FINITE ELEMENT METHOD BROACH TOOL DRILLING ANALYSIS USING EXPLICIT DYNAMICS ANSYS

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Abstract:The broaching is a precision machining process that utilizes a toothed tool, known as a broach, there are two main types of broaching i.e. linear and rotary to remove material. The broaching is used when precision machining is required, especially for odd shapes. It is specially machined surfaces includes circular and non-circular holes, flat surfaces, splines, keyways.The present study shows a 3D model of broach tool and the workpiece which were developed by using finite element software ANSYS. Here we considered the linear type toothed broach tool. The developed model gives an idea about the force and deformation analysis of structural steel broach tool, which is applied, to the copper alloy, magnesium alloy, titanium alloy, aluminum alloy. The FEM results shows that maximum equivalent elastic strain is 0.92209 mm/mm and maximum plastic strain is 0.90307mm/mm is observed for the aluminum alloy. The maximum (von Mises criteria) stress is 15795MPa occurred for titanium alloy.
Key words: finite element method, ANSYS, broach tool, structural steel.

1. INTRODUCTION

P.V. Siva Teja et al. has performed drilling on GFRP using LS-DYNA solver, according to them the thrust force and torque initiated by finite element analysis confirmed similar results while compared with the experimental results, [1]. H. Liu et al., has concluded that the maximum equivalent stress ensued at the inside of feed opening, while the extreme deformation occurred at conveyor blade edge of the tapered extremity, [2].Crina A. et al. analyzed the stresses occurred in virtual parts to illustrate the material anisotropy in a deep drawing process, [3]. However, the finite element software used to simulate the stress distribution and fracture of composites under impact, [4]. O. Isbilir et al., established 3D finite element model based on Lagrangian approach. The effects of cutting parameters on induced thrust force and torque anticipated using finite element software, [5]. During AW 6082-T6 aluminum alloy drilling operation, the several numerical analyseshave been carried out using explicit solver for different indentation depths and hole diameters, [6]. B.L. Tai et al., has developed finite element model to predict the workpiece thermal distortion in minimumquantity lubrication deep-hole drilling. In this model, they established the generation of heat fluxes on the drilled hole bottom surface and hole wall surface by using the inverse heat transfer method, [7]. Y. Wang et al., have calculated the stress distribution nearby holes in tempered glasses using a finite element model. They found that the stresses around the holes were considerably higher, than those who have large area, [8].

2. DESIGN APPROACH AND ASSUMPTIONS

The following assumptions were taken into view for the analysis of structural steel broach tool. In this study, a model developed in ANSYS workbench. The force and displacement have been applied from a broach tool for different workpiece materials. Here broach tool considered the as rigid body, workpiece plate as flexible body and supporting base a rigid body. The front diameter of broach tool was about 5mm and end diameter was 44mm. The supporting base size was 50×20×10mm, whereas workpiece material, size was 50×16×5mm with 10mm center hole. The meshed body and boundary conditions, show in figure 1 and figure 2. The table 1 shows that material properties.

Loading and boundary conditions applied to rectangular plate that shown in figure 1.

The following assumptions were taking into considerations:

-The 400N force and 24mm displacement applied to copper alloy, magnesium alloy, titanium alloy, aluminum alloy materials rectangular plate with the structural steel material supporting base plate.

-The structural steel material chosen for broach tool material, which is same for the different materials workpiece.

-The broach tool and supporting base have same material i.e. structural steel. Whereas different materials i.e. copper alloy, magnesium alloy, titanium alloy, aluminum alloy rectangular plates used for analysis.

-Calculate equivalent elastic strain, equivalent plastic strain, equivalent (von-mises) stress and total deformation.

-Comparing results of copper alloy, magnesium alloy, titanium alloy, aluminum alloy materials.

Table 1. Materials Properties

No.	Materials	Density	Young's Modulus (MPa)	Poisson's Ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)	Yield Strength (MPa)
1	Structural steel	7.85e^{-6} kg.mm^{-3}	2.e^{+5}	0.3	1.6667.e^{+5}	76923	250
2	Copper alloy	8.3e^{-6} kg.mm^{-3}	1.1e^{+5}	0.34	1.1458.e^{+5}	41045	280
3	Magnesium alloy	1.8e^{-6} kg.mm^{-3}	45000	0.35	50000	16667	193
4	Aluminum alloy	2.77e^{-6} kg.mm^{-3}	71000	0.33	69608	26692	280
5	Titanium Alloy	4.62e^{-6} kg.mm^{-3}	96000	0.36	1.1429.e^{+5}	35294	930

