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Analysis of Friction Stir Extrusion Process Using Ansys

Nenavath Surya[1*], K. Eshwara Prasad[2], D.V. Ravi Shankar[3]
[1]Assistanrt Professor, [3]Professor & Principal, Department of Mechanical Engineering, Teegala Krishna Reddy College of Engineering and Technology, Hyderabad, Telangana, India*
[2] Professor & Director, Departments of Mechanical Engineering, Siddartha Institute of Engineering and Technology, Hyderabad, Telangana, India
*Correspondence Author: Nenavath Surya[1]**

Abstract
The aim of this work analyzes the results using ANSYS–R15.0 in the friction stir extrusion process. In this process soft metal billet is held in a cylindrical stationary cartridge, a rotating plunger with axial force was applied from the top, due to this force and speed, friction has been generating and it helps to gets consolidate, plasticized then extruded in wire form through the central hole of the plunger. During this process the results could be obtained deformation, field distributions of von miss stress and thermal stress analysis in the billets can be studied.
Keywords**:** *Billet, Friction Stir Extrusion, Process Parameters, Deformation, Stresses.*

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I. INTRODUCTION

Lightweight materials and their alloys are playing a very much important role in applications calling automotive, automotive recycling process, construction and structural etc. for weight reduction to save energy, resistance from corrosion, and long life compared to steel and other materials. These materials are called friendly environment materials because it minimizes green gas house [1]. The major global task we are facing now a day is economy, society, environment, and technology are the factors for sustain, develop and implement for quality product [2, 3]. To reduce economy with good quality product with less price to the customer by protecting the environment from the pollution a novel technology called direct recycling method, it converts from scrap into useful product called 'friction stir extrusion process', it was introduced and developed in Oak Ridge National Laboratory (ORNL) at south wire company by W. Thomas for extrusion of wire or rod and gives saving in material, labour cost and energy consumption [4, 5]. In this process, the material gets consolidated using frictional heat followed by extrusion with saving energy from 25-30%, no reduction in purity, no oxidation losses [6, 7]. And wire extruded is free from defects and exhibited good mechanical properties due to refined grains size. The end quality depends upon the process parameters such as speed, axial force, type of materials etc [8]. The temperature distribution and controlling of surface deformability is measured with a thermocouple in billet, die, and plunger [9-11].in this report, the analysis of stress and deformation was carried out using Ansys.

Friction Stir Extrusion Process

The objective of this analysis is to find out the deflections and stresses in the billet structure. The materials used for this process were Aluminium alloy 6061, Copper and Magnesium at three different speeds and forces. The size of billet is Ø29.5X50 mm in height. The billet is loaded a stationary cartridge a plunger with rotational speed and axial pressure is applied from top to downward direction it helps to create friction between the scrap, cartridge surface and bottom of plunger it causes to generate heat in the material billet due to thermomechanical effect and gets plasticized, consolidated and extruded through the central hole of the plunger in the form of wire or rod shown in figure.1.

