



Investigation Of Microstructure And Hardness Profile On Thermal Friction Drilled Stainless Steel Alloy

KAVIN.S¹, MURUGAN.G²

1 PG SCHOLAR 2 ASSISTANT PROFESSOR

1 M.E ENGINEERING DESIGN

2 DEPARTMENT OF MECHANICAL ENGINEERING

SELVAM COLLEGE OF TECHNOLOGY(AUTONOMOUS), TAMILNADU, INDIA

ABSTRACT

The thermal friction drilling process is widely used as an alternative to conventional drilling with immense potential benefits like environmentally safe, burr free operation, greater shear strength joints, and shorter processing time and used as integrated joining technology using automated robotics. In this investigation, friction drilling of medical grade austenitic stainless steels SS304 and SS316 are extensively studied for bush formation and microstructural observation for different rotational speed and feed using tungsten carbide (WC) form drill. Drilling plays significant role in machining. More than 40% of material removal operations are related with this kind of action. Usually, high temperature is generated during drilling operation. Therefore, the drilling tool becomes dull and leads to a limited-service life. The chips clung to the exit of a penetrated opening decimation the surface quality and weaken drilling exactness. To eliminate this difficulty form drilling established. Form drilling, also known as “thermal drilling”, “flow drilling”, “friction drilling”, or “friction stir drilling”, is the best result to the above-mentioned difficulty. Form drilling is a non- traditional hole making operation. A rotating conical tool is implemented to penetrate a hole and create a bushing in one step without initiating chip. The form drilling process depends on the heat produced from the frictional force between the tool and workpiece to soften the work material, penetrate, and deform the work material into a bushing. The present review focus on an explanation of the influence of various drilling process parameters of form drill tool on different work material in form drilling process.

KEYWORDS: Bushing, Form Drilling, Temperature and Materials.

1.INTRODUCTION

Thermal friction drilling, or what's more commonly known simply as friction drilling, is a cutting process that uses friction to assist with the removal of material. With friction drilling, the tool bit creates friction as it rotates into the workpiece. Friction, of course creates heat, which then helps to remove material from inside the workpiece. Friction drilling requires the use of a special tool bit to create friction and, thus, heat. The tool bit features a conical shape and is constructed of a heat tolerant material the most common being cemented carbide. When used in friction drilling, the tool bit will rotate against a workpiece's surface. Combined with pressure, the rotational movement of the workpiece while creating friction to assist with the removal of material but here friction drilling is going to experiment in austenitic stainless steel by tungsten carbide tool. Friction drilling, also known as thermal drilling, flow drilling, form drilling, or friction stir drilling, is a non-traditional hole making method. The heat generated from friction between a rotating conical tool and the workpiece is used to soften the work material and penetrate a hole. The tip of the conical tool approaches and contacts the work piece. The tool tip, like the web center in twist drill, indents into the work piece and supports

the drill in both the radial and axial directions. Friction on the contact surface, created from axial force and relative angular velocity between tool and work piece, produces heat and softens the work piece material.

2. LITERATURE SURVEY

S. RAJENDRA BOOPATHY, G. SOMASUNDARAM AND K. PALANIKUMAR [2011] [1]: Utilized conical drill tool with $d=5.3$ mm, $\alpha=90^\circ$, $\beta=36^\circ$, $h_c=0.970$ mm, $h_n=7$ mm, $h_l=15$ mm, shoulder region length is 7mm, shank region length is 30mm of high speed steel (HSS) and conducted comprehensive analysis on friction drilling of Al/SiCp metal matrix composites and discussed the roundness errors on friction drilled holes. The result and discussion show effects of individual input parameters on roundness error in form drilling process. They prepared design of experiments by using response surface methodology. They analysed roundness errors of workpiece with experimental design matrix and gave experimental relation between the process parameters which are spindle speed and feed rate. The conclusion from result explained that this method is suitable to predict the main effects and interaction effects of machining parameters.