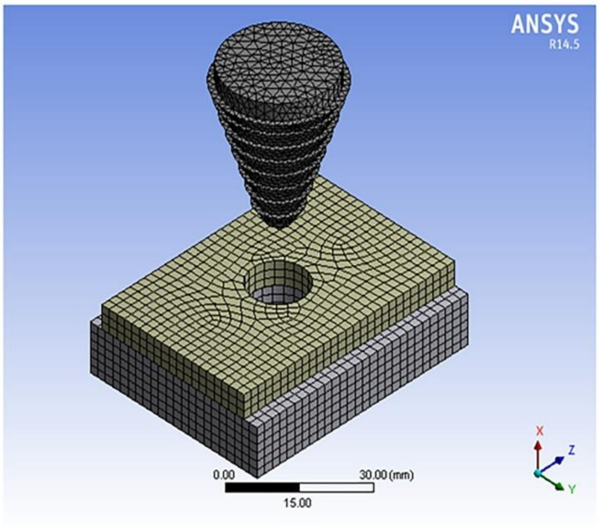

Fig. 1. Meshed Body

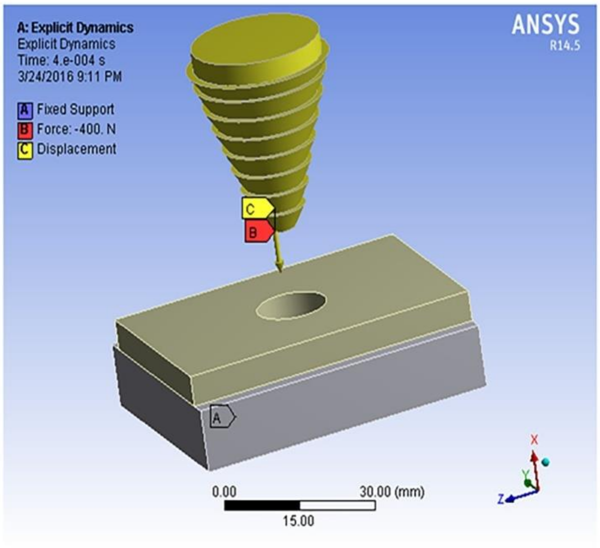

Fig. 2. Boundry Conditions

3. INVESTIGATION OF COPPER ALLOY MATERIAL

The 400N force and 24 mm displacement have applied for structural steel broach tool to the copper alloy rectangular plate with 10mm center hole, which supported by a structural steel plate. In this analysis, broach tool and supported plate have considered as the rigid body having the same material, however workpiece body considered as a flexible body. The FEM analysis results obtained using ANSYS software has shown in table 2. The maximum equivalent elastic and plastic strain found to be 0.80245 mm/mm and 0.83604 mm/mm, which shown in the figure 3 and figure 4. However, the maximum equivalent (von Mises criteria) stress and maximum total deformation found to be 12171 MPa and 40.083 mm, respectively, which shown in the figure 5 and figure 6 respectively. The observations of the given analysis show that equivalent elastic strain was observed in the area of central hole, however, the equivalent plastic strain has produced a side area of central hole with vertical throughout the wokrpiece. In case of equivalent (von Mises) stress occurring into the middle portion of the broach tool though, total deformation has occurred in broach tool body.

Table 2. FEM Results of Copper Alloy Material

No.	Equivalent Elastic Strain (mm/mm)	Equivalent plastic Strain (mm/mm)	Equivalent (von Mises) stress (MPa)	Total Deformation (mm)
1	0.80245	0.83604	12171	40.083
2	0.71331	0.74315	10820	35.629
3	0.62417	0.65025	9469.8	31.176
4	0.53503	0.55736	8119.2	26.722
5	0.44589	0.46447	6768.7	22.268
6	0.35675	0.37157	5418.1	17.815
7	0.26761	0.27868	4067.6	13.361
8	0.17847	0.18579	2717.1	8.9073
9	0.089329	0.092893	1368.5	4.4537
10	0.0001886	0	15.967	0