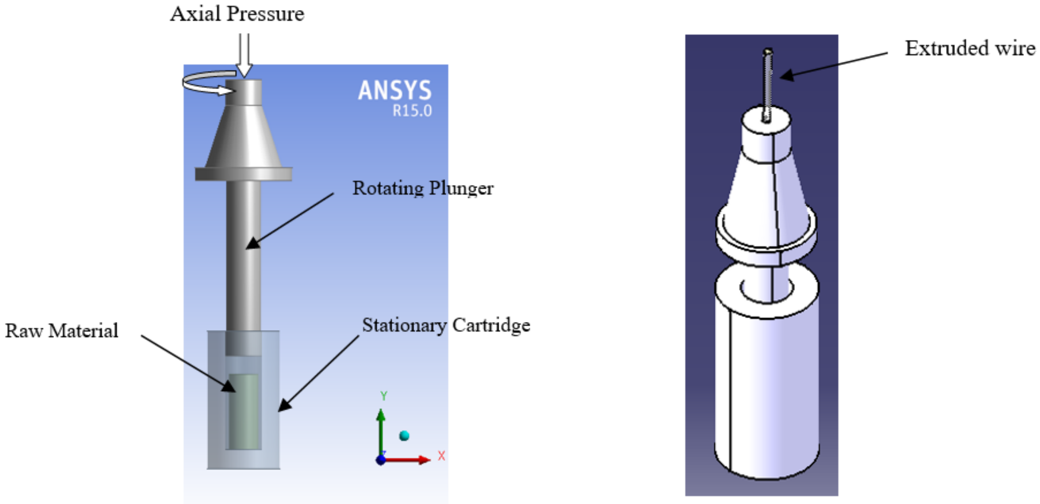


Fig. 1. Schematic representation of 3D model wire extrusion

Finite Element Model
Solid185 element description:
SOLID185 is used for 3-D modeling of solid structures. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyperelasticity, stress stiffening, creep, large deflection, and large strain capabilities.
SOLID185 is available in two forms:

- Homogeneous Structural Solid
- Layered Structural Solid

SOLID185 Structural Solid is suitable for modeling general 3-D solid structures. It allows for prism, tetrahedral, and pyramid degenerations when used in irregular regions. The element is defined by eight nodes and the orthotropic material properties. The default element coordinate system is along global directions. You may define an element coordinate system using ESYS, which forms the basis for orthotropic material directions.

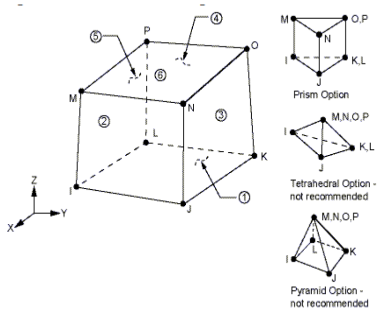


Fig. 2. Solid185 element geometry

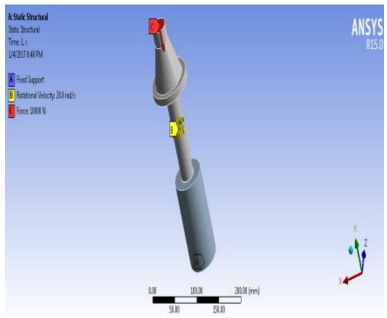


Fig.3. Boundary conditions

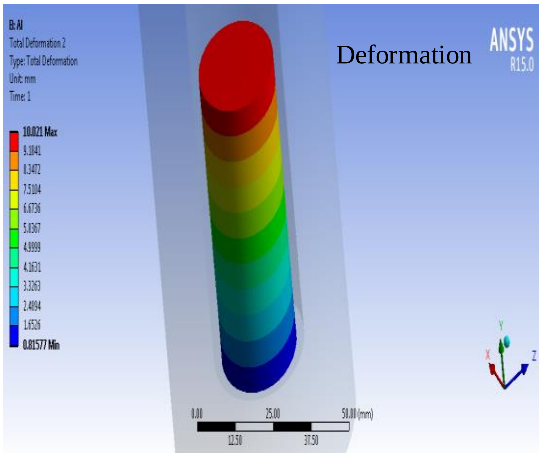
Material	Speed (RPM)	Axial Force (kN)	Temp °C	Thermal conductivity W/mK	Thermal Expansion µm/mK	Density g/cc	Poisson's ratio
Aluminum(AA6061)	250, 300, 350	10, 12, 14	529	237	23.1	2.7	0.33
Magnesium			468	72.3	25.2	1.81	0.27
Copper (Cu)			650	320	18.7	8.6	0.34

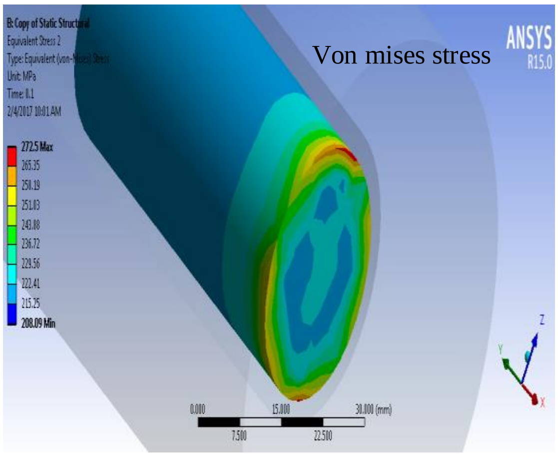
Table.1. Process parameter and properties of materials

