Experimental Analysis of Burr formation in face milling of aluminium alloy by varying in-plane exist angle

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ABSTRACT

Burr can be defined as an undesirable projection of materials attached to the edge of the workpiece that is created due to plastic deformation. Burr generation in workpiece produced by milling operation is a serious concern because the presence of burr on the cutting edges could significantly affect the cutting performance which is associated with increased cost and time of manufacturing. For this reason there is great motivation for the manufacturers who try to avoid or reduce burr formation. In face milling it is possible to reduce burr by changing in-plane exist angle. In this work, experiments have been carried on horizontal CNC milling machine to perform face milling of Aluminium alloy block with carbide coated milling cutter for observing the nature of burr formation by varying in-plane exist angle in flood cooling environmental condition. It was observed that different types of burr was generated by changing in-plane exist angle and minimum burr or no burr were noticed at low angle. An optimum exist angle is found and discussed in this paper.

Keywords: burr, face milling, aluminium alloy, in-plane exist angle, flood cooling.

1. INTRODUCTION

Burr is plastically deformed material that remains attached at workpiece edges after machining. Burrs must be removed for making the surface smoother. The existence of burrs decreasing fit and ease of assembly of parts, damaging dimensional accuracy and surface finish, increasing cost and time of production due to deburring, reducing cutting performance and tool life. Burrs are problematic even during machining because they hit the cutting edge and may cause groove wear. This groove wear, in turn, accelerates the growth of burr [1].

Material removal by milling process is considered as one of the most extensively used machining processes. During milling operation, burrs are created mainly where milling cutter exits the machined part. During face milling Silva et al. [2] found that proper minimization was achieved by optimizing the cutting parameter such as cutting speed, feet per tooth, and depth of cut, for obtaining minimum surface burr. Lin [3] investigated burr formation and tool chipping during face milling of stainless steel and found burr height to be strongly dependent upon the milling process and large depth of cut contributes to the formation of the wave-type burr and with high feed rate the cutting edge of tool is chipped, which is responsible for built-up edge formation. Other researchers, Olvera and Barrow [4] investigated the influence of main cutting parameters on the formation of exit burr produced in face milling operations. Experimental work depicted that exit angle influence for exit burr in cutting direction and depth of cut mainly responsible for exit burr in feed direction. Shyu [5] developed a finite element model of face milling to study burr formation. He used Eulerian formulation to develop this model so as to avoid difficulties associated with mesh generation and material separation criterion in Lagrangian model. Saha et al. [6] found optimum value of exit edge bevel angle of 15˚, where burr formation is significantly less or negligible, if not completely eliminated. They also observed higher cutting velocity resulting in high plastic deformation. Das et al. [7] found that minimum burr occurred in face milling using coated carbide tool at an in-plain exit angle of 30˚ without any exit edge bevel at all machining conditions undertaken. Different types of burr formed are highly dependent on in-plane exit angle (ψ) as stated by Chern [1]. He defined in-plane exit angle as "the angle between the cutting velocity vector V, at the point where the tool coincides with the edge of the workpiece, and the vector that contains the theoretical edge, pointing from tool entrance to tool exit region".

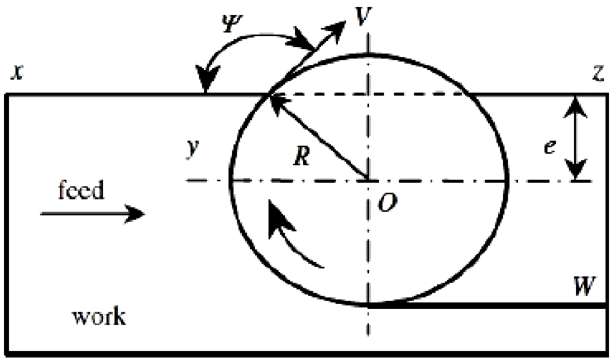

Figure 1: In-plane exit angle (ψ) [1]