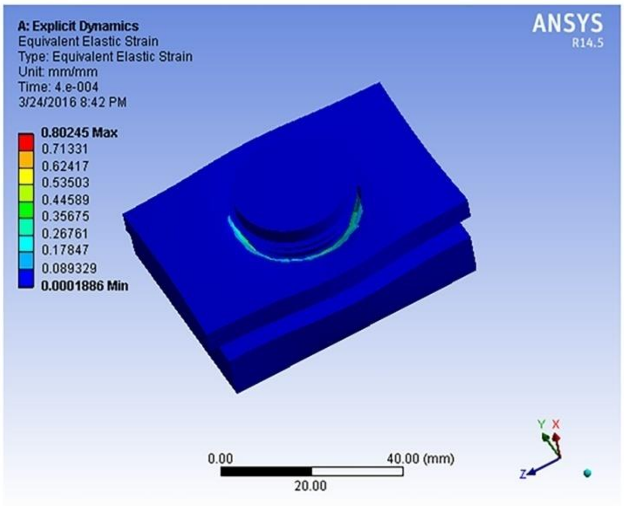

Fig. 3. Equivalent Elastic Strain of Copper Alloyworkpiece

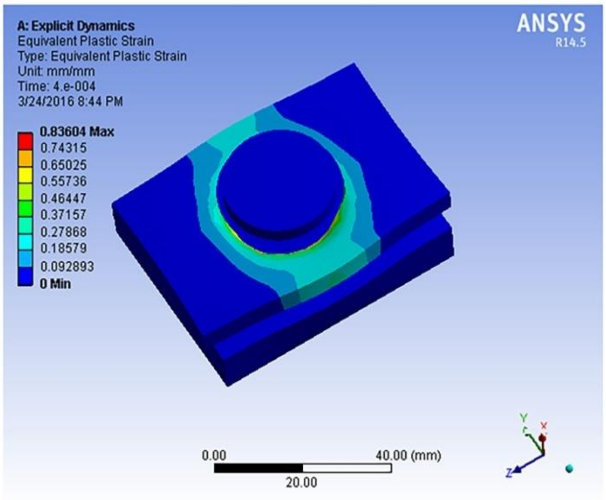

Fig. 4. Equivalent Plastic StrainStrain of Copper Alloyworkpiece

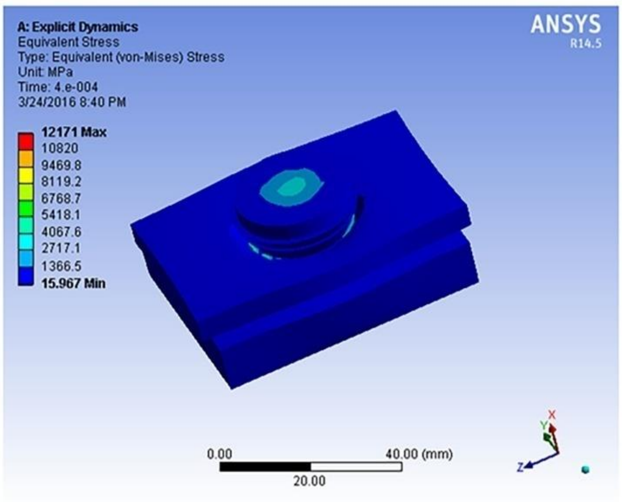

Fig. 5. Equivalent (von Mises) Stress of Copper AlloyWorkpiece

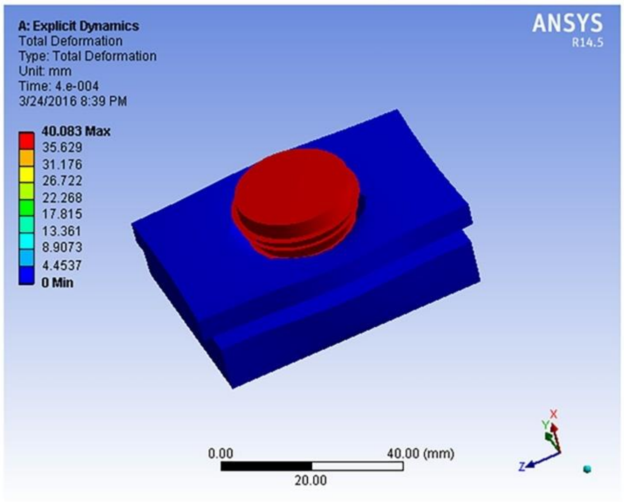

Fig. 6. Total Deformation of Copper Alloy workpiece

4. INVESTIGATION OF MAGNESIUM ALLOY MATERIAL

The 400N force and 24 mm displacement applied for structural steel broach tool to the magnesium alloy rectangular plate with 10mm center hole, which supported by a structural steel plate. The FEM analysis result obtained using ANSYS software shown in table 3. The maximum equivalent elastic and plastic strain have found to be 0.69083 mm/mm and 0.71804 mm/mm, which shown in the figure 7 and figure 8. However, the maximum equivalent (von Mises) stress and maximum total deformation have found to be 7301.9 MPa and 40.079 mm respectively, shown in the figure 9and figure 10 respectively. The observation of the given analysis shows that equivalent elastic strain and equivalent plastic strain have just lower than copper alloy workpiece material. The equivalent (von Mises) stress is lower than copper alloy, whereas; the total deformation has same as copper alloy material.