II. RESULTS AND DISCUSSION

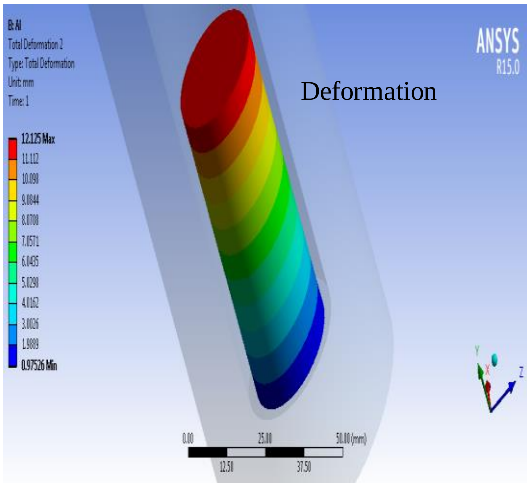
Using ANSYS -R15.0 analysis was carried out at various process parameters such as speed, axial force, and material types. The results obtained in this work by varying process parameters as shown in the table.

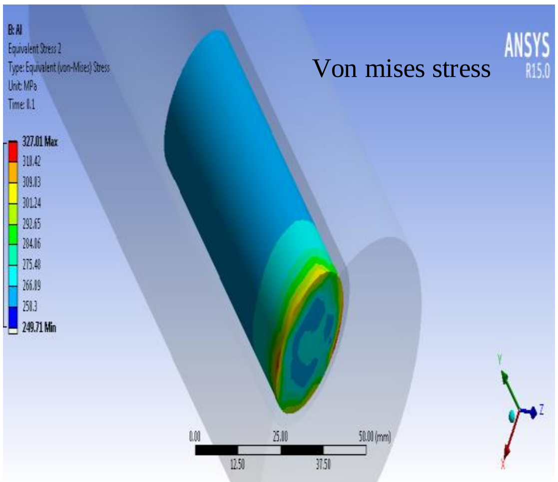
For Aluminium 6061 material at 10kN, 200rpm



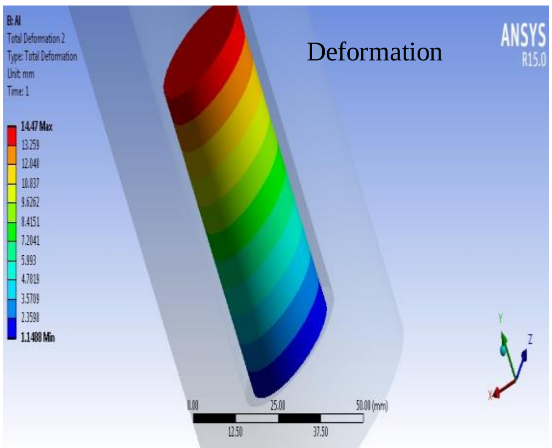


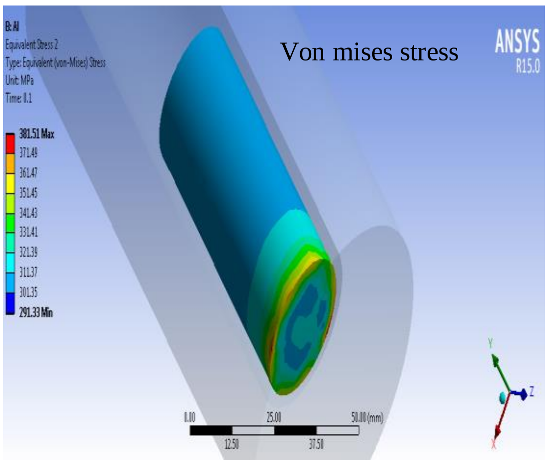
For Aluminium 6061 material at 12kN, 250rpm



