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3D Finite Element Modeling and Simulation of Friction Drilling Process

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Abstract: ***Friction drilling is an advanced drilling process in which that can be utilize the heat produced between the workpiece and rotating drilling tool bit to soften the work material and producing a hole on it. In this investigation our interest is to choose work material is Al 7075-T351 to analyze the stress, strain, temperature and work material deformation in friction drilling. Al 7075-T351 square-tube materials were drilled on a computer numerical control (CNC) machine centre by friction drilling has analyzed at different rotational speed and feed rate through controlled operation tests. The temperatures in work piece and tool were more in Friction drilling. Simulation has required perceiving the material flow, stresses, temperatures, and strains. Those are tough to quantify experimentally through friction drilling. In this study, CATIA is used to design the tool model and the software which is used to simulate the performance of friction drilling is DEFORM-3D and effect of tool material speed and feed rate on shape of bushing formed is observed. Taguchi's technique L9 Orthogonal Array was used to analyze the optimum values. Signal to noise ratios also administered for optimization of parameters.***

Keywords: ***Friction drilling, DEFORM 3D, cutting temperature.***

I. INTRODUCTION

Now a days friction drilling become getting more recognition technique in hole making with bushing generation process. For research and industrial application it was more engrossment technique. A special tool require for this process for forcing through work piece that will heated up and form a bushing. But here Friction drilling is the new technique going to experiment in aluminium, steel and Titanium alloys with the use of tungsten carbide tool. Friction drilling also called friction stair drilling, thermal drilling, and flow drilling is an unconventional machining process [1]. In Friction drilling no chip was formed that was the most advantage in this process, so that no pollution reduced machining time, minimal tool wear and longer tool life [2]. Generally bush shape depending upon proportion of work material thickness (t), and Drill bit diameter (d) .Height of bushing was approximately 2-3 times of material thickness[3]. Ozler et al. [4] and some other performed an experimental investigation of hole geometry in friction Drilling of AISI 1010 Steel when the feed decreasing and speed increases temperature at hole zone increase. Similarly, good geometry of washer was gets at more speed, and at the same time bushing height expanded. Demir [5] investigate the both diameter and depth of traditionally pre-drilling effect on the frictional heat, bushing shape, and the initial deformation in Friction drilling of A7075-T651 aluminium alloy, some are found the cylindrical shape with minimum petal formation and cracks at time of pre-drilling depths bigger than its length and pre-drilling diameter close to the end diameter of the tip of the tool. Raju and Swamy [6] performed that FEM analysis of friction drilling using DEFORED-3D they predicted that when feed, speed increase stress decreases. Miller et al. [7] performed Friction drilling of cast metals to machining of aluminum Al380 as well as AISI 1020 carbon steel used and explored experimentally the relationship between axial thrust force and torque under different spindle speeds and feed rates. Miller et al. [8] performed on Experimental and Numerical Analysis of the Friction Drilling Process Under the constant tool feed rate, the experimentally measured thrust force and torque were analyzed. Figure 1 shows systematic representation of Friction drilling it has different stages Tool composed of five regions center region which will be the angle alpha (α) and height (hc). This region is generally initiates more force and heat. Conical region has the angle β (beta) and height. This has sharper than the center region, the shoulder region which region rubs against the work material and helps in bush forming. The cylindrical region has diameter d and height hl. This helps to shape the bushing. The shank region is to form the boss on the hole and this will help to grip the tool at tool holder of the machine [9].

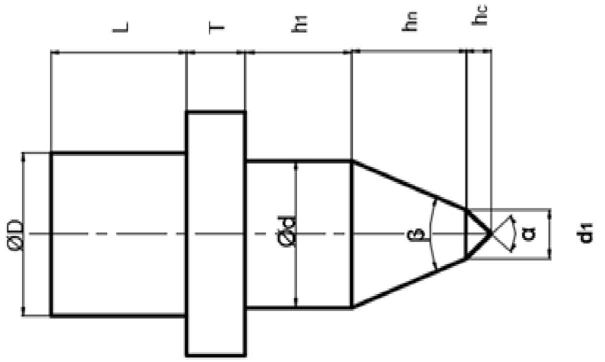

Figure 1 Geometry friction drilling tool

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II. EQUIPMENT SETUP, METHODOLOGY AND MATERIALS

In this Friction drilling A CNC milling machine was employed.A7075-T351aluminum alloy sheets with 3 mm in thickness were used as work material.

