Experimental Investigation in Friction Drilling on Copper and Aluminum Component by Using Tungsten Carbide Tool

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Abstract- *Mostly used for sheet materials and hollow tubes, friction drilling now becomes a promising process particularly for mass production in the manufacturing and automotive industries. This project investigates comparative analysis of friction drilled holes on Copper and Aluminium by using tungsten carbide tool. Holes have been drilled on AISI 1015 Copper and AISI 1008 Aluminium square tubes by the friction drilling process which utilizes frictional heat between a rotating conical tool and work material to soften and penetrate the thin walled work piece to form a hole with bushing. The bushing increases depth for threading and the clamp load capacity and best suitable for threading. Naturally formed bush during friction drilling have wide range of application in sheet metal operation and increases productivity. The t/d ratio of friction drilled holes and the spindle speed are the two main parameters affecting the process. Experiments have been carried out using Taguchi's orthogonal array L18. Thermal analysis and Microstructure variation during the friction drilling process are measured and analyzed.*

Keywords- Friction Drilling, Taguchi Method, Material type, Speed, Feed, Temperature, Thermal Stress, Hardness, Surface Roughness, Bush length and Microstructural variation.

I. INTRODUCTION

Friction drilling [1] is a non-traditional hole-making method that utilizes the heat generated from friction between a rotating conical tool and the work piece to soften and penetrate the work-material and generate a hole in a thin walled work piece. The purpose of the bushing is to increase thickness for threading and available clamp load. Form tapping is a chip-less process. The thread profile is produced by displacement of the material in a cascaded forming process. Basically all formable materials can be thread formed, usually materials with less than 1200N/mm² tensile strength and a breaking elongation of more than 8%.

Introduction to Taguchi approach to quality

The quality engineering methods of Dr. Taguchi is one of the important statistical tools of total quality management for designing high quality systems at reduced cost. Taguchi method is one of the simplest and effective solutions for parameter design and experimental planning. It analyzes the influence of parameter variation to performance characteristics. Thereby, an optimal result can be obtained so that the sensitivity of performance characteristics in respect to parameter variation. Taguchi recommends a three stage process to achieve desirable product quality by system design, parameter design and tolerance design. While system design helps to identify working levels of the design parameters, parameter design seeks to determine levels of parameter that provide the best performance of product or process under study. The optimum condition is selected so that the influence of uncontrollable factors (noise factors) causes minimum variation to system performance.

II. MATERIALS AND METHODS

The material selected for present work is Copper and AISI 1008 Aluminium is selected for experimentation purpose. The material is in square tube form. Material has same thickness.

METHODS

Following input and output parameters are considered:

Input parameters Material type, Spindle speed (rpm), and Feed (mm/mint) Output (responses) measured during the experiments are: Friction drilling Temperature (^{0}C), Roughness ,Bush length (mm), Thermal stress and Hardness (Hv) input parameters and their levels are shown in Table-I

Table I Process factors and their levels

Levels	Speed (Rpm)	Feed(mm/min)
1	2500	80
2	3100	120
3	3700	160

Selection of Taguchi L18 orthogonal array

Any nonlinear relationship among the process parameters, if it exists can only be revealed if more than two levels of parameters are considered. In friction drilling process many input process parameters affect on the vertical machining centre like tool type,tool material,material thickness, spindle speed, feed rate in present work the process parametrs i.e. material type, spindle speed, and feed rate depending upon the input parameter 3 levels were selected.

III. EXPERIMENTATION

The experiments are carried on Vertical Machining Centre PVM 40 machine, to carry out experiment the VMC program designed in such a way that initially drilling cycle was carried out with the help of CNC program.

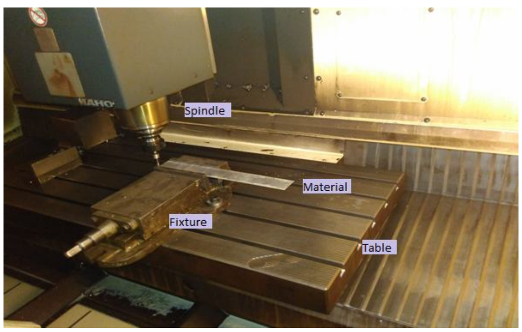


Fig 3.Friction drilling of Aluminium

Table II Design table with actual values (For Taguchi Analysis)

Expt. No	Speed (Rpm)	Feed (mm/min)	Material
1	2500	80	Copper
2	2500	120	
3	2500	160	
4	3100	80	
5	3100	120	
6	3100	160	
7	3700	80	
8	3700	120	
9	3700	160	
10	2500	80	Aluminium
11	2500	120	
12	2500	160	
13	3100	80	
14	3100	120	
15	3100	160	
16	3700	80	
17	3700	120	
18	3700	160	

