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Design and Analysis of Friction Drilling Using Various Angled Tools

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Abstract - Friction drilling is a nontraditional hole making process in which a conical rotating tool is applied to penetrate into work piece and create the hole in a single step, without generating chips. The process relies on the heat generated due to the frictional force between tool and work piece, to soften, penetrate and deform the work material into a bushing shape. In this present work we designed complete friction drilling assembly models with different tool angles by using cad tool (solid works) here we took 45 angle tool as an existing tool and we designed 3 more tools (30 angle, 60angle, 75 angle). After designing we analyzed each
tool assembly with static and thermal loading conditions by using (Ansys workbench), here we took steel material for tool and Al-6061 T6 Al Alloy material for plate in each case.

***Key Words*: Solid works, Ansys workbench, Al-6061, Steel tools with Different angles**

1.INTRODUCTION

Friction drilling is a method of making holes in metal in which the material is pushed out of the way with the aid of heat from friction. The process is also called thermal drilling, flow drilling, form drilling, or friction stir drilling.
Friction drilling is commonly used on bicycle frames, heat exchangers, and to create holes for mounting bearings.

2. PRINCIPLE

Friction drilling uses a conical bit made of very heat-resistant material such as cemented carbide. This device is pressed against a target material with both high rotational speed and high pressure. That way, there is a high local production of heat which softens the object, making it plastic. The tool then "sinks" through the object, making a hole in it. Lubricants help prevent work-material from adhering to the bit. Unlike drilling, material that is flowed is not lost but it forms a sleeve around the hole. The length of that sleeve is up to 3 times the original thickness of the material. The presence of this metal lip around hole edges makes connections stronger. Several options are available with this technology. Bits may include a cutting device that removes the typical "collar" of plasticized material that flows upwards, so that an even top surface is the result. Drilled starter holes may be used to reduce the required axial force and to leave a smooth finish in the bushing's lower edge. Internal screw threads may be cut with taps or rolled with dies.

The mechanism of hole formation in friction drilling is due to work. Drilling is mechanism of present work is this method as or friction stir drilling The formation of can be used as observed to be no cutting fluid is in the workpiece and heat is generated due to friction between mating surfaces, owing to this the work softening occurs and on further advancement of tool into the workpiece, the softened material is pushed side ward and forms the bushing. The shoulder of tool contacts the workpiece and does the trimming. Friction drilling is a technique to create a bushing on sheet metal, tubing, or thin walled profiles for joining devices in a simple, efficient way. The bushing thickness can be threaded, providing a more solid connection for attachment than attempting to thread the original sheet. It produces bushes for a tapped and untapped hole. All work material from the hole contributes to form bushing. In addition, no cutting fluid or lubricant is necessary, which makes friction drilling a totally clean, environmentally friendly process.

Fig -1: Friction Drilling

3.TOOL AND DRILLING PARAMETERS

As visualized, the tool consists of three regions. The first α and height hc. This at in this study α is the conical to and length of the cone-shape conical region are marked as β and hn, respectively. The friction angle 30◦ is considered. Lastly, the cylindrical region is the third region. It helps to form the hole and shape of the bushing. The length and diameter of this region are designated as hl and d, respectively. The tool with d = 6.7 mm and hl = 13.4 mm.

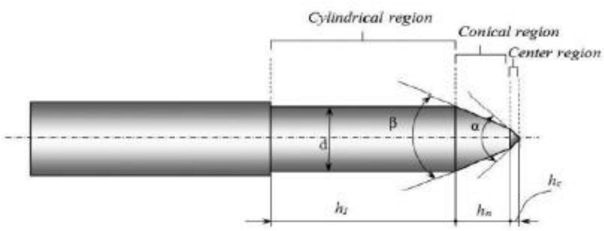


Fig-2: Shape of Friction Drilling Tool

MATERIAL: Al 6061 T6 Al Alloy

Composition of Al 6061 T6 AlAlloy

Mg	Si	Fe	Cu	Zn	Mn	Cr
0.99	0.66	0.25	0.31	0.01	0.08	0.16

Mechanical Properties :

0.2 % of Yield Strength – 275 Mpa
UTS – 310 Mpa [Ultimate Tensile Strength]
Elongation – 12%

This study assumes that friction between the tool and Workpiece follows Coulomb's friction law.