The experimental setup was shown in following Figure 2. The tool was machined by Tungsten material with conical angle of 36˚ and diameter of 8mm where different speeds 3000, 3500 and 4000rpm, and feed rates are 30, 40, and 50 mm/min.

Figure 2Experimental setup (high speed 3 axis vertical CNC machine)

The aim of the study is modeling and simulation of friction drilling with tungsten Tool. Aluminum work piece is drilled. Friction drilling process is analyzed and simulated in DEFORM-3D software [10-11]. The variation of effective stain, effective stress and formation of bushing are in Friction drilling were analyzed. Finite component simulations were administered for various feeds keeping speed constant in DEFORM-3D. From simulations, varying elements like stresses, strains, velocities temperature distribution are often observed. Mechanical properties of tool and workpiece as follows in Table 1.

Table 1 Mechanical properties of tool and workpiece

S.no	Mechanical properties	Tungsten carbide (WC)	AL7075-T351
1	Young's modulus(GPa)	600	72
2	Poisons ratio	0.2	0.3
3	Thermal conductivity(W/m.k)	88	130
4	Thermal expansion(10^6/K)	7.1	23.2
5	Density (Mg/m^3)	15.88	2.8
6	Specific heat(J/Kg-k)	184	960

The formation of the depth of hole and bushing are two necessary points to calculating the in Friction drilling. The observations of the bushing formation, roundness, depth, petal formation, and roughness, were created to gauge the favorable of Friction drilling hole. The shape of bushing of AL7075-T351 at various speeds is being studied. A major effect in bush form is observed by varying the spindle speed and feed rates. The temperature was decreased at high spindle speed; the bushing form remains poor at the extreme spindle speed. Notable petal formation was observed at each of the hole [12].

III. RESULTS AND DISCUSSIONS

4.1 Simulation of friction drilling using DEFORM-3D

Friction drilling method is simulated and analyzed with the help of DEFORM-3D software. The variation of effective strain, effective stress, and bushing formation of thermal drilling were observed. FEM simulation has administered to various feeds and speed in DEFORM-3D. As per simulation analysis, variables such as total forces, strains, stresses, temperature distribution and velocities are often obtained. However, all these are very tough to measure experimentally.

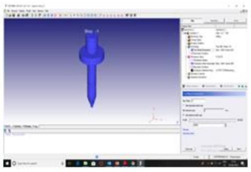

Figure 3(a) Meshed Tool

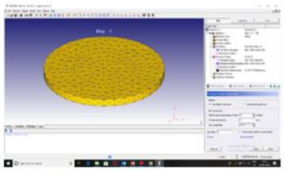

Figure 3(b) Workpiece

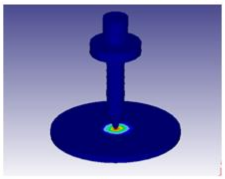

Figure 3(c) Initial stage of Friction drilling.

Figure 3(a) gave the meshed model tungsten carbide tool and meshed model of the work piece Al 7075-T351 presented in Figure 3(b). Hear deformed 3D software use for modeling and simulating the busing shape and hole formation in Friction drilling. Figure 3(c) gave the initial position of friction drilling when the tool tip will contact with the work piece, at this stage temperature of tool will transfer to wok material and it start melting.

