Friction Drilling an Emerging Technique in Hole Making Process

Mathew Alphonse and V. K. Bupesh Raja

Abstract Friction drilling is identified as a new way of hole making process, which is also known as nontraditional drilling method. The traditional drilling process has been covering in 90% of the machining process and it is not suitable for sheet metal application. Researchers are focusing on nontraditional drilling process for completing the drilling on sheet metal. This method is more preferable for automotive and aeronautical applications. Friction drilling is a hole making process which completes the process in five steps, the advantage of friction drilling is a chipless hole making process. The chips melt due to heat and pushed due to tool movement into top and bottom of the material called bushing. Bushing is used for support, threading etc. In this review emerging technique friction drilling is in the drilling process has been reviewed and throws light on sheet metal hole making process.

Keywords Friction drilling · Bushing height · Coated tool · Uncoated tool · Surface roughness

1 Introduction

Friction drilling a nontraditional way of make hole process. Heat produced in-between the tool and work piece has used for the piercing tool into the work piece. It is a five step hole making method [1, 2]. Due to the heat developed, the metal melts and tool plunged into the work piece, the metal pushed and pulled to top and bottom side of the work piece material called as bushing [3]. This has more advantages like support, threading etc. [4]. In recent years enormous effort has been taken for research on studying of bushing height formation. From the researches it has observed that bushing height depends upon various factors like material thickness, work material,

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spindle speed, feed rate and machining condition [5, 6]. Roughness of the surface is another key factor in friction drilling process. In friction drilling process the tool is pierced into the material, depends upon the heat produced in between tool and the material. While comparing with conventional method the temperature developed is very high, this may affect roughness of the drilled surface Ozek et al. [7] has compared work material aluminum and stainless steel and tool material high speed steel and tungsten carbide in the investigation. Surface roughness of aluminum is more because aluminum is softer than steel. The roughness of the surface can be controlled by feed rate and spindle speed.

Another solution of decreasing the surface damages has been identified is pre-drilling process. For aluminum plate at several feed rate and spindle speed have verified with and without pre-drilling. From the survey it has been identified that predrilled hole cracks were less and petal also formed better than normal friction drilling process [8]. Latif Ozler [9] has investigated the impact of surface roughness and bushing height with fixed and variable feed rate. It has been found that the variable feed rate 50–100 mm/min has lesser surface roughness and higher bushing height, which is compatibility better for friction drilling process. In recent years enormous effort has taken for studying the formation of bushing height. Bushing height depends upon the material thickness, material nature, tool and input parameters. The chips formed in traditional drilling method is formed as bushing in nontraditional drilling process [10, 11]. Bushing is formed in a single step [12]. Dehghan et al. [13] has taken effort to study the effect of bushing height produced. They used titanium alloy as tool material. Depends upon the process parameters the bushing height also varied. Petals are formed that depends upon spindle speed, feed rate and tool material. It has concluded that lower feed rate and higher spindle speed plays a vital role in bushing height. Latif Ozler et al. [14] experimentally proved the formation of bushing height depends upon various factors like spindle speed, feed rate, friction cone angle and drilling conditions. They have used tungsten carbide as tool material and concluded that during machining time the conditions varied depends upon above said factors. Due to the change in temperature the chances of varying bushing height also differs. At lower spindle speed and lower feed rate the temperature produced is more and the bushing height produced is very less, whereas at higher spindle speed and lower feed rate the bushing produced is more. Somasundaram et al. [15] conducted experiment based on bushing height formation; they have concluded that at lower temperature the bushing height produced is improper, this is also because of lesser softening and ductility. Boopathy et al. [16] has evaluated the temperature difference while machining process going on. Aluminum, Brass and Stainless steel has been compared. It has concluded that at initial stage of drilling temperature is very less, but while dept of cut increases the temperature increases. For stainless steel temperature is more than other two materials.

Optimization techniques are utilized to find the best result. The response and significance can be analyzed using ANOVA [17–19, 21]. Wei–Liang Ku et al. [17] has observed the friction drilling tool with various factors like feed rate, spindle speed and friction contact area ratio (FCAR). ANOVA tool were used to find the significance of result. It has been observed that smooth roughness and maximum bushing height is observed for 50% FCAR tool. Response Surface Methodology (RSM) is the best tool identified for optimization. Without losing the accuracy the most possible solution can be identified from RSM [15].

