

Impact Of Strain Rate On Mechanical Properties Of Metallic Sheets At Various Temperatures

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ABSTRACT: It is known that in warm and hot forming processes, the forming speed and with-it combined strain rate has immense role on material flow in bulk and sheet metal operations. In contrast, the influence of the strain rate on the flow curve has been rarely analysed at room temperature. This work analyses the influence of strain rate on flow curve of bimetallic sheets, Copper and Aluminium metals. Evaluation of the flow curve is carried out as a function of strain rate. In this work three different strain rates are considered for three different materials viz bimetallic sheets(Cu-Al), Copper and Aluminium. In addition to this ,the evaluation of flow curve at elevated temperatures is carried out. The Variation of mechanical properties with strain rate are plotted and analysed.

Keywords: strain rate , bimetallic strip ,Flow curve.

1 Introduction :

Often materials are subjected to external force when they are used. Mechanical Engineers calculate these forces and material scientists investigate how materials deform or break as a function of force, time, temperature, and other conditions. Materials scientists learn about these mechanical properties by testing various materials and evaluating the mechanical properties like Brittleness, Creep, Ductility, Elasticity, Fatigue, Hardness, Malleability, Stiffness, Yield strength. Heating the metal will displace atoms from their position and the displaced atoms form a new structure.

The earliest surviving bimetallic strip was made by the eighteenth-century clockmaker John Harrison who is generally credited with its invention. He made it for his third marine chronometer (H3) of 1759 to compensate for temperature-induced changes in the balance spring. It should not be confused with the bimetallic mechanism for correcting for thermal expansion in his Giridon Pendulum. His earliest examples had two individual metal strips joined by rivets but he also invented the later technique of directly fusing molten brass onto a steel substrate. A strip of this type was fitted to his last timekeeper, H5. Harrison's invention is recognized in the memorial to him in Westminster Abbey, England.

Bimetal refers to an object that is composed of two separate metals joined together. Instead of being a mixture of two or more metals, like alloys, bimetallic objects consist of layers of different metals. Trimetal and tetrametal refer to objects composed of three and four separate metals respectively. A bimetallic sheet is usually made of combinations of Copper-Aluminium, steel-Copper. It is achieved by cladding, roll bonding, explosive welding.

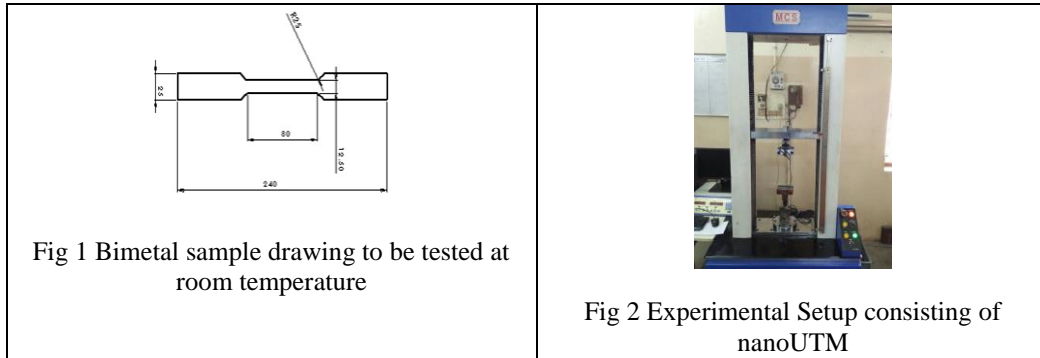
S. Nagarjuna and M. Srinivas^[1] investigated the high temperature tensile properties of Cu-1.5 wt.% Ti alloy in the temperature range of 100-550 °C. Substantial increase in yield and tensile strengths of solution treated alloy is observed with increasing temperature, with a peak at 450 °C and decrease in strength beyond this temperature. Cu-Ti alloys have been developed with the aim of substituting them for the toxic and expensive Cu-Be alloys. It reports the results obtained on high temperature tensile properties of a Cu-1.5 wt. % Ti alloy in solution treated (ST) and peak aged (PA) conditions . Radovic et al ^[2] investigated that the tensile response of Ti₃SiC₂ is a strong function of strain rate and temperature. Increase in testing temperature and decrease in testing strain rate leads to large tensile plastic deformations. The high value of strain rate sensitivity (0.42 to 0.56) of Ti₃SiC₂ was obtained from tensile tests and confirmed by strain rate jump/drop test and stress jump creep tests. That value is equal to or greater than the strain rate sensitivity of most superplastic ceramics. The deformation of fine-grained Ti₃SiC₂ also has another aspect in common with superplastic ceramics -- significantly larger elongation to failure that are typically observed in ceramics. The large elongation to failure appears to result from a high degree of damage, not from a structure that remains self-similar throughout deformation. J. O'noroa et al.^[3] studied The mechanical properties of particulate-reinforced metal-matrix composites based on aluminium alloys (6061 and 7015) at high temperatures . Boron carbide particles were used as reinforcement. All composites were produced by hot extrusion. The tensile properties and fracture analysis of these materials were investigated at room temperature and at high temperature to determine their ultimate strength and strain to failure. Rao, K.P.et al ^[4] suggested that an understanding of the plastic behaviour of various metals and alloys is necessary for their successful forming. Flow curves facilitate understanding of the plastic behaviour of materials. The determination of the flow curves at different temperatures and strain rates is equally important for both the researcher and the production engineer. The different test methods used for determining the flow curves, together with their relative merits and demerits and the influencing parameters, are discussed.

