TOOL DESIGN FOR BURR REMOVAL IN DRILLING OPERATIONS

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ABSTRACT

One of the most significant problems encountered in machining, particularly in drilling, is that of burr formation. Burrs usually comprise of work piece material which has been plastically deformed during the machining process and projects beyond the desired edge of the work piece. The adverse effects of burrs depend on the component application but may include; stress concentration and related fatigue failure and increased wear on components and tools involved in the manufacture of the part. The minimisation or eradication of burrs produced during the drilling process is therefore of the utmost importance.

Currently there is a focus on reducing burr formation through optimisation of process control parameters and drill geometry. However previous studies have shown that, while it is possible to reduce the size of the burr, it is not possible to eliminate it entirely. Although numerous companies have developed methods for removing drilling burrs, these invariably involve extra process steps and increase cycle times and costs. A combined drilling and deburring tool would provide the optimal solution, removing the burr while not significantly increasing drilling time.

This paper reviews the current state of art in the field of burr reduction and removal in drilling operations, with a focus on tool design.

KEYWORDS: Drilling, Burr, Deburring

1. INTRODUCTION

Drilling burrs are a significant problem within the engineering industry. Their removal is necessary in most cases and can prove costly depending on accessibility to the burr. Significant international collaboration is currently taking place through the "Burr Working Group" within the International Academy for Production Engineering (CIRP).

Burr removal may represent a considerable part of the total manufacturing cost of a precision component. Most documented literature indicates an incurred extra cost of approximately 10-14% of direct manufacturing cost [1, 2], while others report it to be up to 30% [3]. In addition to the considerable cost, burrs lead to a significant number of other problems specific to drilling for example, close tolerances on critical holes cannot be realised in the aircraft industry [4] while brittle burrs may serve as crack initiation points and reduce component fatigue life [5]. Loose burrs can cause mechanisms to jam, increase wear, or potentially cause personal injury [6].

Many of the costs incurred due to deburring come from the labour time involved in the process. In certain circumstances it is necessary to dismantle assemblies after drilling in order to remove any burrs, this significantly increases cycle times. Alternatively, if automated deburring is being used, it requires an extra process step leading to increased cycle times and increased cost.
2. DRILLING BURRS

2.1 Types of drilling burr

There are a number of different types of burr produced during the drilling process. Two burrs are produced in the drilling of every hole; an entrance and an exit burr (see Fig. 1). The entrance burr is produced on the side of the work piece where the drill enters, this burr is usually considerably smaller than the exit burr and is usually of little concern as it may be removed easily by chamfering the hole. This may be achieved using a combined chamfering and drilling bit so as to not add an extra process step and therefore more time to the process. The exit burr is formed on the opposite side of the work piece as the drill breaks through. These burrs are usually more substantial than the entrance burr, and as they are on the opposite side of the work piece to the machine, they are more challenging to remove. They can also be located within a cavity in the work piece where there is no access to the exit side of the hole.

There are different systems of classification of burr types. For the purpose of this paper they will be described according to their shape, i.e. uniform, transient and crown burrs.

When drilling through a number of layers, interlayer burrs are often formed between the layers (see Fig. 1). In certain circumstances these burrs must be removed. In order to do this, it may be necessary to dismantle the parts to remove the burrs.

2.2 Creation of exit burrs

Exit burrs are created as the drill bit exits from the work piece. As the drill emerges from the work piece the material in front of the drill tip is plastically deformed. The material is stretched and thinned, this causes the material to fracture. Different types of burr are formed depending on where the initial fracture occurs. If the fracture occurs at the centre of the tip a larger crown burr will be formed. If however the fracture occurs at the edge of the hole then a smaller uniform burr will be formed. A transient burr is formed when fracture occurs at both locations simultaneously [7].

2.3 Burr minimisation

A number of different approaches have been adopted to control burr formation.

2-Axis Drilling Burr Control Charts

Drilling Burr Control Charts (DBCC) can be used to predict what type of burr will be formed given certain drilling parameters, this can be used to minimise burr or to alter the type of
burr produced [5]. There are a number of parameters which affect the burr produced during drilling, these relate to drill geometry, material properties, process conditions, tool wear and tool material. A DBCC is formed using experimental results, they can be used to relate feed rate ($f$), drill diameter ($d$), tool rake angle ($\alpha$) and spindle speed ($N$) to the type of burr produced. An example of a DBCC is shown in Fig. 2, this is DBCC is for Stainless Steel AISI304L [8]. $F_n$ is a nondimensionalised feed parameter ($=f/d$), $S$ is a cutting parameter ($=\alpha d N$).

![DBCC for Stainless Steel AISI304L](image)

Fig 2: Drilling Burr Control Chart for stainless steel (AISI304L) [8] Note: Type I are Uniform burrs, Type II are transient burrs, Type III are crown burrs

### 3-Axis Drilling Burr Control Charts

It is possible to add a further axis to the DBCC. This axis allows the graphs to be applied to different work piece materials [9]. In order to add the third axis it is necessary to develop a parameter (G) which will relate the tendency of the material to produce a burr to some of its material properties. As the G value increases the tendency to form large burrs moves towards lower feed and speed rates. An example of a 3-Axis DBCC as developed by Reich-Weise et al. [9] is shown in Fig. 3. $F_n = f/d$, $S = (N)(d)10^3$, $G = K^{-1} (\sigma_t - \sigma_y)(A+Z)$ Where $\sigma_t$ = Material tensile strength, $\sigma_y$ = Material yield strength, $A$ = Percent area reduction at fracture, $Z$ = Percent elongation at fracture, $K$ = A constant used to create a dimensionless number.