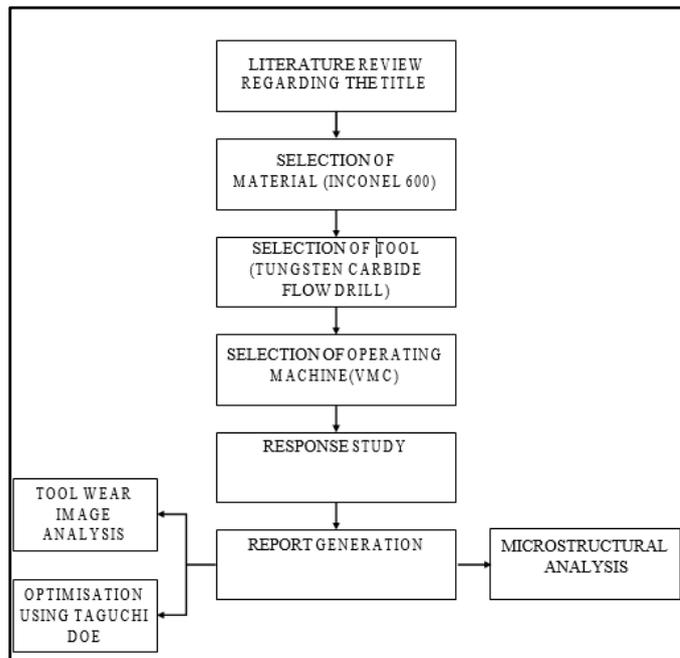
G.SOMASUNDARAM, S.RAJENDRA BOOPATHY [2010] [2]: Adopted a low volume low-cost fabrication technique to fabricate the AlSiC MMC plates and manufactured conical drill tool with $d=5.3$ mm, $\alpha=90^\circ$, $\beta=36^\circ$, $h_c=0.970$ mm, $h_n=7$ mm, $h_l=15$ mm, shoulder region length 7mm, shank region length 30mm of high-speed steel (HSS), which is an economical and efficient one. They proposed the efficiency and advantages of this technique on drilled holes and analysed the interaction effect of parameters by using design of experiments method called response surface methodology. They concluded that roundness error increase with increase in spindle speed, feed rate and thickness of plate. Also, it decreases with increase in weight percentage of SiC.

DR. A. GOPICHAND, M.VEERABRAHMAM, D. BHANUPRAKASH [2014] [3]: Used optimal drill tool geometry with $d=7.3$ mm, $\alpha=90^\circ$, $\beta=36^\circ$, $h_c=0.970$ mm, $h_n=8.490$ mm, $h_l=8.896$ mm of tungsten carbide (WC) conical tool and proposed to use FEM to analyze the stress, strain and deformation of the work material in friction drilling as modelling and simulation is essential tool to understand the material flow. They used the Ansys software to simulate the behavior of friction drilling process which is difficult to measure experimentally. The modelling of the friction drilling tool HSS, WC and work material A7075-T6 was developed in PRO/E software. They conclude that the minimum equivalent von-mises stress is obtained at maximum speed and feed rate for HSS tool and proper burr formation occurred at 2000 rpm and 40 m/s feed rate for both HSS and tungsten tools.

DIWAKAR REDDY.V, KRISHNAIAH.G, GOPI CHAND AND INDUMATHI [2011] [4]: Analysed mechanical aspects of form drilling by using Aluminium (A1100) as work material and high-speed steel as conical drill tool. They designed Experiment layout by full factorial method and did analysis by analysis of variance ANOVA method. They applied Taguchi method to estimate the performance of high-speed steel form drill on AA1100 work piece of thickness 6mm. The experimental measurements revealed that for base tool requires less torque and thrust force compared to pointed tool, also from the contributed values it is concluded that the R2/R1 ratio is a critical parameter.

P. V. GOPAL KRISHNA, K. KISHORE AND V. V. SATYANARAYANA [2010] [5]: Investigated mechanical aspects of friction drilling by taken Aluminium (AA6351) as work material. They designed proper experimental design and applied taguchi method to estimate the performance of HSS drill on AA6351 workpiece of 1mm thickness. They concluded that a highly burnished surface is obtained for AA6351 at low and medium speed, at high-speed discolorations is observed.