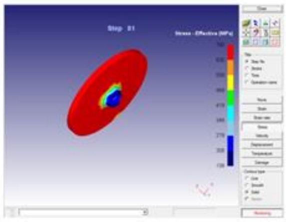

Figure 4.(a)

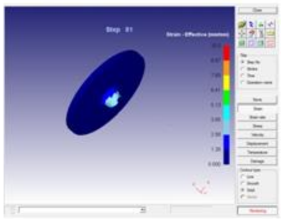

Figure 4.(b)

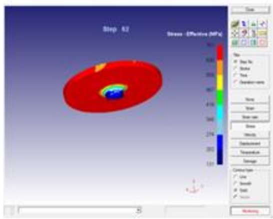

Figure4.(c)

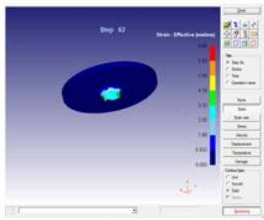

Figure4.(d)

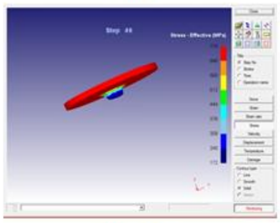

Figure 4.(e)

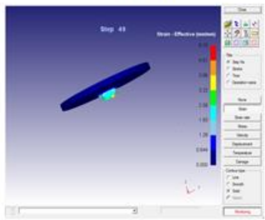

Figure 4.(f)

Figure 4 Bush formation at 3000 rpm and 30, 40 and 50mm/min at feed rate

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The views of bushing forming at bottom surface of the work piece are shown to compare variation in bushing and hole at different speed with different feed rate.

As discussed in the introduction, present research work is aimed at the speed and feed rates will effect on effective stress and effective strain. Thus, to validate results at various speed and different feed rates. Figure 4 represents the 3D finite element simulation results at different feed rates with constant speed. The main purpose of this stage is to show the effect of speed and feed rate on bushing formation and hole geometry. Figures 4(a) to 4 (f) shows that bushing form, effective stress and effective strain at constant speed of 3000rpm and feed 30, 40, and 50 mm/min. while observing Figures 4(a) to 4 (f) when feed increases effective stress increase and effective strain decreases . Similarly feed decreases temperature increases. We will get better bushing at speed of 3000rpm and feed rate of 50mm/min.

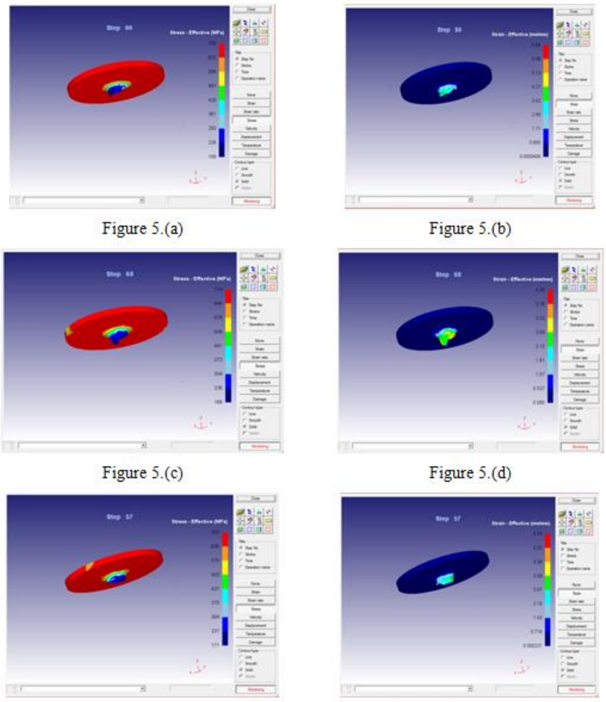

Figure 5.(a) Figure 5.(b) Figure 5.(c) Figure 5.(d) Figure 5.(e) Figure 5.(f)

Figure 5 Bush formation at 3500 rpm with 30, 40 and 50mm/min feed rates

Figure 5 represents the 3D finite element simulation results at different feed rates with constant speed. The main purpose of this stage is to show the effect of speed and feed rate on bushing formation and hole geometry. Figure 5(a) to 5 (f) shows that bushing form, effective stress and effective strain at constant speed of 3000rpm and feed 30, 40, and 50 mm/min. when feed decreases temperature increases.