2 Methodology:

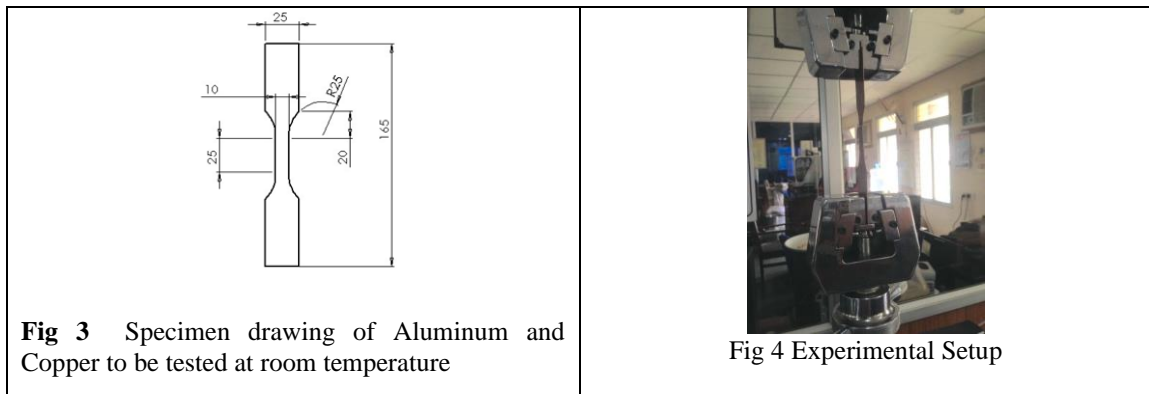
2.1 Experimental procedure for bimetallic strip at room temperature

The bimetallic strip that is used for testing is obtained by roll bonding process-the combination of bimetallic strip is Copper on one side and Aluminium on other side. The bimetallic sheet is cut according to the ASTM E8

standard using milling machine. A total of 3 specimen are cut for testing at three different strain rates. The edges of the specimen are rubbed with emery paper to keep the edges smooth for gripping. The specimen is then fixed in NANO UTM and tested at three different feed rates viz., 5mm/min, 10mm/min and 15mm/min . The final tests were performed at SUNRAY laboratories Nacharam.