The frictional force Ff is directly proportional to normal force, Fn., The coefficient of friction, μ i.e., Ff = μ Fn. The frictional heat generation rate, is equal to Ff Times the by μ ; μ surface velocity of with tool radius, R,

V = 2πRN, $2\Pi RN\mu Fn$ the heat generation rate

$qp = \eta\sigma\varepsilon pl$ Where η is σ stress, and έ Pl is elastic portion of the workpiece of η was set to 0.7.

Horse power is,

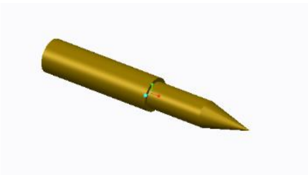
$$HP=(2\pi N(\mu F\times r))/4500$$
$$3=(2\times\pi\times374\times0.61\times f\_f\times3.35)/4500$$
$$\therefore ff=2.81\ KN$$

Frictional force is, ff=μ×F_n Normal force is, Fn= ff/μ =2.81/0.61 =4606 N.
Rotational velocity is, V =2πrN =2×π×3.35×374 =7.872 m/sec.

4.LITERATURE SURVEY: El-Sonbaty et al., [1] conducted the drilling experiment with twist drills of diameter 8, 9, 10, 11, 12 and 13 mm in order to investigate the effect of drill size over thrust and torque in the drilling of glass fiber reinforced plastic. The constant speed of 875 rpm was used. The feed rates of 0.1, 0.23 and 0.5 mm/rev were considered. They identified that, the thrust and torque increases with increase in drill diameter because of the increment in the shear area. They also noticed elevation in thrust force and torque as the spindle speed and feed rate increases. Bhatnagar et al., [2] from their experiment conducted on the composite laminate of glass fiber reinforced plastic, identified that the eight facet and Jo-drills produce the lower thrust force and toque. Hence, they suggested the use of these drills in the drilling of composite materials. The experimental results reveal that the drill with special geometry such as core drills, multifaceted drills, candle stick drills, parabolic drills etc., with modification of drill geometry such as chisel length, rake, clearance, point and helix angle are preferred when the drilling operation carried out with the tungsten carbide tools. Standard twist drill and special geometry drills perform equally in case of HSS drills. Lachaud et al., [3] conducted the drilling experiments over the polymeric composites in order to estimate the delamination. They divided the delamination into four categories such as delamination during entry of the drill, defects due to drill geometry, damage due to temperature, and damage during the exit of the drill. They observed that, the delamination during entry of the drill is not always present. The damage related to tool geometry is always related to the angle between the cutting edge and the fiber orientation. Friction between the drill and wall of the hole is the principal reason for the temperature related damages. Delamination during exit is probably because of the fact that during this stage all fibers are not cut and thus develops the normal stress which opens the matrix/fiber interface. The authors also predicted that the drills which are used for the metal cutting are not suitable for machining of polymeric composites. Crack and petal formation are both undesirable for the thread inside the drilled holes. They are poor traits of bushing due to low ductility of material. Observed by experiments, the number of petals is related to the ratio of the workpiece thickness t and the drill bit diameter d. With the same spindle speed and feed rate, the shape of bushing becomes more ideal and cylindrical, as the workpiece temperature raises. The quality of the bushing has nothing to do with feed rates experimentally.