Theoretically ψ varies from 0 to 180 and it can be derived from equation 1, where R is radius of cutter and e is the offset of O from the edge xz. e can be either positive or negative. e is defined as negative value if O which is outside the workpiece. Thus, e varies from a maximum value of R to a minimum of -R

$$\Psi = 90 + \sin^{-1} (e / R) \quad (1)$$

Five types of burrs were formed in face milling of aluminium alloy as observed by Chern [1] they are knife-type, wave-type, curl-type, edge breakout and secondary burr. The knife-type burr [1, 9] is created when ψ reaches 150˚. The burr height is same as depth of cut and it is formed by plastic bending moment. At approximately 90˚ in-plane exit angle, wave-type burrs were formed. These types of burrs are produced at regular interval from the machined surface. For in-plane exit angles less than 45˚, curl-type burrs are formed where burr height gets reduced. However, according to the experimental observations, burr root thickness, is larger than those of knife-type burrs. In-plane exit angles less than 90˚ are not suggested in real applications since the cutter center is outside the workpiece and the material removal rate is low in this case. The edge breakout [1], burr is generated when metal removal rate becomes very high. A rough chamfer and sharp burrs are created along tool exit edge. Secondary burr [1, 9] is formed when fracture causing separation of the primary burr occurs near its root. It takes place when the plastic strain at the root of primary burrs becomes too high for material to sustain. The burr height is thus reduced. The existence of secondary burrs is difficult to recognize. It can be felt by rubbing our figure on the machined surface. A number of research works has been done on different areas of milling burr. Burr formation cannot be eliminated, but to minimize burr is an important aspect.

The main objective of the present work is to investigate the burr formation mechanism in face milling process and to observe the influence of cutting condition at different in-plane exit angles (ψ). The experiment was carried on aluminium alloy with coated carbide single insert milling cutter under flood cooling environment. Formation of burr are discussed in detail by varying feed rate keeping cutting velocity and depth of cut constant.

2. EXPERIMENTAL INVESTIGATION

In this work, experiments have been carried out on a horizontal 3-axis CNC milling machine to perform face milling on aluminium alloy (6061 T-6) blocks with single inserted coated carbide tool on a 60 mm diameter cutter for observing the nature of burr formation. Depth of cut (t) has been maintained constant at 2 mm and cutting velocity (V_c) as 240 m/min for all sets of experiments. In each set of experiment five in-plane exit angles (ψ) was taken. Nature of burr was observed by changing feed rate (S_o) for all angle. Burr height was measured with Mitutoyo height gauge. All experiments have been performed in flood cooling condition with a flow rate of 3500ml/hr

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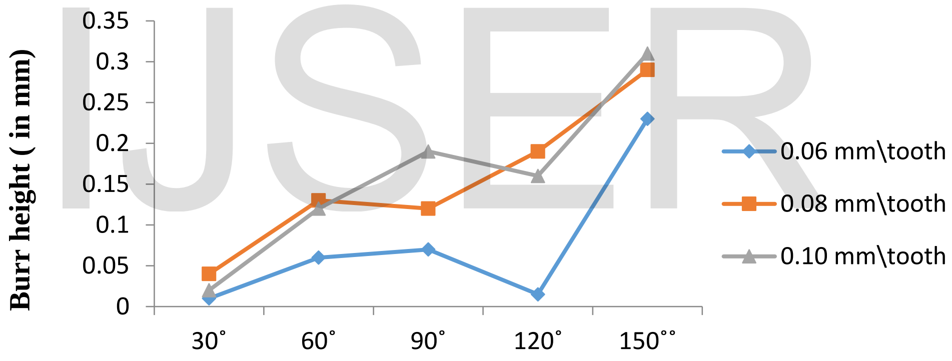
Table 1 Experimental Conditions