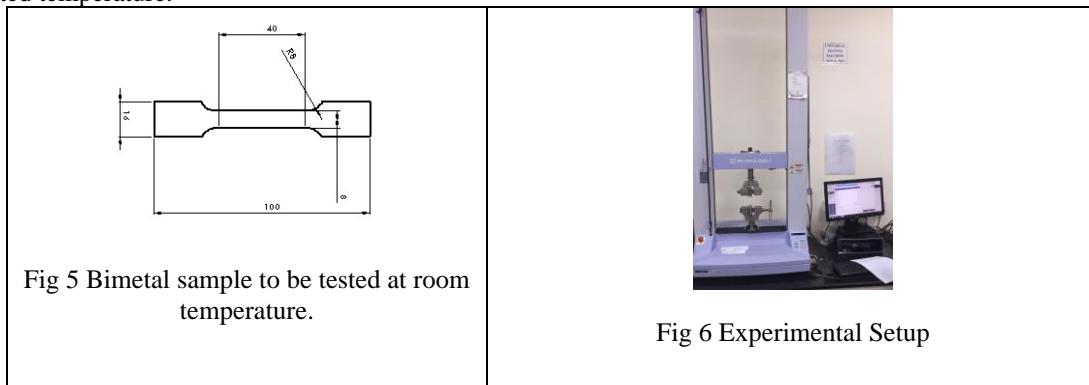
2.2 Experimental procedure for Aluminium and Copper at room temperature



Firstly, the bimetallic sheet is cut according to the ASTM E8 standard using milling machine. A total of 6(3 Aluminium and 3 Copper) specimens are cut for testing under 3 different strain rates. Then the edges of the specimen are rubbed with emery paper to keep the edges smooth for gripping. Then the specimen is tested using NANO UTM at feedrates of 0.5mm/min , 2.5mm/min and 5mm/min and the results are noted. Fig 1 & 3 are the specimen drawing of Aluminium and Copper to be tested at room temperature .Fig 3 & 4 consists of experimental setup.

2.3 Experimental procedure for bimetallic strip at elevated temperatures

The bimetallic strip that is used for testing is obtained by roll bonding process and is the combination of Copper on one side and Aluminium on other side. The bimetallic sheet is cut according to the ASTM E8 with a milling machine. A total of 3 specimen are cut for testing under 3 different strain rates. The edges of the specimen are rubbed with emery paper to keep the edges smooth for gripping. The specimen is then fixed in NANO UTM and a feed rate of 0.5mm/min is applied and the test is carried out. Similarly, the test is carried out with two feed rates of 5mm/min and 50mm/min.This specimen drawing shows the drawing of bimetal sample to be performed at elevated temperature.



3 Results & Discussions:

3.1 For Bimetals at room temperature

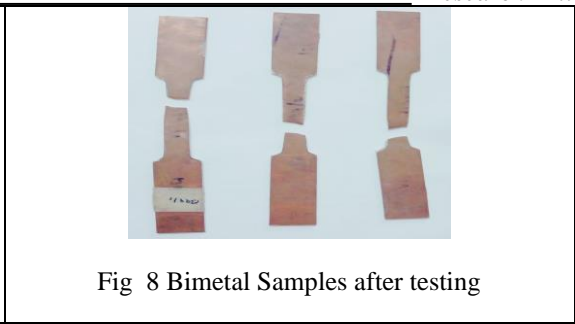


Figure 7 and 8_ shows the work samples of bimetals after testing at room temperature.

Table 1 Strain rate vs Mechanical properties of bimetals

S.No	Strain rate(mm/min)	Yield Point Strength(MPa)	Ultimate Tensile Strength(MPa)	%Elongation	0.2% Proof load(KN)
1	5	142.824	146.351	12.88	3.561
2	10	151.165	153.279	11.300	3.688
3	15	151.11	154.61	11.22	3.596

Table1 shows the data of mechanical properties of bimetals at room temperature at various strain rates of 5,10,15mm/min.

From the data, corresponding graphs are drawn which include Strain rate vs Yield Point Strength, Strain rate vs Ultimate Tensile Strength ,Strain rate vs% Elongation and Strain rate vs 0.2% Proof load.