The aim of this review is to focus on the emerging technique of friction drilling process. Majority of the manufacturing field uses drilling process. But the major drawback of the drilling technique is to make a hole in sheet metal. This nontraditional technique has filled the space in sheet metal hole making process. In this review the process, advantages and limitations is covered.

2 Experimental Setup

Friction drilling is a five step hole making process, were tool plunged into the work material with the help of heat generated due to high rotation of spindle speed as shown in Fig. 1. Initially tool is kept in contact with the work piece then due to the heat, metal starts melting, at the same time the tool starts piercing into the work piece. The conical area of the tool plunged into the work piece in next stage. Further the cylindrical portion of the tool smoothen the drilled hole. The metal is pushed top and bottom side of the work material called bushing. Finally the tool is retracted to its original position.

The tool is rotated at higher rpm. The thrust force and torque developed is very high, which depends upon the material and tool. A high power machine is only capable of withstanding all the above said issues. Vertical machining centre (VMC) is used for drilling process. Friction drilling setup is shown in Fig. 2. Dynamometer is attached to the vice in the VMC machine. It is to evaluate thrust force and torque.

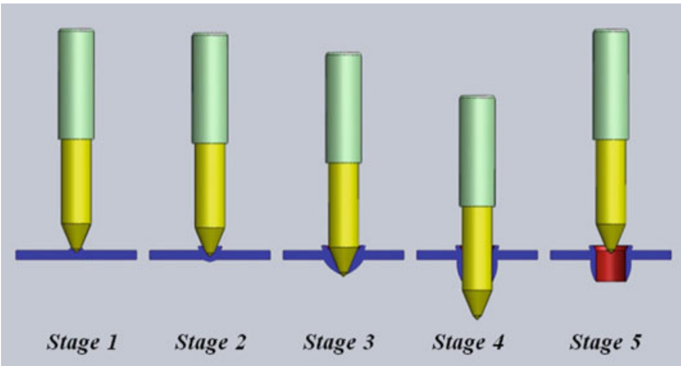

Fig. 1 Friction drilling stages (*Source* [20], p. 321)

Fig. 2 Setup for friction drilling

2.1 Selection of Tool

The tool geometry is shown in Fig. 3. The nomenclature is chosen depends upon the results produced. In Table 1 shows different dimensions chosen by different researchers.

The center portion of the tool has key role in friction drilling process. Initial punching of the tool into the material is initiated by center portion. Conical portion

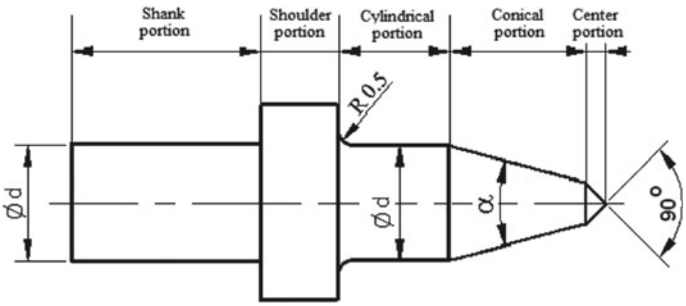

Fig. 3 Tool geometry (*Source* [14], p. 471)

Table 1 Dimensions of previous research work for a friction drilling tool

Dimensions	Mathew et al. [2]	Miller et al. [10]	Somasundaram et al. [15]
Diameter (d)	4 mm	5.3 mm	5.3 mm
Center angle (α)	90°	90°	90°
Conical angle (β)	18°	36°	36°
Center height (hc)	0.8 mm	0.940 mm	1 mm
Conical height (hn)	10 mm	5.518 mm	10 mm
Cylindrical height	10 mm	7.043 mm	15 mm

