WORKPIECE EDGE BEVELING TO CONTROL FORMATION OF BURR IN FACE MILLING

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ABSTRACT : Presence of burr at the edge of finished workpiece often leads to difficulty in assembly operation and injury to operator necessitating incorporation of additional processes of deburring. Exit burr formation by milling usually occurs when cutter moves out of the work piece. One method for minimizing this problem is to prevent the tool from exiting the workpiece while removing material. Burr formation can also be reduced considerably by edge beveling of the workpiece. In the present work, the influence of beveling the exit edge of the workpiece on the burr formation in milling has been experimentally investigated to find out the optimum condition to control the formation of burr.

1. INTRODUCTION

Formation of burrs in the milling causes problems in making the finished workpiece. This often necessitates additional operation of deburring. To avoid formation of burr, a number of studies were made . Nakayama et al. studied [1] burr formation in various orthogonal metal cutting operations including milling. In milling, the burr formation occurs in the same direction as the primary tool motion and the burr which is three-dimensional appears on the exit surface. Kishimoto et al.[2] and Kitajima et al. [3] did experiments in face milling on burr formation. They analyzed the effects of cutting conditions, lead angle and work piece exit angle on burr size and shape. Chern [4] studied the effect of in-plane exit angle on burr size, and showed the importance of the workpiece geometry and tool geometry on burr formation. Some researchers tried to find out the dependence of burr formation on the stress field in machining [5]. An important aspect of tool and work piece geometry is the exit order of the tool edge because the burr appears near the final exit position of the tool along the work piece edge. Exit here refers specifically to the tool cutting edges moving out of the work piece at an edge while removing material. The exit order of the tool may greatly influence the burr formation in terms of burr position on the work piece in face milling [6].

Optimum tool paths that would maintain favorable cutter tooth entry/exit conditions were also developed [7]

When burrs remain in the finish material, it lead to assembly failures, sort circuit, injuries to workers or even fatigue failures. All these increase the lead time in production, and hence the production cost. Although there are different deburring processes such as grinding, barrel tumbling, vibratory finishing, centrifugal and spindle finishing, chamfering, abrasive jet matching, water jet cutting, wire brushing, belt sanding, buffing filing, ultrasonic machining etc, the optimum selection of job bevel angles is also reported [8] to have the capacity of reducing the burr formation significantly.

The aim of the present work is to study the burr formation mechanism and to investigate the influence of edge beveling conditions of test piece on burr formation in high production face milling of medium carbon steel test pieces. Single tooth uncoated carbide inserts are used to carry out face milling. For all the experiments a milling cutter having diameter 128.6 mm and depth of cut 3 mm were kept constant. Experiments were carried out to find out the optimum range of exit bevel angles of jobs for different machining conditions such that formation of burrs are reduced significantly or eliminated.

2. MECHANISM OF BURR FORMATION

The type of burr formed is highly dependent on the in-plane exit angle influencing the mechanism of its formation. Generally five types of burr in face milling are formed. They are knife type burr, wave type burr, curl type burr, edge break out and secondary burr. Knife type burr is created by the pushing out of the uncut part near the transition machine surface when exit angle reaches 150^0. The wave type burr is formed when exit angle reaches 90^0 approximately. Curl-type burr is found after machining when exit angle is less than 45^0. The edge break out is observed when the metal removal rate becomes very high; a rough chamfer and sharp burrs are noted along the tool exit edge. The secondary burr is created when fracture causing

Table 1.1. Experimental Set-up

Machine Tool	Knee type milling machine, FN 2V Group, HMT Ltd. (India)Speed range (RPM) : 35.5 – 1800 (18 Steps)Longitudinal and Cross feed range (mm/min) : 16 – 1800 (18 Steps) Main Motor Power : 5.5 KW, Feed Motor Power : 1.5 KW
Tool Holder	Cutter diameter : 128.6 mmHolder type (Positive rake) : R/L 265.2-125 ME- 20 AL (Sandvik)
Cutting Tool	SPKN 1203 ED R, Uncoated SM30 (HW)-P30 insert (Sandvik)
Job Material	Medium carbon steel (45 C8), Hardness(BHN) : 175Composition: C(0.4-0.5%), Si(0.15-0.35%), Mn(0.60-0.90%), S(0.045max), P(0.04%max).
Job Size	100 mm x 70mm x 35mm

separation of the primary burr occurs near the root of the burr [9].

