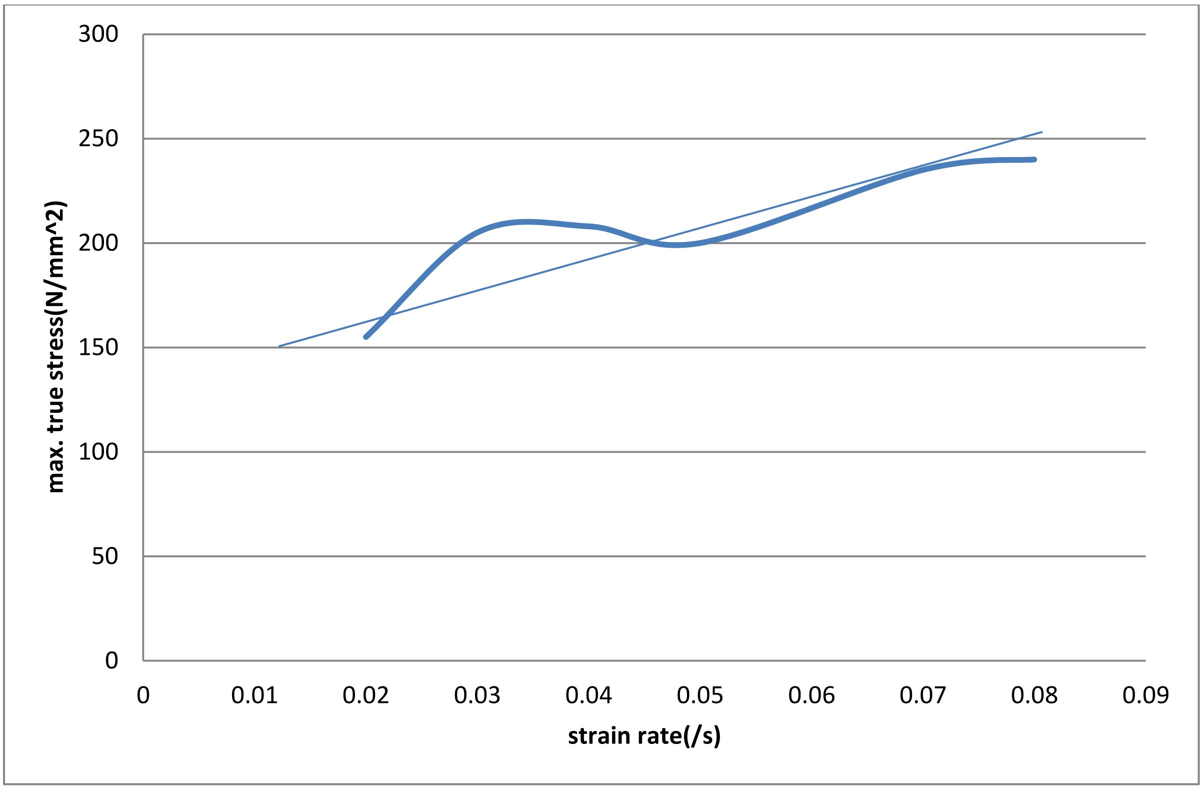
4.2 Linear regression analysis

Regression analysis is used for modelling and analysing variables, which demonstrate mathematical relationship between a dependent variable and one or more independent variables. A large no of techniques have been developed for carrying out regression analysis. Out of all those, linear regression and least squares regression are more commonly used. Least squares problems fall into two categories: linear least squares and non-linear least squares. The main difference between these two is linear least square has a closed-form solution whereas the nonlinear has no closed-form solution.

The purpose of using Regression Analysis is to produce a mathematical relationship between true stress and true strain, which will define the flow stress behaviour of the material. The most common is a power expression of the form

$$\sigma = m\dot{\epsilon} + \mathrm{C}$$

This equation represents the straight line y= mx+c, which can be used to find the maximum stress at different value of strain rate.



Graph should be linear but due to less accuracy graph is nonlinear.

$$\sigma = m\dot{\epsilon} + C$$

$$150 = m(0.011) + c$$

$$200 = m(0.047) + c$$

After solving equation

$$m = 1388.9$$

$$n = 134.2$$

Chapter-5
Conclusion

Following conclusions were obtained from results:

- True stress decreases with decreasing true strain.
- Strain hardening component depends on the stress and strain
- Increase of stress with strain rate can be represented by the linear equation $\sigma=1388.9\,\dot{\epsilon}+134.2$ for the present aluminium material.
- The increase of stress with strain rate is found to be erratic. It may be due to the experimental error.

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