The change of spindle speed has no big effect on bushing shape in Al 380 at room temperature. There are still significant crack and petal formation at highest spindle speed. However, spindle speed has negative effects on bushing shape in MgAZ91D. At 9 highest spindle speed, 15000 rpm, evident petal formation even layered one is observed which is similar to the bushing shape at room temperature in Al 380. It concluded that the brittle cast metal was less appropriate than ductile sheet metal in friction drilling due to improper bushing shape exhibiting cracks or petal formation [9]. The friction drilled hole geometry was investigated experimentally in AISI 1010 steel square-tube material. The geometry including the washer (boss) geometry, the height of bushing, and the petal geometry was examined with respect to different spindle speeds and feed rates. The experimental results showed the washer (boss) geometry was improved by increasing spindle speeds, and thus the height of bushing is extended. The decrease in radial forces caused by the increase of spindle speeds made sure the smoother washer (boss) was created because of less effect on washer geometry. With high feed rates, the geometry of washer (boss) and the bushing was distorted. For the reason, the low temperature caused by the increased thrust forces in high feed rates effects the washer geometry on the increased ruptures. In the analysis of the bushing shape, the bushing length, petals, and the bushing hemlines are investigated. As the spindle speed increases, the bushing length extends, and less petal formation at the bushing hemline is examined. Compared to the spindle speed effect, the effect of feed rate on the bushing length is small. Nevertheless, the bushing length is found reduced in the high feed rate operation. At the lower hole zone temperature, the deformation hardening on the workpiece is caused by the rapid deformation in the high feed rate condition. Therefore, the extrusion length reduces, and more petals are generated [5]. 10 Pre-drilling friction drilling was investigated as a novel method for improving the bushing shape using A7075-T651 aluminum alloy, which is a brittle cast material. Due to less contact area between the tool and work material, pre-drilling technique caused less temperature increase. Thus, for compensating the temperature deficiency in pre-drilling friction drilling process, higher spindle speed and lower feed rate are inevitable to gain more rotational cycles for generating more friction heat. With the preferred spindle speed and feed rate, the surface roughness decreased as the diameter of the pre-drilling hole increased. To judge the quality of bushing shape, the cracks and petal formation were observed eliminated in pre-drilling friction drilling process. With the larger pre-drilling diameter, the shape of bushing including cylindricality, cracks, and petal formation were improved [6].

5. TOOLS DESIGN



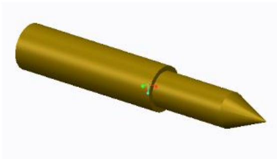
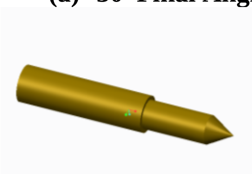


Fig-3 – (a): **Fig-3 – (b)**:

(a) 30^0 Final Angle Tool ; (b) 45^0 Final Angle Tool



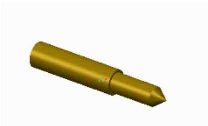


Fig –3- (c): **60^0 Final Angle Tool** ; **Fig –3- (d)**: **75^0 Final Angle Tool**

6.ASSEMBLY OF MODELS

Import rectangular base plate first into assembly window then select default option this default option makes object planes coincide with assembly planes. And then import various angle tools and place at middle of the plates and we created complete assembly model by using only constraint option only.

7. IMAGINARY DRILLING HOLES IN PLATES

Drilling holes are created on the base rectangular plate With all the tool models.

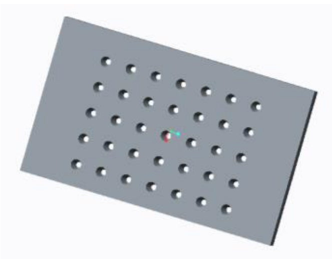


Fig-4-Sample Plate Showing Drilling Holes (30^0 Final Angle Tool)