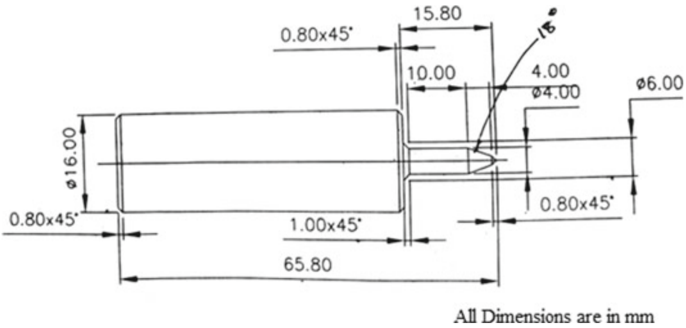

Fig. 4 Preferable tool dimension for friction drilling (*Source* [22], p. 471)

of the tool helps to plunge the tool into the work piece. Cylindrical portion of the tool polishes the surface in forward movement as well as retraction movement of tool.

Friction drilling tool with the dimensions best suited for drilling operation is shown in Fig. 4. The dimensions are chosen from various literature surveys. The conical area is mainly involved in cutting the work material. The maximum allowable work piece thickness is 4 mm for work piece.

In tool geometry two different profile exits conical and straight profile exits. From the literature survey it is noted that hole quality is best found for conical profile, because the conical profile find easy to pierce into the work piece initially. But in a straight profile tool stress is more to get tool pierced into the work pierce.

3 Observations

Friction drilling is a newer technology in machining process, though this process exits before. Many challenges are facing in this field, in this review few issues that make challenges in this friction drilling process are brought forward. Observations are based on literature survey.

Figure 5 shows tool wear. Tungsten carbide tool has used as friction drilling tool material. Low carbon steel has used as work material. Tungsten carbide tool has very good property for its hardness. Initially the tools have lesser wear, but wear increases after so many drills only while using a tungsten carbide tool. It has been observed that tool has unique property to withstand wear. At 11,000 drilled hole only the tungsten carbide tool started to wear. Optical microscope is use for capturing the image.

The Edax and SEM image of friction drilling tool is shown in Fig. 6. It is observed that large flow of material is transferred to tool. C, Si, and Fe are deposited into the tool material, from the work material.

The bushing height developed in various feed rate and angle is shown in Fig. 7. It is noted that higher rpm, lower feed rate and minimum angle produces better quality

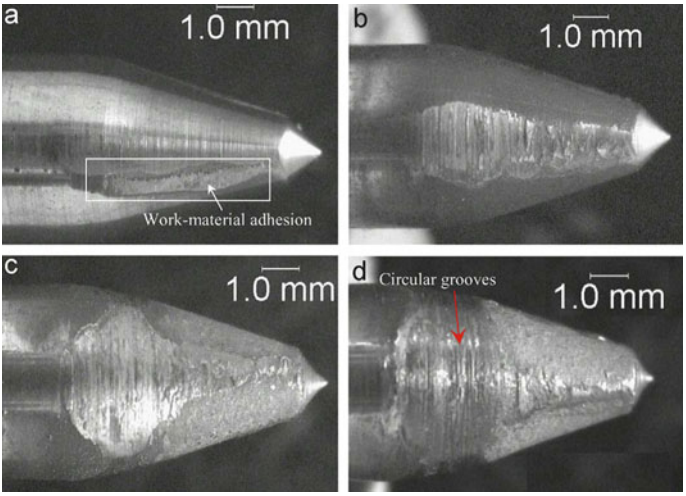

Fig. 5 Tool wear (*Source* [10], p. 1641)