Similarly when feed decreases effective strain increases. Better hole geometry occur at 4000rpm at feed of 50 mm/min. Similarly, Figure 6 represents the 3D finite element simulation results at different feed rates with constant rotational speed of 4000 rpm. The main purpose of this stage is to show the effect of speed and feed rate on bushing formation and hole geometry. Figure 6(a) to 6(f) presents the formation of bush, corresponding effective stress and effective strain at constant speed of 4000rpm and feed 30, 40, and 50 mm/min. when feed decreases temperature increases. Similarly when feed decreases effective strain increases. Better hole geometry occur at 4000rpm at feed of 50 mm/min.

While observing above figures 4 to 6 when the speed increase temperature may also increase because of temperature is dependent on mechanical and thermal properties of the material. In generally while doing any machining when the cutting speed increases simultaneously the temperature also increases at the interface between tool and work piece. This will cause in softening of the work material. As the time of temperature increases which will result in Expansion or contraction of a structure at the stage stress will be increased [13].

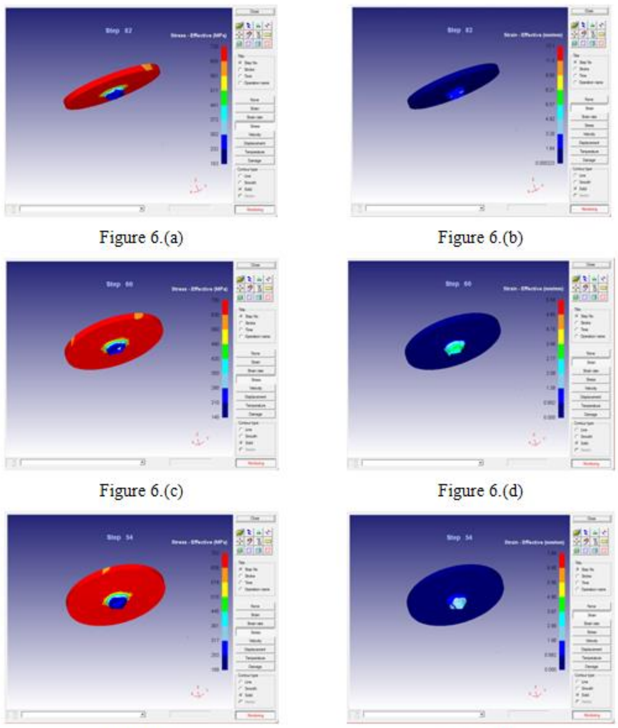

Figure 6.(a) Figure 6.(b) Figure 6.(c) Figure 6.(d) Figure 6.(e) Figure 6.(f)

Figure 6 Bush formation at 4000 rpm with 30, 40 and 50mm/min feed rates

4.3 Taguchi analysis

With the help Taguchi analysis design of experiments were conducted and analyzed the obtained result. In this Taguchi analysis we can able to obtain various graphs like S/N ratio, means, and correlation between any two parameters [BSME]. Taguchi analysis uses for optimization process in 2-steps. Step-1 identifies the control factors that will be reduced variability with the use of Signal- to – noise ratio. Step-2 control factors identifies that move the mean to target and have a small or no effect on the signal-to-noise ratio.

4.3.1 Signal to noise ratio analysis

It is a very useful parameter and also a most significant by considering variation and target with samples of two sets, by comparing mean alone. It uses ANNOVA calculations in Taguchi method of DOE. In general it will be quality characteristics are

1. "Nominal is Better"
2. "Bigger is better"
3. "Smaller is better"

In this case the output are effective strain, stress, and temperature are considered. Hence in case of stress strain and Temperature smaller is better has taken for the analysis.