3.METHODOLOGY



4. SELECTION OF MATERIALS, TOOLS AND MACHINES

4.1 MATERIALS USED

Stainless Steel
 Austenitic Stainless Steels
 Ferritic Stainless Steels
 Martensitic Stainless Steels
 Duplex Stainless Steels
 Precipitation Hardening Grades

4.2 CHEMICAL PROPERTIES OF STAINLESS STEEL

ELEMENT	COMPOSITION (Wt.%)
C	0.08
Mn	2
P	0.045
S	0.3
Si	0.75
Cr	18-20
Ni	8-10.5
Mo	-
Fe	Balance

Fig:1 Chemical Composition of SS304

ELEMENT	COMPOSITION (Wt. %)
C	0.08
Mn	2
P	0.045
S	0.3
Si	1
Cr	16-18
Ni	Oct-14
Mo	02-Mar
Fe	Balance

Fig :2 Chemical Composition of SS316

4.3 MECHANICAL PROPERTIES OF STAINLESS STEEL

Mechanical properties specified for flat rolled products are normally tensile strength, yield stress (or proof stress), elongation and Brinell or Rockwell hardness. Property requirements for bar, tube, pipe and fittings typically state tensile strength and yield stress.

Yield Strength of Stainless Steel

Ductility of Stainless Steel

Hardness of Stainless Steel

Tensile Strength of Stainless Steel

MECHANICAL CONSTANTS	VALUE
Ultimate tensile strength [N/mm ²]	585
Vickers hardness	155
Thermal conductivity[K], W[m-K]	17
Impact strength	129

Fig:3 Mechanical properties of SS304

MECHANICAL CONSTANTS	VALUE
Ultimate tensile strength [N/mm ²]	515
Vickers hardness	91
Thermal conductivity[K], W[m-K]	15
Impact strength	129

Fig: 4 Mechanical properties of SS304

Temperature (K)	SS304L		SS316L	
	Thermal conductivity (W/cmK)	Thermal diffusivity *10 ² (cm ² /sec)	Thermal conductivity (W/cmK)	Thermal diffusivity *10 ² (cm ² /sec)
300	0.1297	3.237	0.1396	3.529
400	0.1459	3.546	0.1553	3.834
500	0.162	3.849	0.171	4.132
600	0.1782	4.148	0.1868	4.424
700	0.1944	4.44	0.2025	4.71
800	0.2106	4.727	0.2182	4.989
900	0.2267	5.009	0.2339	5.262
1000	0.2429	5.285	0.2496	5.529
1100	0.2591	5.555	0.2653	5.19
1200	0.2757	5.82	0.281	6.044

Fig:5 Thermal Conductivities and Thermal. Diffusivities of Stainless Steels Type 304L and Type 316L

5. TOOL USED FOR THERMAL FRICTION DRILLING

Thermal drill tool creates the frictional heat by the combined action of rotational speed and downward feed rate. It allows the sheet metal at the drilling zone to be transformed into “super plastic state” due to that the metal displacement occurs in both downward and upward direction. The bushing is formed due to the downward displacement of material flow along with a boss due to the upward material displacement. In the thermal drilling process, the temperature at the frictional contact of thermal drill and sheet metal work piece is the most significant parameter. While processing, the temperature of the thermal drill could the damaging of metal structure leads to affect the bushing shape and also the microstructure of the bush wall surface is altered by hot thermal drill. Normally, the temperature of sheet metal work piece increases to 600 °C and the thermal drill tool temperature varies from 650 to 750 °C. These values of temperature have been reported to vary according to the drilling tool shape and thermal properties of sheet metal to be drilled.

As visualized, the tool consists of three regions. The first one is the center region. It has an angle α and height. This region provides the support in the radial direction for the friction drilling process and keeps the drill from walking at the start of the drilling process. The tools used in this study has $\alpha = 90^\circ$ and $h_c = 1$ mm. The second one is the conical region. It has a sharper angle than the center region. The tool in this region rubs against the workpiece to generate the friction force and heat, and pushes the work-material side ward to shape the bushing. The friction angle and length of the cone-shape conical region are marked as β and h_n , 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 h_l and d , respectively.