Table 3. FEM Results of Magnesium Alloy Material

No.	Equivalent Elastic Strain (mm/mm)	Equivalent plastic Strain (mm/mm)	Equivalent (von Mises) stress (MPa)	Total Deformation (MPa)
1	0.69083	0.71804	7301.9	40.079
2	0.6141	0.63826	6490.6	35.626
3	0.53737	0.55848	5679.2	31.172
4	0.46064	0.47869	4867.9	26.719
5	0.3839	0.39891	4056.6	22.266
6	0.30717	0.31913	3245.3	17.813
7	0.23044	0.23935	2434	13.36
8	0.15371	0.15956	1622.6	8.9064
9	0.076973	0.079782	811.32	4.4532
10	0.00023996	0	0	0

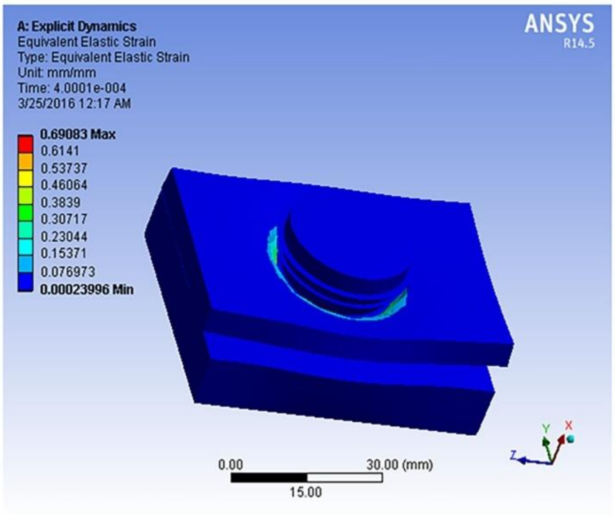

Fig. 7. Equivalent Elastic Strain of Magnesium Alloyworkpiece

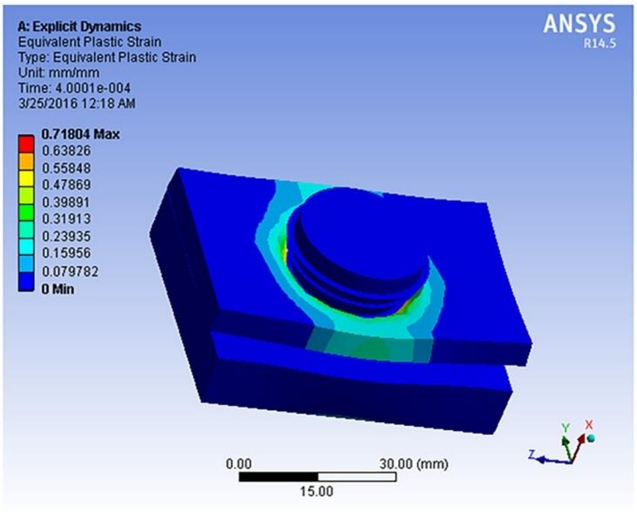

Fig. 8. Equivalent Plastic Strain Stress of Magnesium Alloyworkpiece

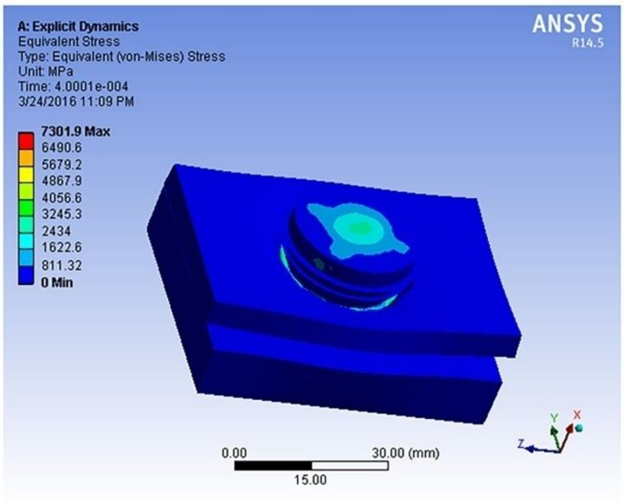

Fig. 9. Equivalent (von Mises) Stress of Magnesium Alloyworkpiece

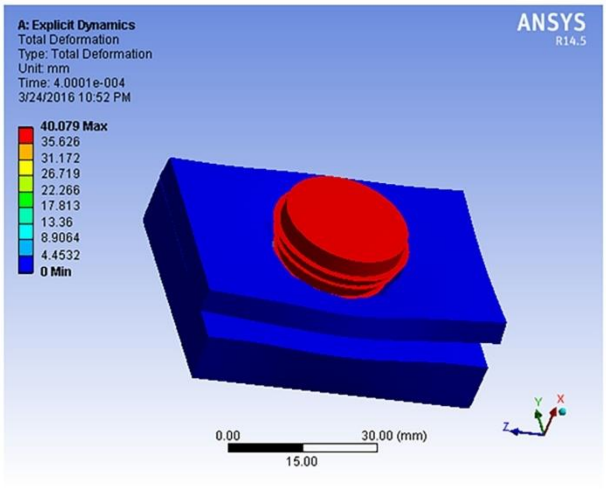

Fig. 10. Total Deformation of Magnesium Alloyworkpiece

5. INVESTIGATION OF TITANIUM ALLOY MATERIAL

The 400N force and 24 mm displacement applied for structural steel broach tool to the titanium alloy rectangular plate with 10mm center hole, which supported by a structural steel plate. The