IV. RESULTS AND DISCUSSION

A. Temperature (^{0}C), Roughness (Rz), Thermal stress (N/mm2) and Hardness (Hv):

Measurement of Temperature is done through infrared pyrometer on CMM and Hardness through Vickers Hardness Tester. The tool surface temperature was increased with increasing spindle speeds, decreasing feed rates and thermal conductivity of frictional drilled material. The maximum heat was measured as 141.2°C & 61.2°C at the surface of the friction drilled hole for Copper and aluminium alloy respectively, which has the lower thermal conductivity coefficient, at 80 mm/min feed rate and 3700 rpm spindle speed. The minimum heat was measured as 90.1°C for copper and 48°C aluminium alloy respectively, which has the lower thermal conductivity coefficient, at 160 mm/min feed rate and 2500 rpm spindle speed. Therefore with decrease and increase feed rates the frictional heat was increased and decreased respectively. And with decrease and increase speed rates the frictional heat was decreased and increased respectively. Table 2 shows type of material with incremental values of speed and feed.

Table III Experimental Output Responses

Ext. No	Temp (°C)	Hardness (Hv)	Surface Roughness (Rz)	Material
1	98.9	128.7	12.85	Copper
2	95.2	124.2	17.1	
3	90.1	115.3	13.55	
4	121	118.6	10.61	
5	116	116.5	12.3	
6	110	114.5	15.18	
7	141	112.9	15.5	
8	140	111.3	16.73	
9	136	110.6	15.99	
10	51.5	50.2	14.05	Aluminium
11	49.9	43	23.99	
12	48	49.8	22.85	
13	56.3	47.8	31.41	
14	55.1	48.5	20.05	
15	53.9	49.9	15.85	
16	61.2	42.5	13.99	
17	59.9	42.7	14.85	
18	58.6	57.8	25.1	

B. Analysis by using software

A finite element model using the ANSYS software was created for a more comprehensive approach. Experiments with similar process parameters were conducted for validation of temperature generated in the model. This study builds the foundation for friction drilling prediction and process optimization. The structure to be analyzed is subdivided into a mesh of finite sized elements of simple shape. Within each element, the variation of displacement is assumed to be determined by simple polynomial shape functions and nodal displacements. Equations for the strains and stresses are developed in terms of the unknown nodal displacements. From this, the equations of equilibrium are assembled in a matrix form which can be easily be programmed and solved on a computer. After applying the appropriate boundary conditions, the nodal displacements are found by solving the matrix stiffness equation. Once the nodal displacements are known, element stresses and strains can be calculated. The Thermal stresses obtained for various experiments by FEA are tabulated.

C. Multiple Regression Method

For establishing relationship between Temperature of Friction drilling and three input parameters,

Temperature (^{0}C), thermal stress (e), Roughness (Rz) and Hardness (Hv) is expressed as an exponential function of Material type (Mt), Speed (S) and Feed (F) as,

$Tp = K\ Mt^{m1}S^{m2}F^{m3}$

$Rz = K\ Mt^{m1}S^{m2}F^{m3}$

$Hv = K\ Mt^{m1}S^{m2}F^{m}$

As per regression calculation, values of K, m^1, m^2, and m^3 have been calculated.

Regression Equations in Coded Form as

For Temperature (^{0}C)

$Tp = 10^{2.6037} x Mt^{-0.0927} x S^{0.01008} x F^{-0.03981}$

For Hardness (Hv)

$Hv = 10^{1.9875} x Mt^{0.19304} x S^{0.01023} x F^{0.0049}$

For Surface Roughness (Rz)

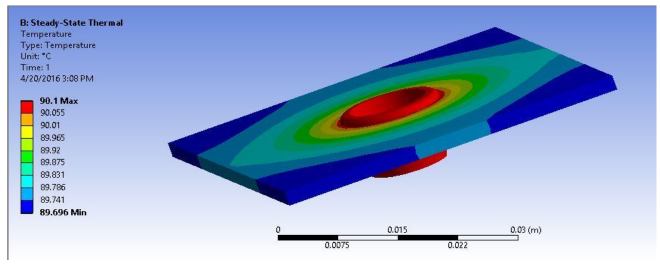
$Rz = 10^{0.9965} x Mt^{0.006} x S^{0.0046} x F^{-0.0078}$

D. Optimization Using Linear programming

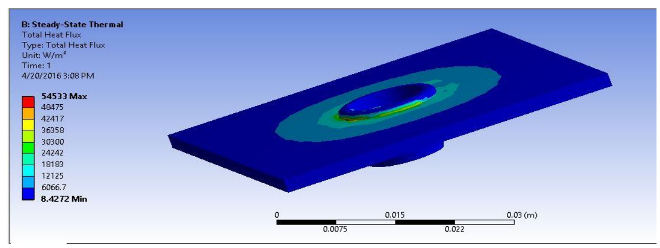
Friction drilled hole. Out of these three parameters, Optimize the best suitable parameter for all three responses.