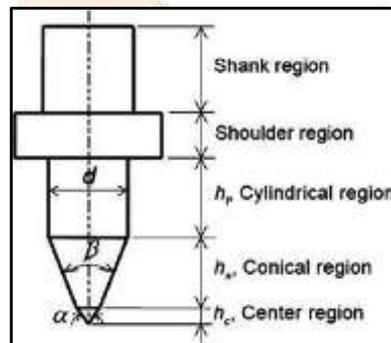


Fig: 6 Schematic Representation of Thermal Drilling. (ref.6)

The tool wear in friction drilling is categorized into three mechanisms, which are named abrasive wear, adhesive wear, and oxidative wear. The material removal from the drilling tool by hard abrasive phases in the workpiece material is defined by abrasive wear. In friction drilling, abrasive wear occurs as circular grooves in the conical and center regions of the drilling tool. The contact between the two sliding surfaces in the friction drilling process, which generates heating, causes material adhesion from the workpiece and drilling tool to each other. However, most material transfer occurs from the workpiece to the drilling tool. The material adhesion from the workpiece to the drilling tool is named adhesive wear. High heat generation in the workpiece–tool interface increases the potential for oxidization on the drilling tool surface. An oxide layer normally covers the surface of the drilling tool, preventing material adhesion and reducing the adhesive wear tendency.

Some of the thermal drills used in the previous research works. As thermal drilling is typically a pre-tapping process, drill manufacturers do not use drill diameters for generating their products. Mainly, the dimension of drill tool bit is determined by determining the size of the thread to be used. Most of the researchers used the material for the thermal drill tool is tungsten carbide and high-speed steel material is used by the research. Generally, the center angle used in the design of tool as 90° and conical angle has varied from 33° to 36° . Different value of center and conical angle is connected with the change of the peripheral speed to decrease friction force after workpiece piercing and not implement thermal changes into workpiece while forming. The height of the cylindrical region has varied based on the thickness of the work piece material. It may be varied from 2 mm to 10 mm.

Dimensions	Krasauskas et al. [46]	Pantawane et al. [51]	Miller et al. [53]	Somasundaram et al. [68]	Miller et al. [72]	Biermann et al. [73]
Diameter (d)	5.2 mm	9.2 mm	7.3 mm	5.3 mm	5.3 mm	5.4 mm
Center angle (α)	86°	90°	90°	90°	90°	90°
Conical angle (β)	33	33	36	36	36	34
Center height (hc)	0.6 mm	1.7 mm	0.970 mm	1 mm	0.940 mm	0.75 mm
Conical height (hn)	4.4 mm	11.5 mm	8.490 mm	10 mm	5.518 mm	7 mm
Cylindrical height	5 mm	9.3 mm	8.896 mm	15 mm	7.043 mm	9 mm

Fig:7 Dimensions of thermal drills used in previous research work.

6. VERTICAL MILLING MACHINE



Fig:8 Vertical Milling Machine(ref.6)



Fig:9 Inside the VMC (ref.6)

In the **vertical milling machine**, the spindle axis is vertically oriented. Milling Cutters are held in the spindle and rotate on its axis. The spindle can generally be lowered (or the table can be raised, giving the same relative effect of bringing the cutter closer or deeper into the work), allowing plunge cuts and drilling. There are two subcategories of vertical mills: the bed mill and the turret mill.

A **turret mill** has a fixed spindle and the table is moved both perpendicular and parallel to the spindle axis to accomplish cutting. Some turret mills have a quill which allows the milling cutter (or a drill) to be raised and lowered in a manner similar to a drill press. This provides two methods of cutting in the vertical (Z) direction: by raising or lowering the quill, and by moving the knee.