FEM analysis results obtained using ANSYS software shown in table 4. The maximum equivalent elastic and plastic strain have found to be 0.66936 mm/mm and 0.71064 mm/mm, which shown in the figure 11 and figure 12. However, the maximum equivalent (von Mises) stress and maximum total deformation found to be 15795 MPa and 40.056 mm respectively, which shown in the figure 13 and figure 14 respectively. The observation of the given analysis shows that equivalent elastic and plastic strain has same as magnesium alloy workpiece material. The equivalent (von Mises) stress is higher than copper alloy, whereas, the total deformation has same as magnesium alloy material.

Table 4. FEM Results of Titanium Alloy Material

No.	Equivalent Elastic Strain (mm/mm)	Equivalent plastic Strain (mm/mm)	Equivalent (von Mises) stress (MPa)	Total Deformation (MPa)
1	0.66936	0.71064	15795	40.056
2	0.59502	0.63168	14040	35.606
3	0.52068	0.55272	12285	31.155
4	0.44633	0.47376	10530	26.704
5	0.37199	0.3948	8774.9	22.253
6	0.29765	0.31584	7019.9	17.803
7	0.2233	0.23688	5265	13.352
8	0.14896	0.15792	3510	8.9014
9	0.074614	0.07896	1755	4.4507
10	0.0002708	0	0	0