8. ANSYS [STATIC ANALYSIS]

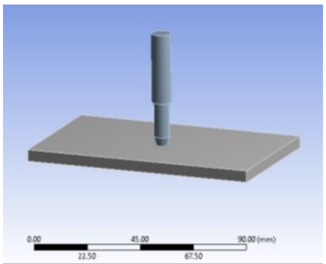


Fig-5-Geometry of Part

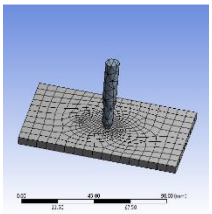


Fig-6-MESHING of Geometry

Applying the boundary conditions i..e for various tool designs

For Stress ; Deformation & Safety Factor. Shown For 45^0 Angle Tool

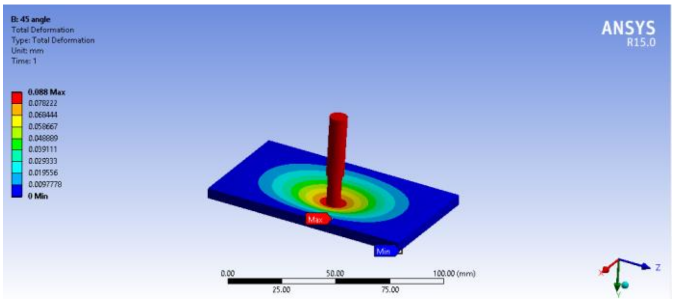


Fig-7- Deformation of 45^0 Tool

The above figure shows deformation results for 45 angle tool here we have maximum deformation 0.088mm