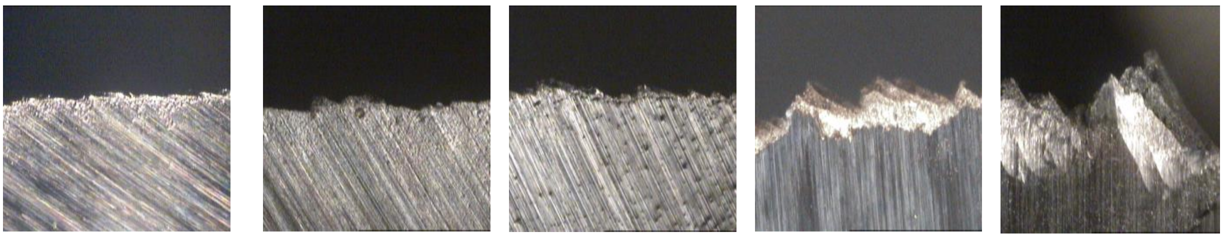
Machine Tool	Horizontal Axis CNC milling machine, Make: Bharat Fritz Werner
Workpiece Material	Aluminium Alloy (6061 T-6), Tensile strength: 298MPa, Size: 80mm x 60mm x 42mm
Cutting Tool	Coated carbide single insert for face milling with cutter diameter of 60 mm
In-plain exit angle	30, 60, 90, 120,150
Cutting velocity (V_c)	240 m/min
Depth of cut (t)	2 mm
Feed (S_o)	0.06 mm/tooth, 0.08 mm/tooth, 0.10 mm/tooth
Cutter speed	1800 rpm
Environment	Flood cooling (cutting oil: Blasocut Combi)

The burr height was measured with height gauge and found less height at low infeed. Under same condition the measurement of burr was done thrice and average value were used for analysis. Increased in feed rate increases burr height, but at an angle of 30˚ it was found minimum height with all three infeed. Below 90˚ angle burrs height was not increase more than 0.2 mm but material removal rate is less in this case. Flood cooling environment also influence the burr size. This may be due to heat reduction in cutting zone. Angle at 120˚ and 150˚ shows maximum burr height this may be due to edge breakdown and formation of secondary burr.



In-Plane exist angle

Figure 2: Variation of burr height at different in-plane exist angle at feed rate of 0.06 mm/ tooth, 0.08 mm/ tooth and 0.10 mm/tooth.



(a) (b) (c) (d) (e)

Figure 3: Microscopic view (in 20X) of burr for in-plain exit angle and feed of (a) 30˚ and 0.08 mm/tooth, (b) 60˚ and 0.08 mm/tooth, (c) 90˚ and 0.08 mm/tooth, (d) 120˚ and 0.08 mm/tooth, (e) 150˚ and 0.08 mm/tooth

Measurement or assessment of burr is one of the biggest challenges for burr research. Burrs formed in machining are irregular and very sharp in shape, it is usually very difficult to measure burr accurately. If the geometry of burr is measured properly, proper deburring method can be recommended. Experimental result shows that with increase in-feed exit angle burr height increase. Microscopic view of burr as shown in fig suggest that burr formation was greatly depend on exist angle and also influence of flood cooling. At 30˚ angle very small or curl type burr are formed but at an angle more than 90˚ wave and saw type burr generate.

3. CONCLUSION

On the basis of the experimental investigation in face milling carried out in this work, following conclusions may be drawn

1. Among all five in-plane exit angles (ψ), 30˚ gives less burr formation at flood cooling condition using carbide coated cutter and also burr height was minimum, so the cost associated with removal of burr of deburring gets reduced.
2. In-plane exist angle of 30˚ and 60˚ material removal rate become quite less. MRR increase as in-plane exist angle goes more than 90˚ but at the same time burr height increased. From the experimental analysis burr height was found maximum at an angle of 150˚. This may be due to plastic bending moment or edge breakdown.
3. Flood cooling environment lowers burr formation by lubricating the cutting zone and taking away the heat and chip.

4. ACKNOWLEDGEMENT

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