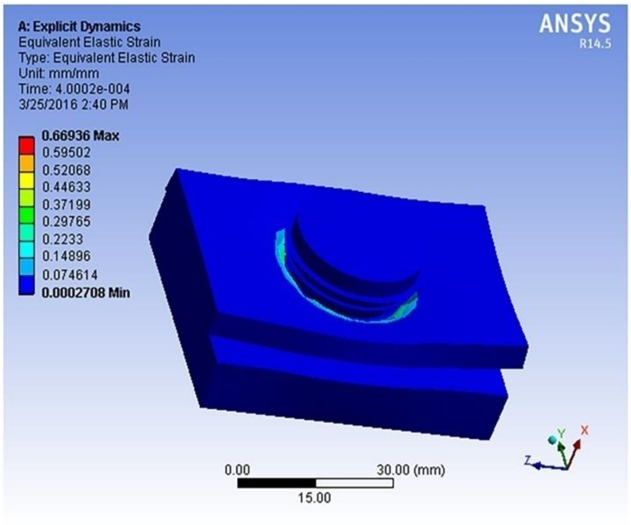

Fig. 11. Equivalent Elastic Strain of Titanium Alloy Workpiece

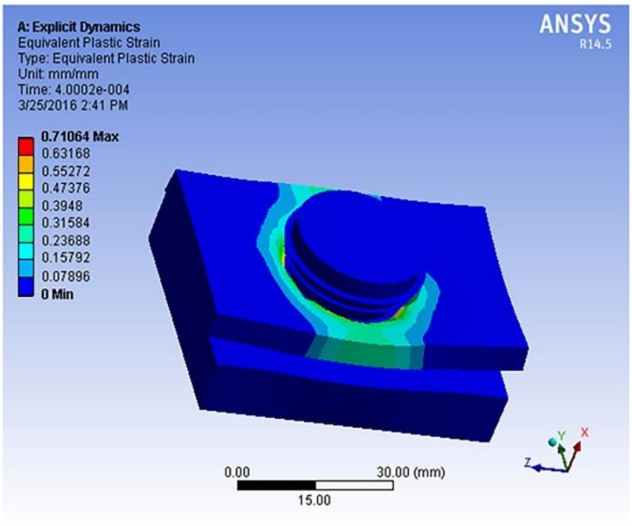

Fig. 12. Equivalent Plastic Strain of Titanium AlloyWorkpiece

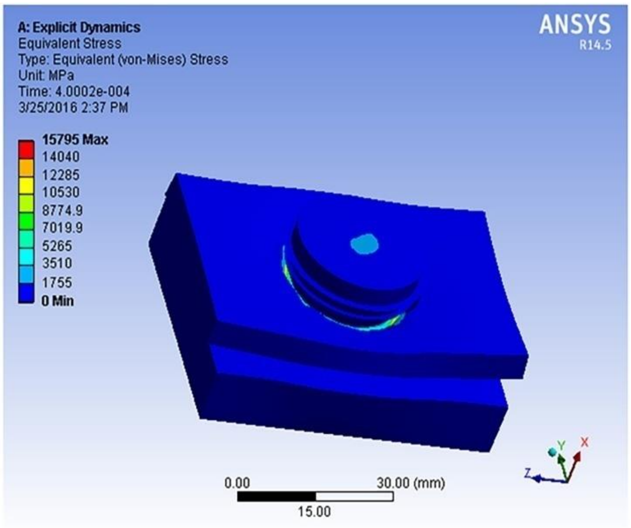

Fig. 13. Equivalent (von Mises) Stress of Titanium Alloy Workpiece

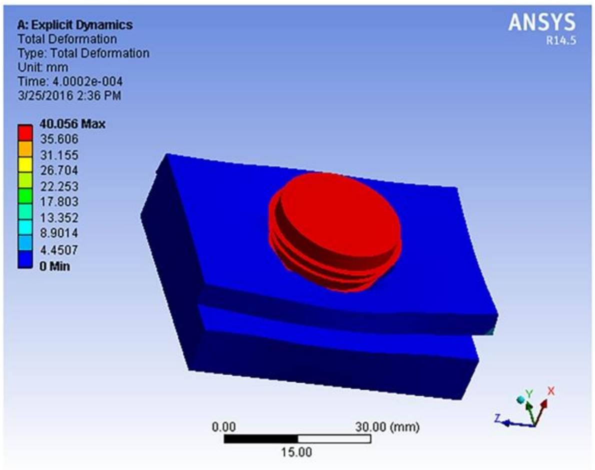

Fig. 14 Total Deformation of Titanium Alloy workpiece

6. INVESTIGATION OF ALUMINUM ALLOY MATERIAL

The 400N force and 24 mm displacement applied for structural steel broach tool to the aluminum alloy rectangular plate with 10mm center hole, which supported by a structural steel plate. The FEM analysis results obtained by using ANSYS software has shown in table 4. The maximum equivalent elastic and plastic strain have found to be 0.92209 mm/mm and 0.90307 mm/mm, which shown in the figure 15 and figure 16. However, the maximum equivalent (von Mises) stress and maximum total deformation have found to be 7355.2 MPa and 40.078 mm respectively, which shown in the figure 17 and figure 18 respectively. The observation of given analysis shows that equivalent elastic and plastic strain has same as magnesium alloy workpiece material. The equivalent (von Mises) stress is approximately same as that of magnesium alloy, whereas, the total deformation has also same as magnesium alloy material.

Table 5. FEM Results of Aluminum Alloy Material

No.	Equivalent Elastic Strain (mm/mm)	Equivalent plastic Strain (mm/mm)	Equivalent (von Mises) stress (MPa)	Total Deformation (mm)
1	0.92209	0.90307	7355.2	40.078
2	0.81966	0.80273	6537.9	35.625
3	0.71723	0.70238	5720.7	31.172
4	0.6148	0.60204	4903.4	26.719
5	0.51237	0.5017	4086.2	22.266
6	0.40994	0.40136	3269	17.813
7	0.30751	0.30102	2451.7	13.359
8	0.20507	0.20068	1634.5	8.9063
9	0.10264	0.10034	817.24	4.4532
10	0.00021194	0	0	0