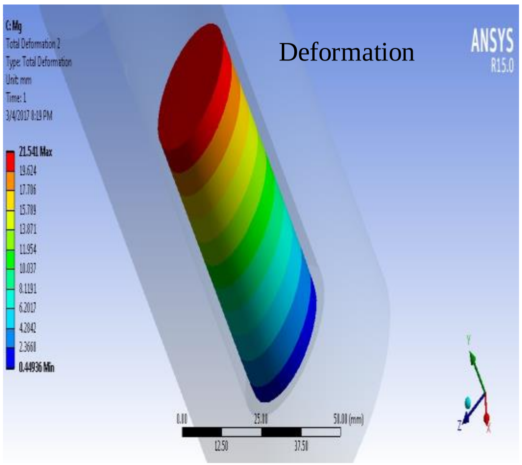


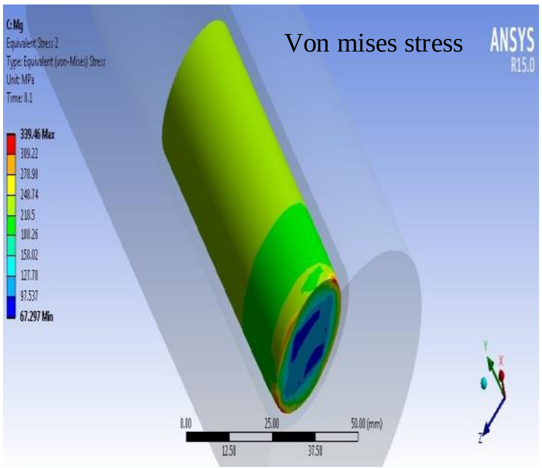
For Aluminium 6061 material at 14kN, 300rpm