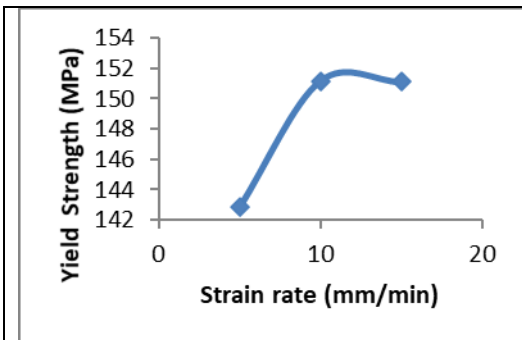


Figure 7 Strain rate vs Yield Strength

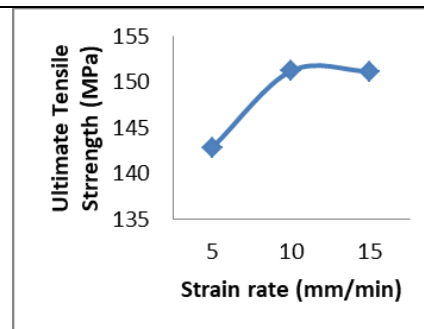


Figure 8 Strain rate vs Ultimate Tensile Strength

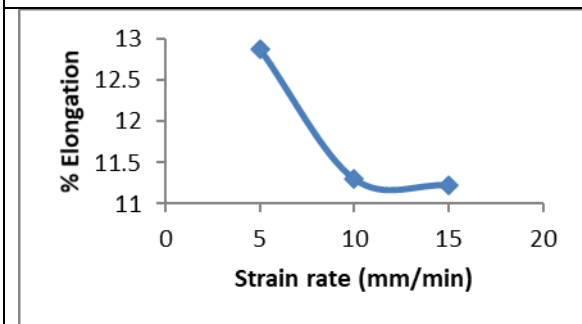


Figure 9 Strain rate vs %Elongation

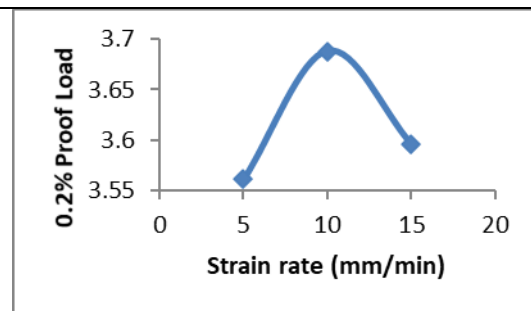


Figure 10 Strain rate vs 0.2% Proof Load

Fig 7 shows the variation of Yield Strength for different strain rates and it is observed that the Yield Point Strength found to increase with increase in strain rate. Fig 8 shows the variation of Ultimate Tensile Strength for different strain rates and it is observed that the Ultimate Tensile Strength increases with increase in strain rate. Fig 9 shows the variation of % Elongation for different strain rates and it is observed that the % Elongation decreases with increase in strain rate. Fig 10 is the variation of 0.2% Proof Load for different strain rates and it is observed that 0.2% Proof load increases with increase in strain rate.

3.2. For Copper & Aluminum at room temperature



Fig.11 Aluminum & Copper samples after testing

Figure11 shows the work samples of Aluminium and Copper after testing at room temperature. The Mechanical properties following after tensile testing of Aluminium are tabulated below.

Table 2 Strain rate vs Mechanical properties of Aluminium

S.No	Strain rate (mm/min)	Ultimate Tensile Strength (MPa)	0.2% Proof Load (KN)
1	0.5	150.707	1.718
2	2.5	151	1.469
3	5	155	1.518

Table 2 shows the variation of mechanical properties of (Ultimate Tensile strength & 0.2% Proof Load) aluminium at the strain rates of 0.5 , 2.5 , 5 mm/min .