![3-Axis DBCC](image)

Fig 3: 3-Axis Drilling Burr Control Chart [9]
Burr minimisation through drill tip design

Gillespie [10] carried out research into the effects of drill geometry on burr, he found that increasing helix angle will reduce burr height by up to 50%, thickness by up to 20% and radius by 6%. It was also shown that burr height increases with drill diameter, however the most important characteristic of a drill bit in terms of burr minimisation is its sharpness. It has been shown [11, 12] that by changing the tip of the drill it is possible to minimise the burr which is formed, however in some cases, due to surface hardening, it can be more problematic to remove the burr which is formed.

Ultrasonic vibration in drilling

The application of an axial (along axis about which drill turns) ultrasonic vibration has been investigated [13, 14]. The ultrasonic force is found to reduce the forces involved in drilling and also to reduce the burr formed, however it does not eliminate burr formation.

Pre-drilling and pre-chamfering

A study carried out into the effect of predrilling and chamfering the predrilled hole was carried out [15]. This study found that by predrilling it was possible to reduce the size of burr formed, however it has been shown that chamfering the predrilled hole can eliminate both entrance and exit burrs [15]. In order to eliminate the burr the hole must be chamfered to the final diameter, as illustrated in Fig. 4. In this figure the hole was predrilled ($d_p$) to 2.75mm, the final hole diameter ($D$) was 6.1mm.

Fig 4: This figure shows the effect of the ratio $d_c/D$ (chamfered diameter to final drilled diameter) on burr height. (a) is the entrance side (b) is the exit side [15]
Effects of other drilling parameters on burr size

Stein [16] carried out an investigation into the effects of certain drilling parameters on burr size. It was found that newer drills produced smaller burrs than worn ones. It was also found that increasing feed rate increased burr size. Further to this it was observed that while at low feed rates increasing the spindle speed had little effect on burr size while at high feed rates burr size increased with spindle speed. A study of the stress fields associated with new and worn tools has been carried out [17]. This shows the effect tool wear has on the stress field around the cutting edge of a tool and its relationship to the size of the burr formed. Tool coatings may maintain the tool geometry for a longer period of time thus minimizing the size of burr formed for longer.

3. CURRENT METHODS OF BURR REMOVAL

There are a number of different methods currently employed in industry for the removal of burrs. These range from dedicated processes to integrated tools. Dedicated processes operate by a chemical, electrical, mechanical or thermal means. Most available methods add further processing steps to the manufacturing process, thus increasing manufacturing time and cost, while many also require extra machines or equipment. Of particular interest are those which do not add an extra processing step, such as integrated drilling and deburring tools.

Many companies remove burrs which have been formed during the drilling process manually, using a scraper or dedicated deburring tool. The parts are removed from a machining centre so they may be deburred adding further steps to the manufacturing process and extra labour costs.

Within the aircraft industry there are further problems as it is necessary to drill holes in a number of components in a stack in order to rivet them together. The components must then be disassembled in order to remove the inter layer burrs before reassembling the components and riveting. By eliminating the deburring step, and associated dismantling and rebuilding steps, significant savings in manufacturing time can be realised. The use of auto-riveting machines avoids this problem, the clamping forces produced by the machine prevent the layers separating and burrs forming.

Integrated drilling and deburring tools

A number of tool companies have developed integrated drilling and deburring tools which are capable of first drilling a hole and then removing any burr which is formed. These tools work for holes with a diameter greater than 9.5 mm [18, 19]. An example of one of these tools can be seen in Fig. 5. This tool is produced by E-Z Burr and consists of a spade drill and a deburring tool. It is also possible to incorporate a chamfering tool which will chamfer the entrance side of the hole. This tool is available to drill holes greater that 9.5mm [18].

Fig 5: E-Z Burr Burrfree drill [18]

Kim et al. developed a drill capable of deburring. This tool incorporated a deburring cutter which is mounted on a cantilever located within a cavity in the shank of the drill [20]. This tool is shown in Fig. 6.
Fig 6: Drill with incorporated deburring cutter [20]

A drill bit has also been developed by Kubota et al. [21] which is capable of deburring. This tool operates by utilising two cutting edges on the reverse of the tip (as shown in Fig. 7) to remove the burr once the hole has been drilled.

Fig 7: Drill capable of deburring [21]

4. SUMMARY

Significant research has gone into burr minimisation and reduction. Many researchers have shown that though burr size may be reduced, it can not be eliminated. This presents a significant problem within industry as deburring is both costly and time consuming. A number of integrated drilling and deburring tools have been developed, however there is potential for optimisation for tool geometry and tool coatings.
ACKNOWLEDGEMENTS

The authors would like to acknowledge that this research has been carried out as part of a project funded by Enterprise Ireland.

REFERENCES