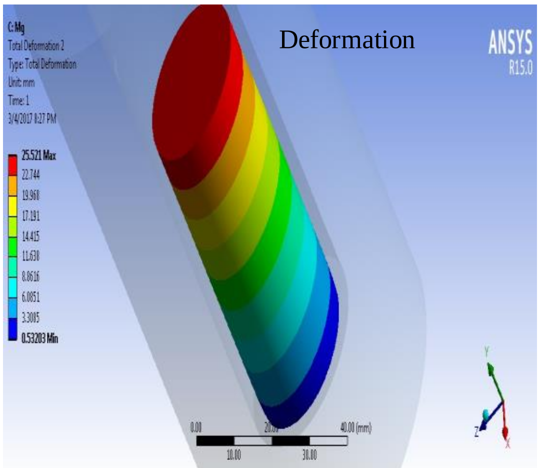


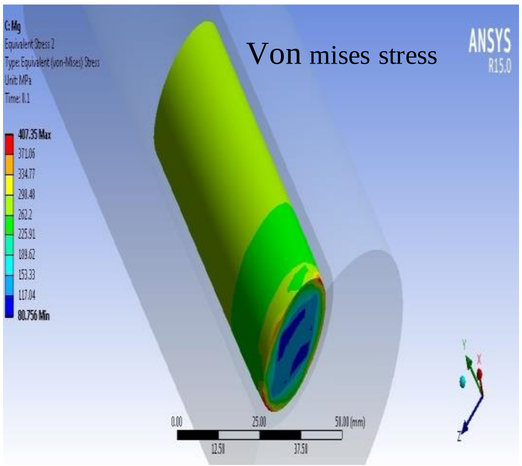
For Magnesium material at 10kN, 200rpm



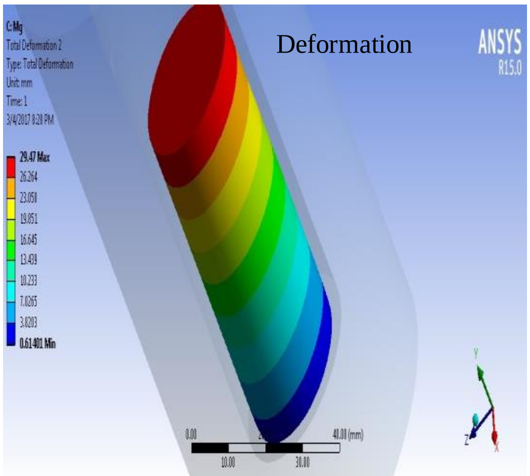


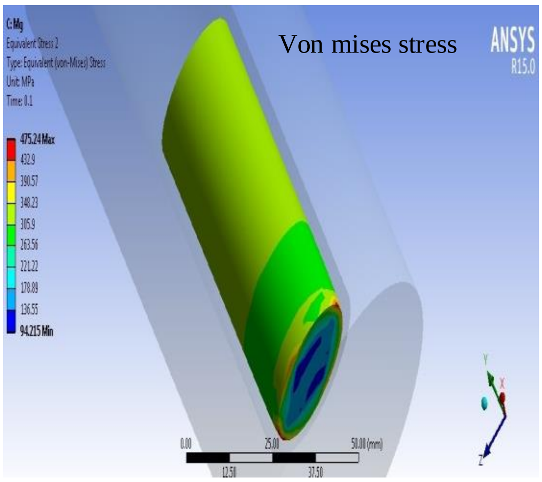
For Magnesium material at 12kN, 250rpm



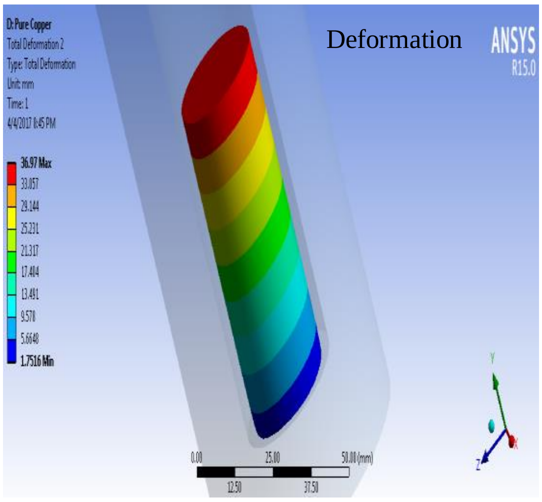


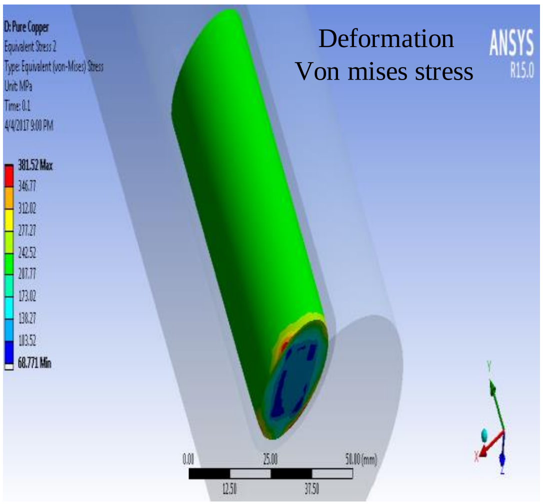
For Magnesium material at 14kN, 300rpm



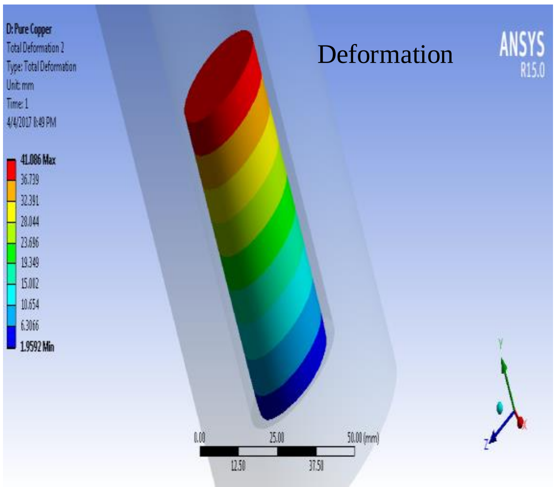


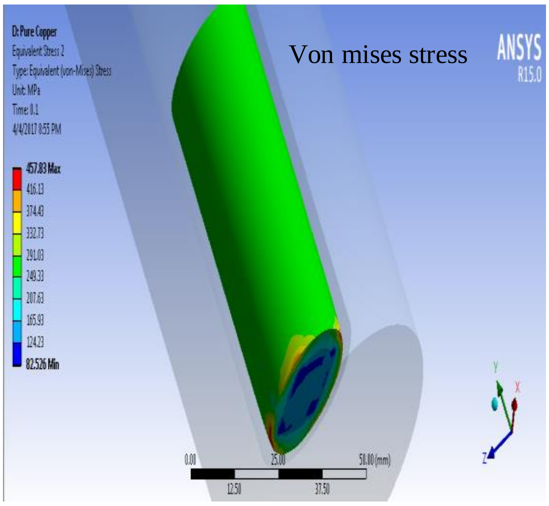
For Pure Copper material at 10kN, 200rpm