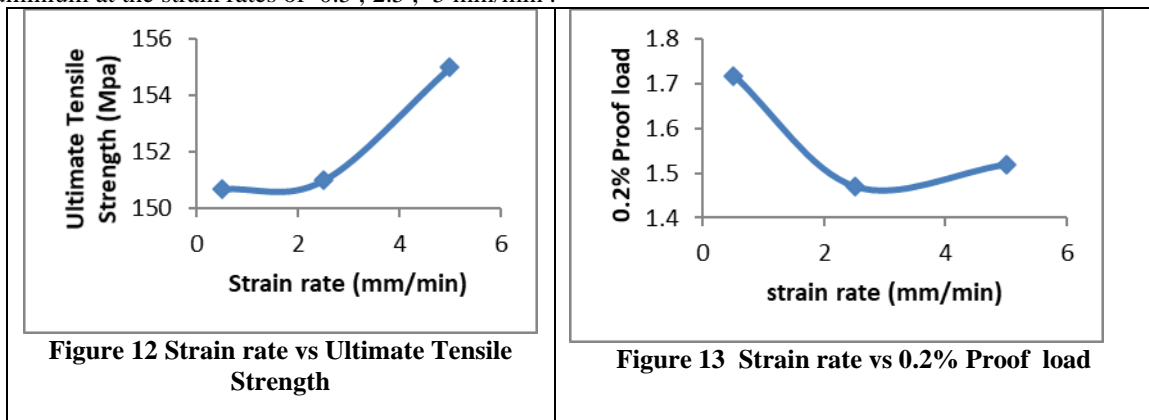


Fig 12 and 13 show the variation of Ultimate Tensile Strength and 0.2% Proof Load for different strain rates and it is observed that the 0.2% Proof Load found to decrease first and then increase with increase in strain rate.

Table 3 Strain rate vs Mechanical properties of copper

S.No	Strain rate (mm/min)	Ultimate Tensile Strength (MPa)	0.2% Proof Load (KN)
1	0.5	220	1.412
2	2.5	239	1.428
3	5	240	1.304

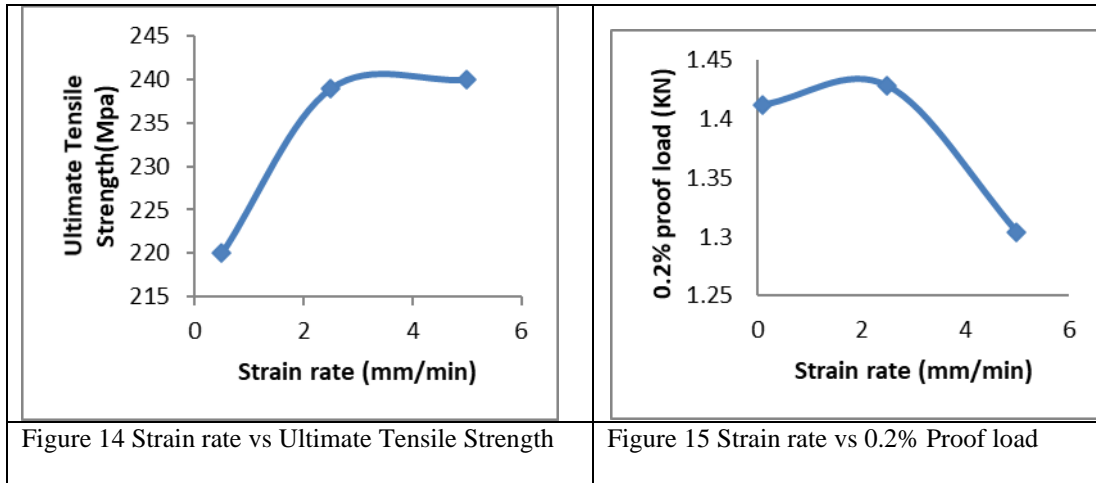


Fig 14 shows the variation of Ultimate Tensile Strength for different strain rates and it is observed that the Ultimate Tensile Strength found to increase with increase in strain rate .Figure 15 shows the 0.2% Proof Load for different Strain rates for copper material

3.3 For Bimetals at elevated temperatures



Figure 16 Bimetal samples after testing

Figure 16 shows the work samples of bimetals after testing at elevated temperatures.

Table 4: Strain rate vs Mechanical properties of bimetals at elevated temperatures

SL NO	TEST PARAMETER	UNITS	RESULTS								
			150°C			200°C			250°C		
Strain Rate (mm/min)			0.5	5	50	0.5	5	50	0.5	5	50
1	Tensile Strength	MPa	130.2	131.6	140.1	116.0	116.7	118.8	97.3	100.8	102.8
2	% Elongation	%	16.7	16.2	15.1	21.2	20.8	19.9	26.5	25.4	25.2

Table 4 shows the variation of mechanical properties like Tensile strength and % elongation at different temperatures of 150°C, 200°C , 250°C.