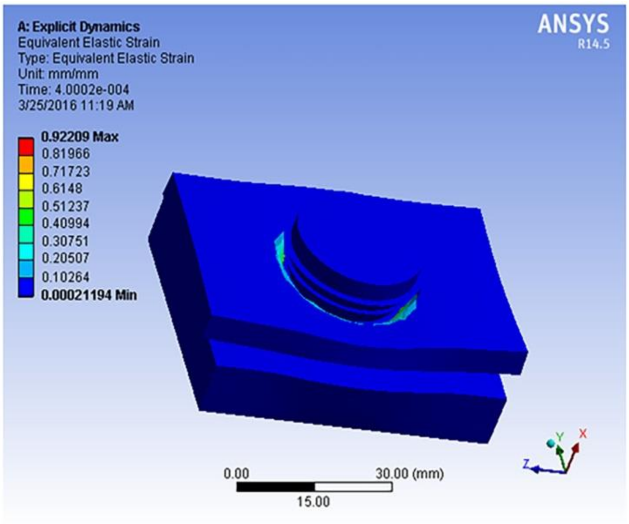

Fig. 15. Equivalent Elastic Strain of Aluminum Alloy Workpiece

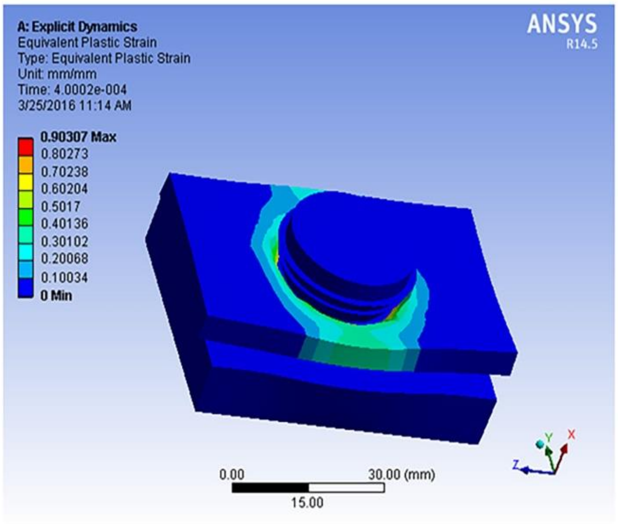

Fig. 16. Equivalent Plastic Strain of AluminumAlloy Workpiece

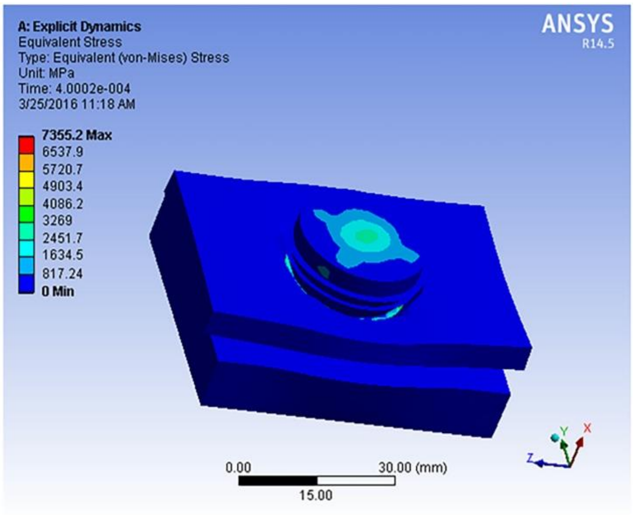

Fig. 17. Equivalent (von Mises) Stress of Aluminum Alloy Workpiece

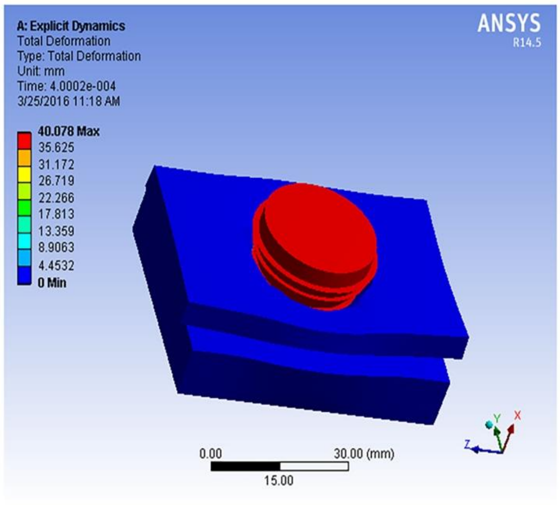

Fig. 18. Total Deformation of Aluminum Alloy Workpiece

7. COMPARATIVE STUDY OF ALL MATERIALS

The structural steel alloy drilling analysis was carried on copper alloy, magnesium alloy, titanium alloy and aluminum alloy workpiece materials by using explicit dynamic ANSYS. The figures 19 and 20 shows that the maximum equivalent elastic and plastic strain was taking place on an aluminum alloy material, while maximum von-mises stress was observed in a titanium alloy material, which is shown in figure 21.