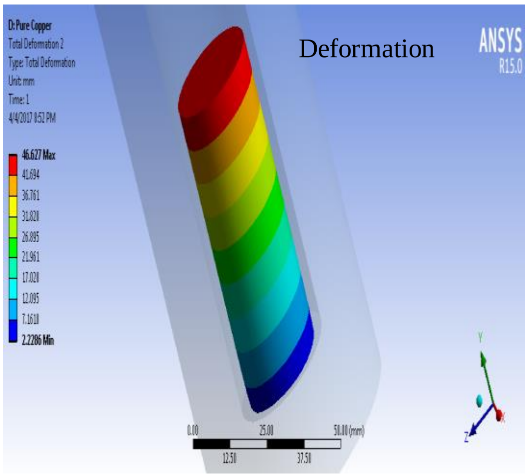


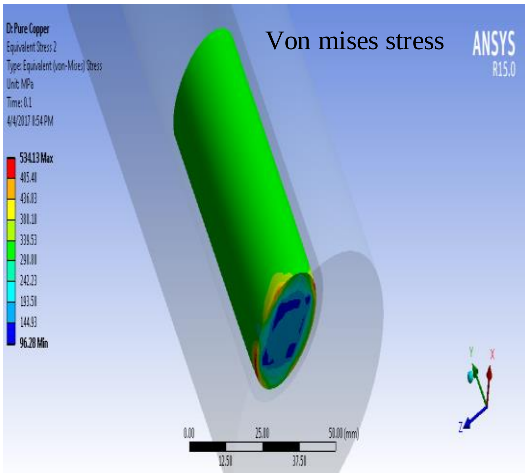
For Pure Copper material at 12kN, 250rpm





For pure copper material at 14kN, 300 rpm





Using Ansys the obtained results were shown in table.2.

S.No	Parameters		Aluminum Alloy AA 6061				Magnesium				Copper			
			Stresses (MPa)		Deformation (mm)		Stresses (MPa)		Deformation (mm)		Stresses (MPa)		Deformation (mm)	
	Speed (RPM)	Force (kN)	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max.
1	200	10	208.09	272.5	0.81	10.02	67.29	339.46	0.44	21.54	68.77	381.52	1.75	36.97
2	250	12	249.71	327.01	0.97	12.12	80.75	407.35	0.53	25.52	82.52	457.83	1.95	41.08
3	300	14	291.33	381.51	1.14	14.47	94.21	475.24	0.61	29.47	96.28	534.13	2.22	46.62

Table.2. Analysis of Stress and Deformation for Various Materials

From the above table, it is observed that the induced stresses in the material increases by increasing the speed and axial force. In copper, it is higher than the magnesium and aluminum alloy AA6061. The Aluminum alloy has the least value of stress and deformation. The deformation in copper material increases three times compared with aluminum alloy and twice with pure Magnesium.

Thermal Analysis

Thermal analysis was carried out using Ansys of three materials of aluminum alloy AA6061, Magnesium and copper, the input temperature was given as shown in table.4.

S.No	Materials	Temperature in ^{0}c	Thermal Stresses (MPa)
1	Aluminum Alloy	529	365.66
2	Magnesium	469	201.69
3	Copper	560	683.91

Table.3. Thermal Analysis of Various Materials

From the above table it is observed that the copper is having higher thermal stress then the aluminium alloy and magnesium is having least value of thermal stress.