Measurement of Surface Roughness of Copper

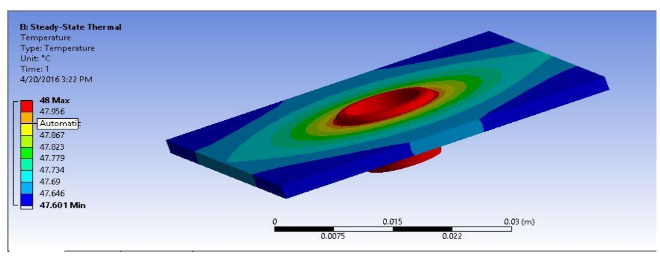
Measurement of Surface Roughness of Aluminium



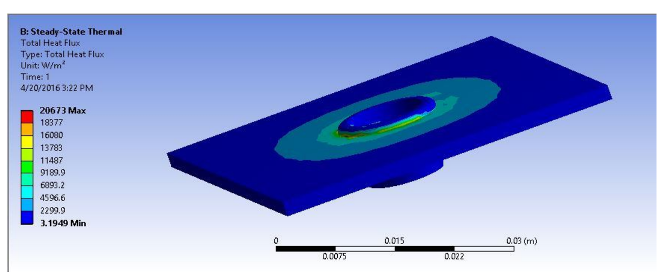
Temperature distribution analysis of Copper



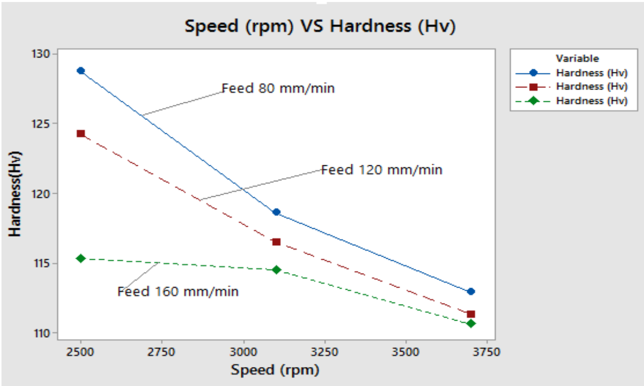
Total heat flux analysis of Copper



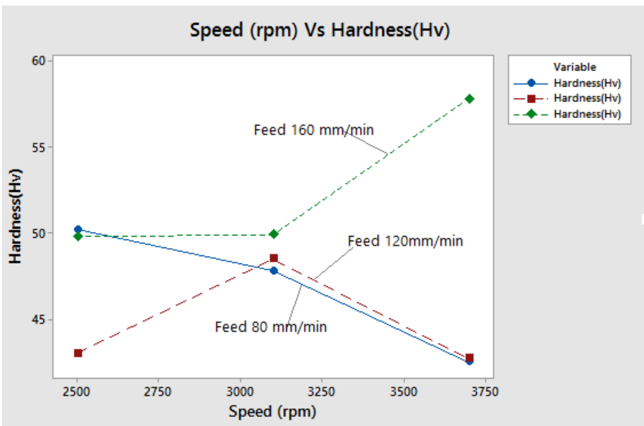
Temperature distribution analysis of Aluminium



Total heat flux analysis of Aluminium



Speed (rpm) Vs Hardness (Hv) for Copper



Speed (rpm) Vs Hardness (Hv) for Aluminium

VI. CONCLUSION

Taguchi analysis is carried out in order to determine the significant process parameters considering the responses as Temperature, Surface Roughness, Bush length, and Hardness in friction drilling operation. Taguchi analysis shows that the factors affecting the Temperature in the order of their significance (delta ranking) is Material type, Speed and feed the delta ranking for Bush length and Hardness are Material type, Speed, and Feed Respectively. The optimum parameter settings found according to the Taguchi analysis are M1S3F1, M2S3F1, and M1S2F1 for Temperature, Surface Roughness and Hardness respectively.

The high frictional heat was generated at high spindle speeds and low feed rate in friction drilling of aluminium and copper. As the feed increases the temperature also increases. Hardness of copper is high as compared to aluminium due to that high temperature is generated in copper.

Because of incomplete softening temperature in aluminium the material was adhering on drill and therefore the surface roughness of the hole increased. If you compared the surface roughness of twist drill with friction drill is too high. So, surface roughness values are low in friction drilling. Surface Roughness values are more in aluminium as compare to Copper after the calculation of three output responses we have done the CAE analysis of friction drilled hole in that it observed that high heat develop in copper as compare to aluminium and around the circumference of circle that heat is dissipated throughout the length. While increasing the feed rates the bushing height was increased gradually but in some cases it might decreases due to softened material were pushed in direction of tool motion, and it was decreased regularly with increasing spindle speed because of the affection of the high momentum. Petal formation is dependent on material properties.

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