In the **bed mill**, however, the table moves only perpendicular to the spindle's axis, while the spindle itself moves parallel to its own axis. Turret mills are generally considered by some to be more versatile of the two designs. A third type also exists, a lighter, more versatile machine, called a mill-drill. The mill-drill is a close relative of the vertical mill and quite popular in light industry; and with hobbyists. A mill-drill is similar in basic configuration to a very heavy drill press, but equipped with an X-Y table and a much larger column. They also typically use more powerful motors than a comparably sized drill press, most are multi-speed belt driven with some models having a geared head or electronic speed control. They generally have quite heavy-duty spindle bearings to deal with the lateral loading on the spindle that is created by a milling operation. A mill drill also typically raises and lowers the entire head, including motor, often on a dovetailed (sometimes round with rack and pinion) vertical column. A mill drill also has a large quill that is generally locked during milling operations and released to facilitate drilling functions. Other differences that separate a mill-drill from a drill press may be a fine tuning adjustment for the Z-axis, a more precise depth stop, the capability to lock the X, Y or Z axis, and often a system of tilting the head or the entire vertical column and powerhead assembly to allow angled cutting-drilling. Aside from size, the principal difference between these lighter machines and larger vertical mills is that the X-Y table is at a fixed elevation; the Z-axis is controlled by moving the head or quill down toward the X, Y table.

7. CONCLUSION

7.1 WORK DONE SO FAR

The purpose of selecting the thermal friction drilling process is more efficient than conventional drilling process.

To study the previous literature reviews and material properties for improvement thermal friction drilling process.

To selection materials, Tools and machines for the thermal friction drilling process.

7.2 WORK TO BE DONE

Tool wear image analysis clearly shows us the tool damage like adhesive (material welded), abrasion (peel of region) and so on.

Microstructural analysis and hardness test for find the formation of fine grain structure near the boundary of the stir zone, and coarse grain structure away from the boundary of drilled hole for SS304 and SS316 material.

SS304 and SS316 materials should be tested for thermal conductivity and compare the result to which one is suitable for thermal friction drilling.

8. REFERENCES

1. G. Somasundaram, S. Rajendra Boopathy and K. Palani Kumar, Modelling and analysis of roundness error in friction drilling of aluminum silicon carbide metal matrix composite, Journal of Composite Materials, 2011, 169-181.
2. G. Somasundaram, S. Rajendra Boopathy, Fabrication and Friction drilling of Aluminium Silicon Carbide Metal Matrix Composites, IEEE Journal, 2010.
3. Dr. A. Gopichand, M. VeeraBrahmam, D. Bhanuprakash, Numerical Simulation and Analysis of Friction drilling Process for Alumina Alloy using Ansys, International Journal of Engineering Research & Technology (IJERT), 3(2), 2014.
4. Diwakar Reddy.V, Krishnaiah.G, Gopi Chand and Indumathi, Analysis in Form Drilling AA100 Using HSS Tools, International Conference on Trends in Mechanical and Industrial Engineering (ICTMIE), 2011.
5. P. V. Gopal Krishna1, K. Kishore1 and V. V. Satyanarayana, Some Investigation in Friction Drilling AA6351 Using High Speed Steel Tools, ARPJ Journal of Engineering and Applied Sciences, 5(3), 2010.
6. Han-Ming Chow, Shin-Min Lee, Lieh-Dai Yang, Machining Characteristic Study of Friction Drilling on AISI 304 Stainless Steel, Journal of Materials Processing Technology, 2008, 180-186.
7. Shin Min Lee, Han Min Chow, Fuang Yuan Huang, Biing Hwa Yan, Friction Drilling of Austenitic Stainless Steel by Uncoated and PVD AlCrN and TiAlN Coated Tungsten Carbide Tools, International Journal of Machine Tools and Manufacture, 2009, 81-88.

8. Scott F. Miller and Albert J. Shih, FRICTION DRILLING – A chip less hole making process, ASME International Conference on Manufacturing Science & Engineering 2006, 8-11.
9. Shi shaojun, zeng xianping and Sun Chengtong, Heat-treatment and properties of highspeed steel cutting tools, IOP Conf. Series: Materials Science and engineering, 2018.
10. Pantawane. P.D, Ahuja. B.B, Experimental investigations and multi- objective optimization of friction drilling process on AISI 1015, International Journal of applied engineering research, 2(2), 2011.