4.3.2 Effect of speed and feed rate on effective stress and effective strain

The effective-stress and strain at varied speeds 3000, 3500, and 4000 rpm, feed rates 30, 40, and 50 mm/min are observed and analyzed as shown in Table 2. Results for effective stress, effective strain and temperature by changing the feed rates. With the help Taguchi analysis design of experiments were conducted and analyzed the obtained result. The following table3.shows the S/N rations & mean with respective effective stress, strain, and temperature.

Table.2 S/N ratio and means for effective stress and effective strain

S.N0	Speed (rpm)	Feed (mm/min)	Effective stress (MPa)	Effective strain	Temp (^0C)	SNRA1	MEAN1
1	3000	30	700	10.3	491	-53.86	400.43
2		40	701	6.66	463	-53.71	390.22
3		50	716	5.15	422	-53.62	381.05
4	3500	30	700	6.84	487	-53.84	397.94
5		40	714	4.30	476	-53.89	398.10
6		50	703	5.74	478	-53.81	395.58
7	4000	30	720	13.1	504	-54.10	412.36
8		40	700	5.54	455	-53.66	386.84
9		50	702	7.94	453	-53.74	387.64

From the response Table 2, Figures 7 and 8 it is observed that speed of 3500 rpm and 30mm/min feed rate are effecting the process for the set of values obtained by the simulation analysis.

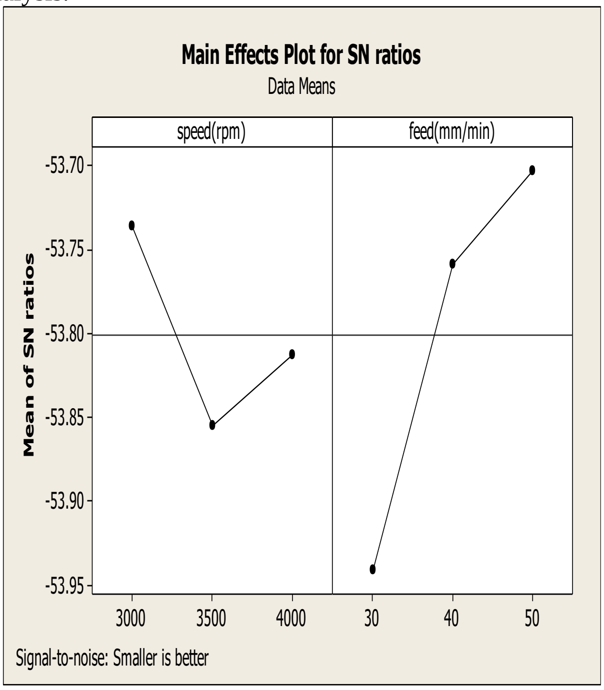

Figure 7 Graph for S/N ratio

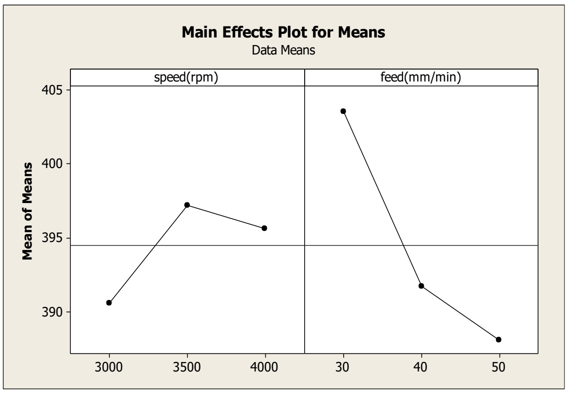

Figure 8 Graph for mean of means

IV. CONCLUSION

Modeling and simulation of Friction drilling has been performed using DEFORM-3D software. Analysis of results has been performed by using MINITAB software. The Friction drilling of AL7075-T351 with Tungsten carbide tool has simulated and observed that there is no chip formation in Friction drilling and there is a slight variation in effective stress by varying speeds and feed rates. Table 3 and figure 7&8 shows that when spindle speed, and feed rate increases, Effective Stress in friction Drilling increases. Where the effective increases with increasing speed, improper bushing formation will occur with increase of speed.

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