MODEL GRAPHS

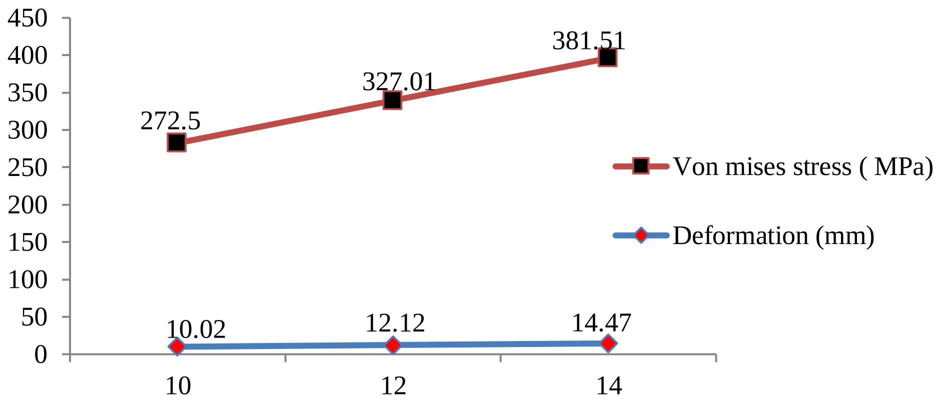


Fig.4. Force Vs Deformation and Von-Misses Stress of AA6061

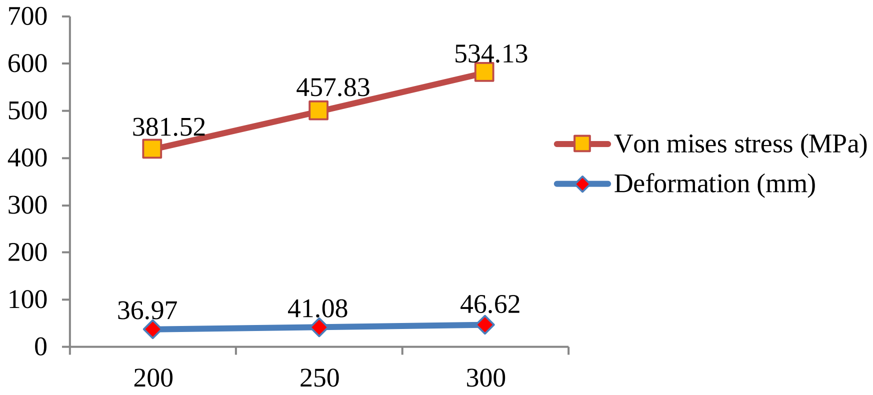


Fig.5. Speed Vs Deformation and Von-Misses Stress of copper

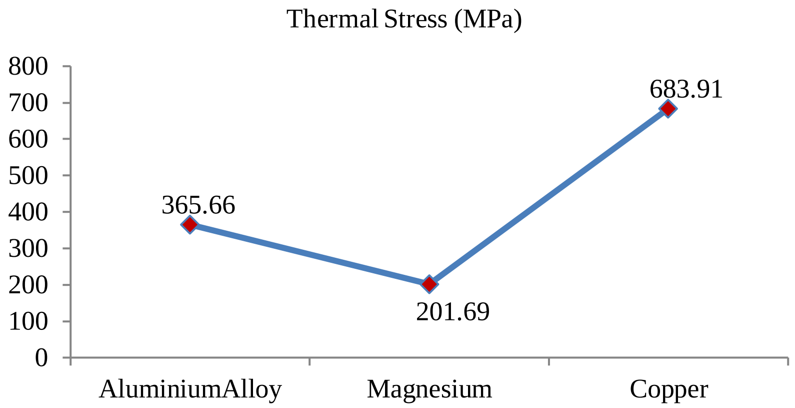


Fig.6. Material Vs Thermal Stress (MPa)

From the above graph it is observed that as the axial force and speed increases, the Von-misses stress and deformation has been increased. The thermal stress has a maximum for copper and minimum for Magnesium.

III. CONCLUSION

- Deformation, stress and thermal analysis of friction stir extrusion process were carried out using Ansys R15.0 version.
- The temperature of the material rises with rising of the speed and axial force.
- The flow of the material depends on heat generated due to friction inside the plunger and cartridge and the type of material to be used.
- Vonmises stress and deformation is directly proportional to the process parameters such as axial force and speed and it has increased with increasing of process parameters.
- Vonmises stress and deformation has Maximum for copper at a speed of 300 rpm and axial force 14kN. Minimum at a speed of 200 rpm and axial force 10kN.
- Vonmises stress and deformation has least for aluminium alloy at a speed of 200 rpm and axial force 10kN.
- The thermal stress has a maximum in copper and least in magnesium material.

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