At 150°C

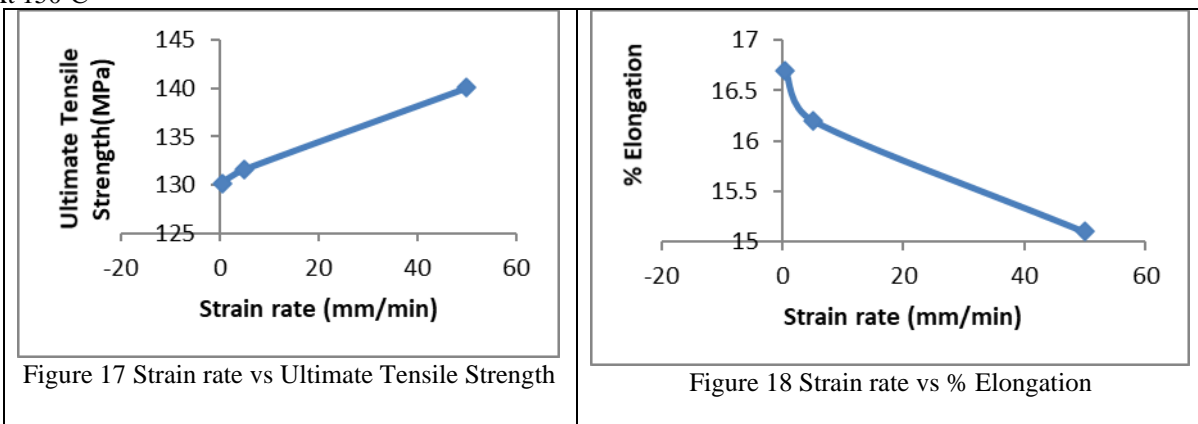


Figure 17 shows the variation of Ultimate Tensile Strength for different strain rates at an elevated temperature of 150°C and it is observed that the Ultimate Tensile Strength increase with increase in strain rate and temperature.

Fig 18 is the variation of % Elongation for different strain rates at 150°C and it is observed that the % Elongation found to decrease with increase in strain rate and temperature.

At 200°C

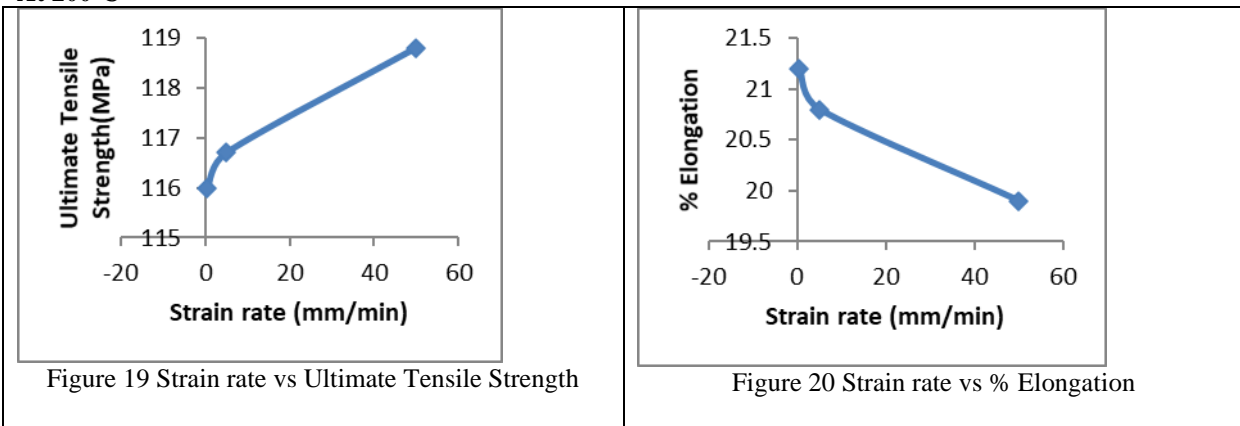


Figure 19 shows the variation of Ultimate Tensile Strength for different strain rates at 200°C and it is observed that the Ultimate Tensile Strength found to increase with increase in strain rate and temperature. Figure 20 is the variation of % Elongation for different strain rates for elevated temperatures and it is observed that the % Elongation found to decrease with increase in strain rate and temperature.