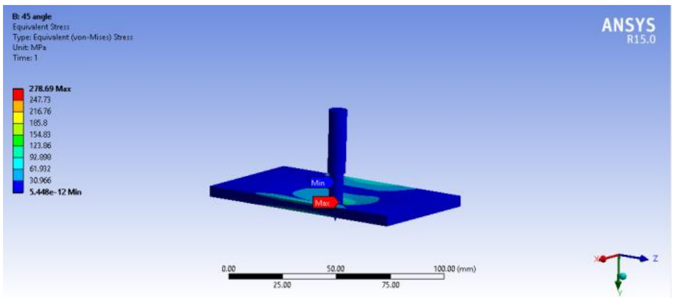


Fig-8- Equivalent Stress of 45^0 Tool

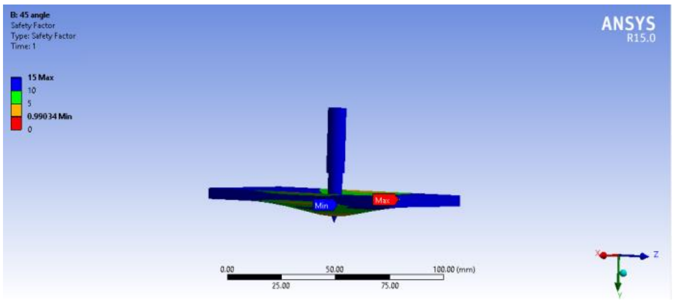


Fig-8- Safety Factor of 45^0 Tool

For Stress ; Deformation & Safety Factor. Shown For 30^0 Angle Tool

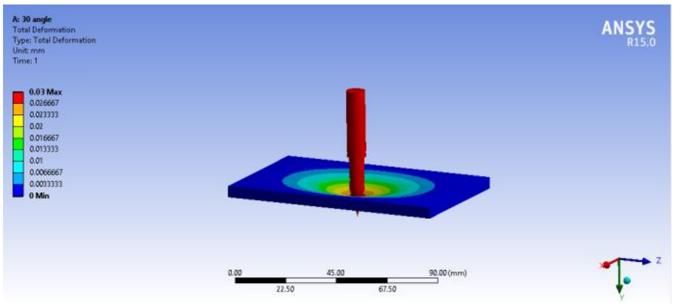


Fig-9- Deformation at 30^0 Tool

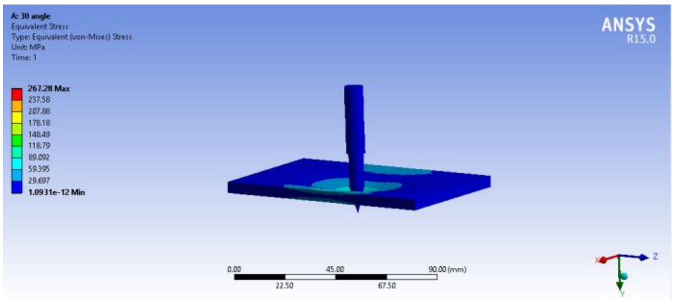


Fig-10- Equivalent Stress at 30^0 Tool

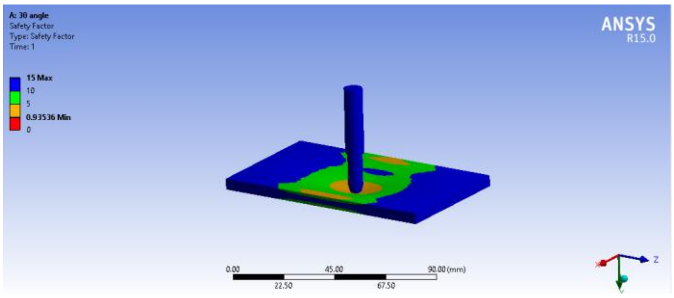


Fig-11- Safety Factor at 30^0 Tool

Similarly We Proceeded and repeated the same process even for 60^0 Angle & 75^0 angle.

RESULTS AND DISCUSSION [STATIC ANALYSIS]

Table 1- : For 30 angle tool

	Deformation(mm)	Stress (Mpa)	Safety factor
Velocity (3e-2mm/s)	0.03	267.28	0.93536

Table 2- : For 45 angle tool

	Deformation(mm)	Stress (Mpa)	Safety factor
Velocity (8.8e-2mm/s)	0.088	278.69	0.99044

Table 3: -For 60 angle tool

	Deformation(mm)	Stress (Mpa)	Safety factor
Velocity (3.75e-2mm/s)	0.0375	284.96	0.96856

Table 4: -For 75 angle tool

	Deformation(mm)	Stress (Mpa)	Safety factor
Velocity (7.5e-2mm/s)	0.075	287.63	0.95955

From the above results here observe it 45 angle tool require more axial velocity to drill the plate but 30 angle and 60 angle tools require very less axial velocity than existing tool, by replacing 45 angle tool to 30 angle or 60 angle tool we can reduce the power requirement
But we cannot decide with only single analysis so here we also analyzing our model with thermal boundary conditions also

9. ANSYS [THERMAL ANALYSIS]

Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the tool is moved downward, a special profile on the probe forces plasticised material from the top face to the bottom, where the high forces assist in a forged consolidation of the drill.

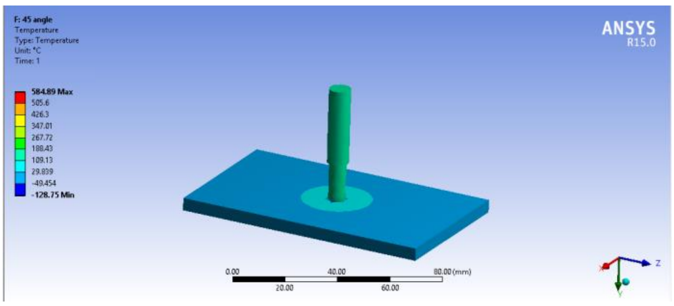


Fig-12- Temperature At 45^0 Tool

The Total Temperature Distribution on plate and tool here we have maximum temperature 584.89^{0}c.

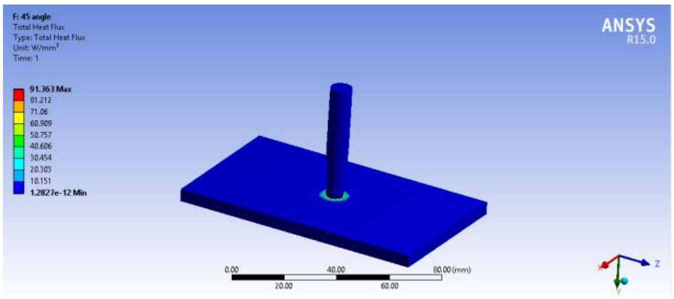


Fig-12- Heat Flux At 45^0 Tool

Similarly We Proceeded with temperature & Heat Flux even for 30^0, 60^0 & 75^0 angle.