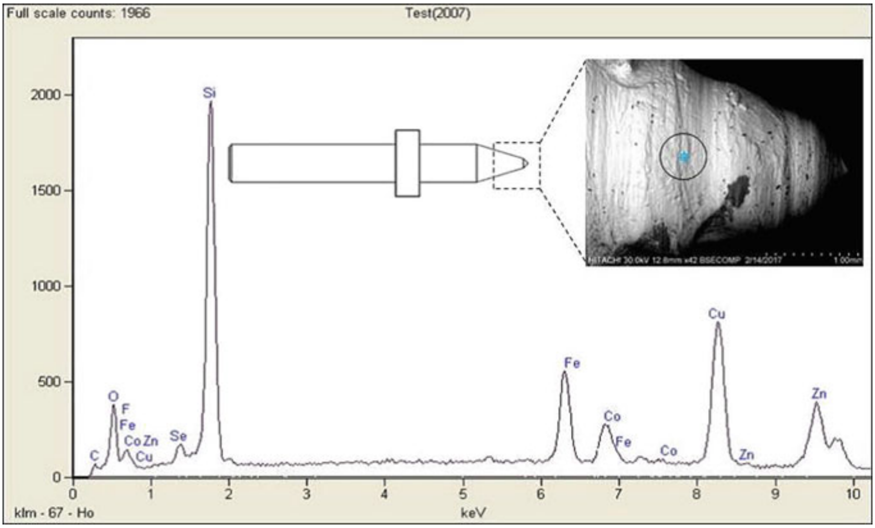

Fig. 6 Tool wear (*Source* [23], p. 100)

hole. At higher feed rate and angle the parent material also gets bending, but in lower spindle speed the bushing height produce is less compactly.

It is important to increase the tool life. The chances of wear is very high in friction drilling process, because of temperature is very high in this process. In Fig. 8 uncoated, titanium aluminum nitride coating and aluminum chromium nitride coating is compared. Figure 8a shown number of holes versus maximum wear. In Fig. 8b

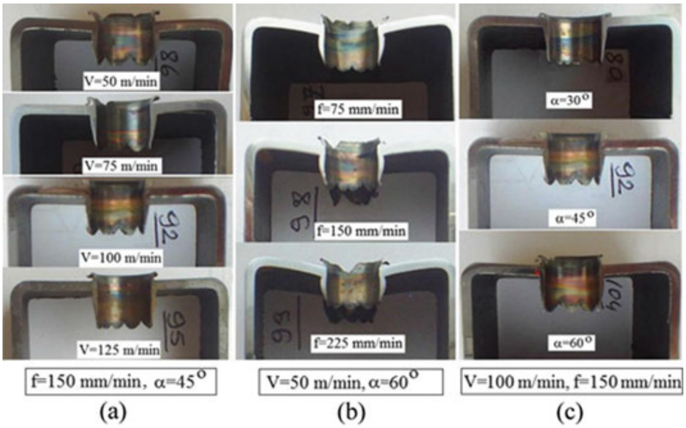

Fig. 7 Bushing height (*Source* [14], p. 474)

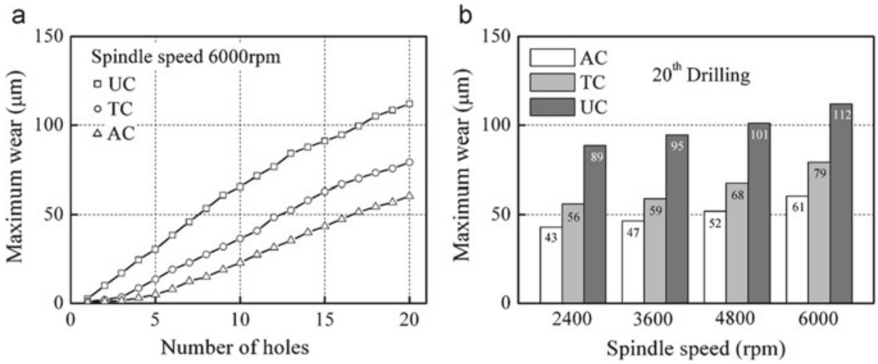

Fig. 8 Wear analysis of different types of drill (*Source* [24], p. 84)

shown, comparison between spindle speed and wear. In both the cases it has noted that uncoated tool has maximum wear. Whereas PVD AlCrN coating exhibit lesser wear that PVD TiAlN coating.

4 Conclusion

The overview of emerging friction drilling technique has been reported in this review. The following points has been drawn from the experience of review.

1. The key highlighting factor is bushing height in sheet metal, the maximum bushing height produced depends upon the tool, material and input parameters used.

2. Coated friction drilling tool helps to reduce wear and improve tool life.
3. Friction drilling is suitable for only material less than 4 mm thickness.
4. Surface roughness can be reduced that depends upon input parameters, coated tool and work piece material.
5. Selection of tool material is another major criteria. The tool material should be based on hardness, wear resistance and higher temperature resistance.

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