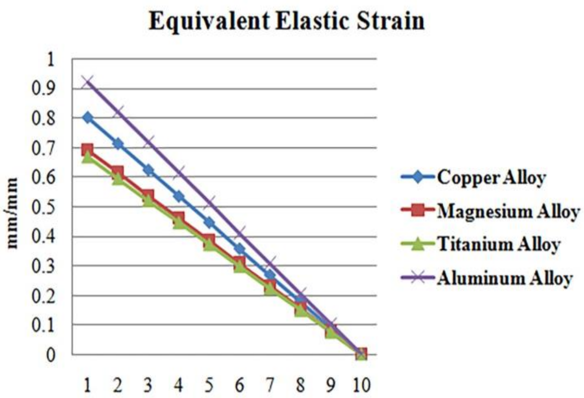

Fig. 19. Graph of Equivalent elastic strain *vs* Different Materials

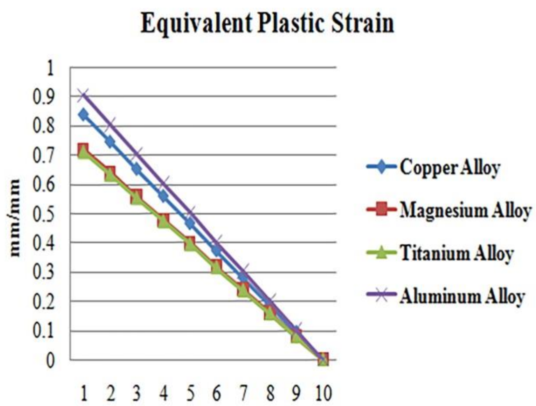

Fig. 20. Graph of Equivalent Plastic Strain *vs* Different Materials

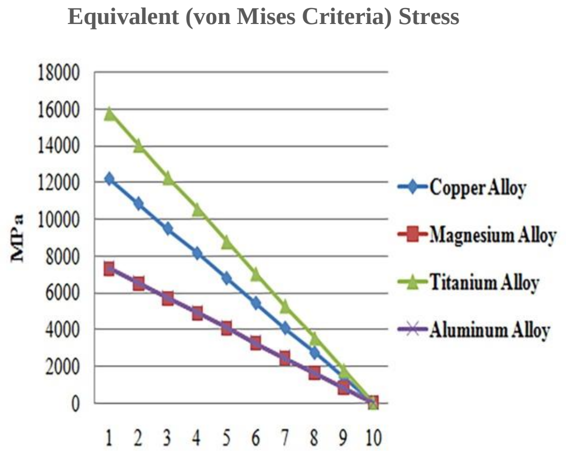

Fig. 21. Graph of Equivalent (von Mises Criteria) Stress vs Different Materials

The figure 22 shows that the total deformation has taken place almost same for all materials.

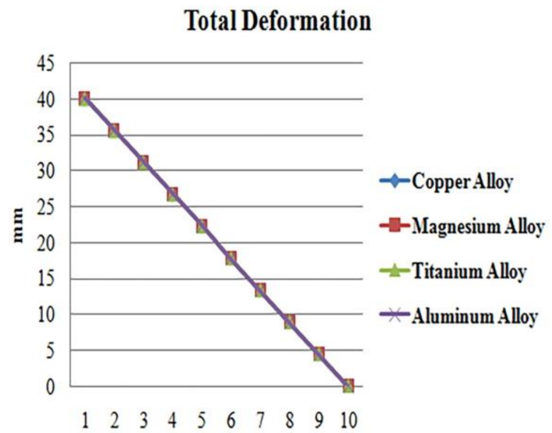

Fig. 22. Graph of Total Deformation *vs* Different Materials

8. CONCLUSIONS

The current research paper shows that the finite element method analysis of structural steel broach tool drilling on copper alloy, magnesium alloy, titanium alloy, aluminum alloy material using explicit dynamics ANSYS. The boundary conditions assumed as 400N force and 24 mm displacement has applied to all materials, whereas the tool material and supporting base material was constant during the analysis. Finally, it can be concluded that, the maximum equivalent elastic strain is 0.92209 mm/mm and maximum plastic strain is 0.90307mm/mm observed for the aluminum alloy followed by copper alloy, magnesium alloy and titanium alloy. The maximum (von Mises) stress is 15795MPa occurred for titanium alloy followed by copper alloy, magnesium alloy and aluminum alloy. However, the total deformation was occurring almost same for all materials.

9. REFERENCES

1. Teja, P.V.S., Prakash, S., Prasad, B.N., Elijah, G., (2015). *Finite Element Analysis in Drilling GFRP Composites*, Indian Journal of Science and Technology, 8(15), 1-5.

2.Liu, H., Li, P., Xiao, H., Mu, W., (2015). *The fluid-solid coupling analysis of screw conveyor in drilling fluid centrifuge based on ANSYS*, Petroleum, 1, 251-256.

3. Crina,A., Ion,C.,Petrica, R., (2010). *State of Stresses Predicted by A Numerical Model Based on Different Plasticity Criteria*, International Journal of Modern Manufacturing Technologies, II(2), 9-14.

4. Huang, C.Y., Chen, Y.L., (2016). *Design and impact resistant analysis of functionally graded* Al_2O_3*–*ZrO_2 *ceramic composite*, Materials and Design, 91, 294–305.

5. Isbilir, O., Ghassemieh, E., (2013). *Evaluation of drilling process in Ti6Al4V using 3D FE simulation*, Int. J. Machining and Machinability of Materials, 13(2/3), 174-190.

6. Marannano,G., Pasta, A., (2015). Parrinello F., Giallanza, A., *Effect of the indentation process on fatigue life of drilled specimens*, Journal of Mechanical Science and Technology, 29(7), 2847-2856.

7. Tai, B.L., White, S.B., Stephenson, D.A., Shih, A.J., (2011). *Finite element modeling of the workpiece thermal distortion in mql deep-hole drilling*, Proceedings of the ASME 2011 International Manufacturing Science and Engineering Conference, Corvallis, Oregon, USA, 1-6.

8. Wang, Y., Wang,Z., Liang, Y., Du, X., Shi,Y., (2016), *Study on the stress and failure strength around the hole in point supported glass panels*, Materials and Structures, 49(10), 4375-4387.

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