RESULTS AND DISCUSSION

Table 5: For 30 angle tool

	Total temperature (*C)	Heat flux (w/mm^2)
Conduction 410*c	592.15	82.674

Table 6 : For 45 angle tool

	Total temperature (*C)	Heat flux (w/mm^2)
Conduction 415*c	584.89	91.363

Table 7 : For 60 angle tool

	Total temperature (*C)	Heat flux (w/mm^2)
Conduction 450*c	601.92	344.43

Table 8 : For 75 angle tool

	Total temperature (*C)	Heat flux (w/mm^2)
Conduction 450*c	586.65	161.85

From the above results here observe that 30 angle tool require less temperature to reach their melting point, it means it take less time than any other tool because it required lower temperature. Values only varies from all these values we can say 30 angle tool only required less time and reaming tools take some time to reach their melting point.

Even though in static results both 30 and 60 angles are required less axial velocity but by comparing both static and thermal results we can replace only 30 angle tool

Graphical Representation of RESULTS

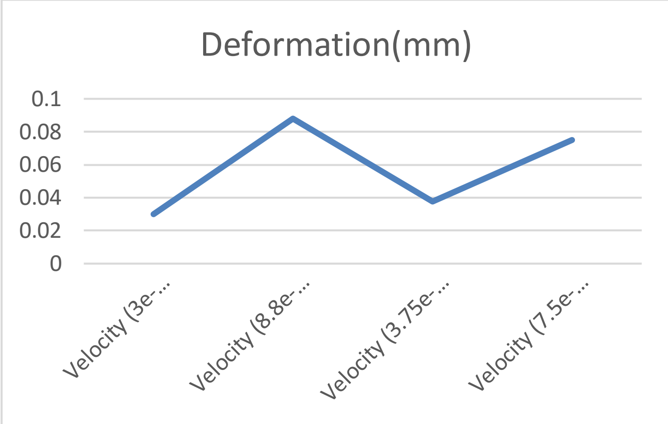


Fig-13- Graphical Representation of Deformation – STATIC ANALYSIS

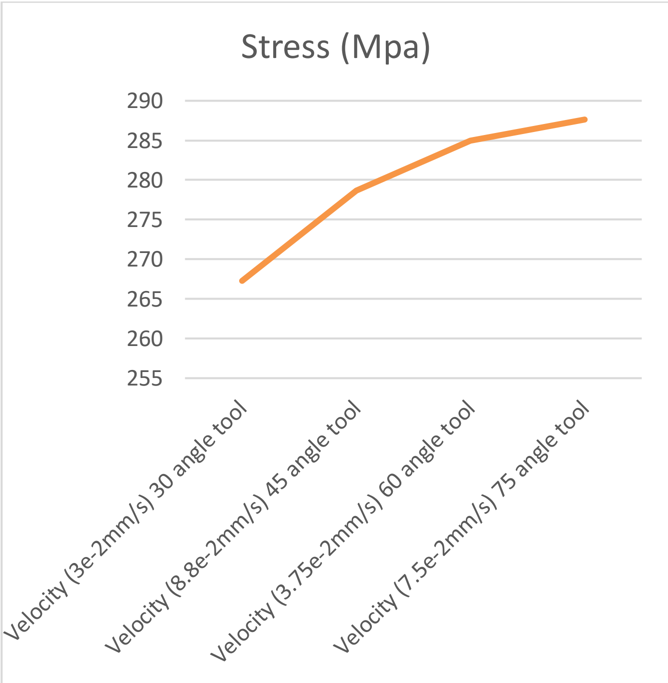


Fig-14- Graphical Representation of Equivalent STRESS – STATIC ANALYSIS

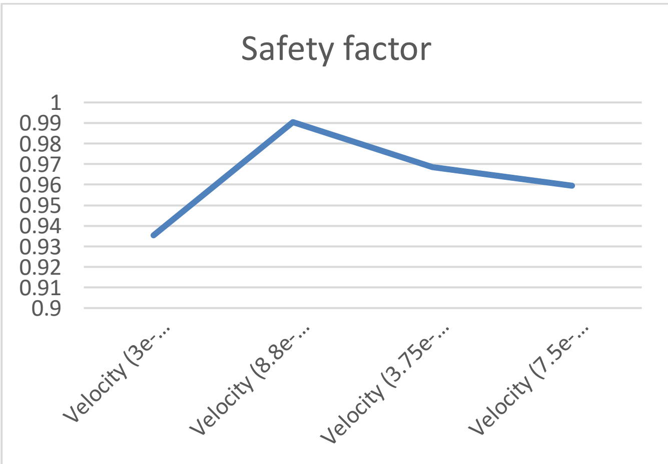


Fig-15- Graphical Representation of Safety Factor – STATIC ANALYSIS

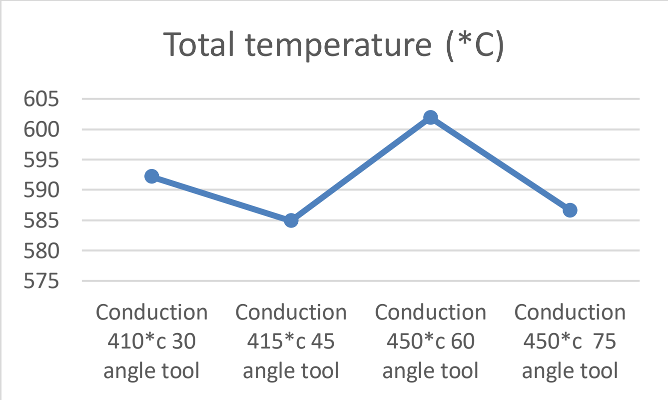


Fig-16-Graphical Representation of TOTAL Temperature – Thermal ANALYSIS