At 250°C

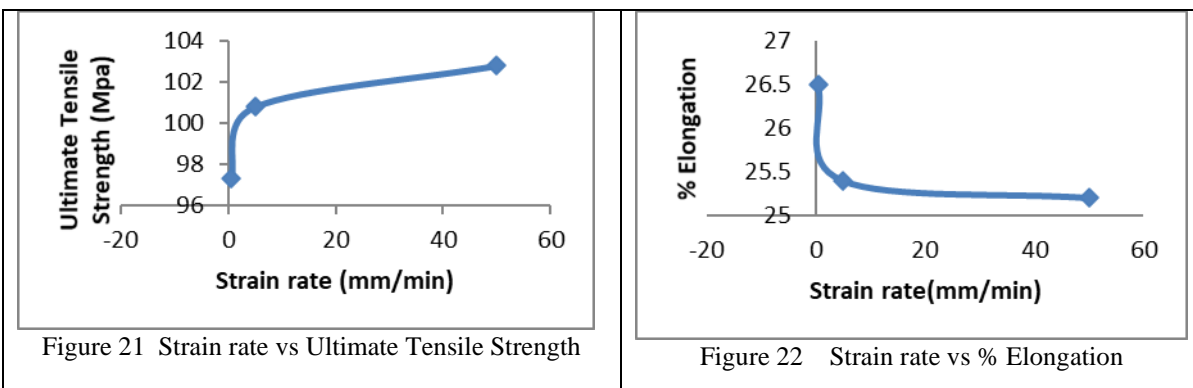


Fig 21 shows the variation of Ultimate Tensile Strength for different strain rates for elevated temperatures of 250°C and it is observed that the Ultimate Tensile Strength increase with increase in strain rate and temperature. Fig 22 shows the variation of % Elongation for different strain rates for elevated temperatures and it is observed that the % Elongation decrease with increase in strain rate and temperature

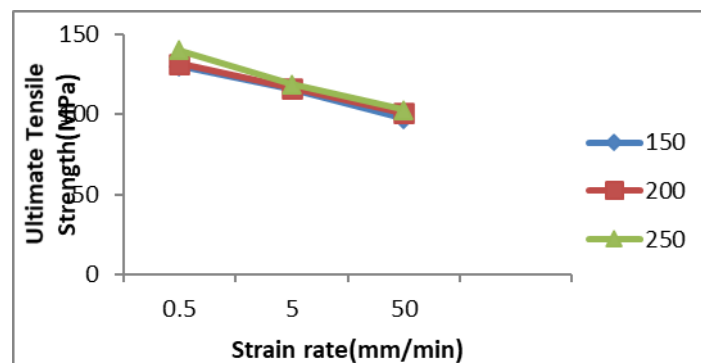


Figure 23 Variation of Ultimate Tensile Strength for different strain rates at different temperatures

Fig 23 shows the comparison of variation of Ultimate Tensile Strength and strain rate at different temperatures viz., 150°C, 200°C and 250°C.

5 Conclusion

- With increase in strain rate the mechanical properties like yield point and ultimate tensile strength are found to increase.

- With increase in strain rate ,% elongation and yield load moderately decrease.
- As temperature varies ,it is evident that the properties of materials change at high rate i.e., with increase in temp and strain rate, the yield point and ultimate tensile strength goes on decreasing.
- At room temperature, variation in mechanical properties seem to be less significant.

6. Future scope:

- Using the above results cylindrical cups can be drawn at different strain rates and also the microscopic structure of these drawn cups can be evaluated.
- Also for metals like Titanium, Invar, Trimetallic, the above tests can be performed.

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