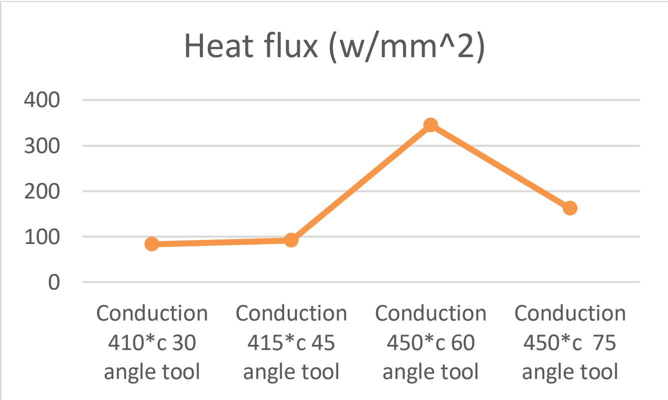


Fig-17-Graphical Representation of HEAT FLUX – Thermal ANALYSIS

10. FINAL CONCLUSIONS AND RESULTS FROM ANALYSIS OF BOTH STATIC & THERMAL

From the static results 45 angle tool require 8.8e-2mm/s axial velocity to drill the plate but when replace this tool with 30 angle tool, it requires only 3e-2mm/s axial velocity only, for 60angle tool 3.75e-2mm/s and 75 angle requires 7.5e-2mm/s axial velocity's, from the results here we can say that 30 angle and 60 angle tools required less axial velocity's than other tools by replacing these tools here we can also reduce the power requirement because high velocity's required high amount of power, but we cannot replace our tool by single analysis, to get more accurate values her we performed thermal analysis on it.
From the thermal results here observe that 30 angle tool require less temperature to reach plate melting point, it means it take less time than any other tool because it required lower temperature Values only from all these values we can say 30 angle tool only required less time and reaming tools take some time to reach their melting point
Even though in static results both 30 and 60 angles are required less axial velocity but by comparing both static and thermal results we can replace only 30 angle tool
Finally By replacing our 30 angle tool we can reduce the usage of power and time both.

ACKNOWLEDGEMENT

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