3. EXPERIMENTAL INVESTIGATIONS

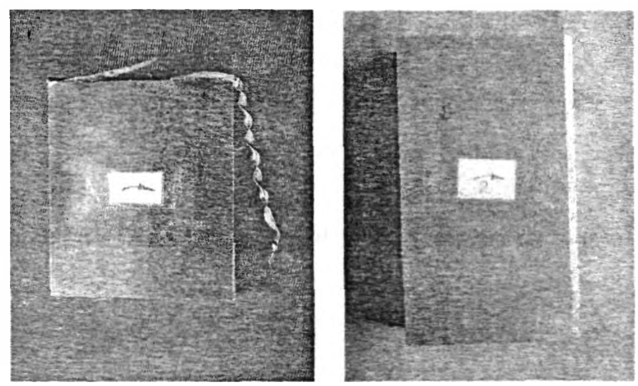
Generation of the burr mainly depends on the edge beveling of the workpiece. Some experiments have been carried out for observing the amount of burr formation corresponding to different edge beveling of workpiece conditions. Details of the experimental set up are given in Table 1.1 and machining conditions is shown in Table 1.2.

Table 1.2. Machining Conditions
Depth of cut (t): 3 mm (Constant), Number of cutting insert fitted in the cutter : 01
Environment : Dry
In plane exit angle : 120^0 (Constant)

Experiment Sl. No.	Cutting velocity, V_c (m/min)	Feed, S_z (mm/min)	Edge Bevel Angles for each experiment (Degree)
1	363	31.5	15, 20, 25, 30
2	286	40	

4. RESULTS AND DISCUSSIONS

Experiments were performed in dry condition on the workpieces with four different exit bevel angles of 15, 20, 25 and 30 degrees at a particular machining condition. At one end of the workpiece, bevel was made for a height of 3 mm. Machining conditions were chosen with two different cutting velocities, 363 m/min and 286 m/min and two different feeds, 40 mm/min and 31.5 mm/min. Details of the experimental observation are given in Table 1.3. At both cutting velocities and feeds, minimum burr has been observed at 15^0 edge bevel angle of test piece.



(a) (b)

Figure 1.1: Photographic view of typical specimens (a) For no bevel angle, (b) for 15 degree edge bevel of the job)

Table 1.3. Details of Experimental Results

Experiment Sl. No.	Cutting Velocity, V_c (m/min)	Feed, S_z (mm/min)	Burr Height (mm) at Edge Bevel Angles (Degree)			
			15	20	25	30
1	286	40	*	****	**	***
2	363	31.5	*	***	****	**

Note: * - Negligible burr, only can be felt upon touching; ** - Considerable, but not visible; *** - Tiny, but visible; **** - Small but visible.

It was found out earlier [10] that when backup material is less or even absent, burr formation is more hence when edge bevel angle is less backup material will be more resulting in less burr formation. Following this reason, similar tendency has been observed at low range of speed in the present case of experimental findings.

Figure 1.1. (a) shows sizcable amount of burr formation obtained after milling a job with no edge bevel angle (at cutting velocity 363 m/min, feed 31.5 mm/min), while Figure 1.1. (b) shows no formation of any burr with 15^0 edge bevel angle made on the job. This has been experienced during milling with both cutting velocities and feeds. These two photographs clearly indicate the effect of providing edge bevels on the job in controlling the formation of burrs.

Details of the experimental results are shown in Table 1.3., where under different machining conditions and bevel angles, formation of burs are compared. Similar results have also been reported by these authors elsewhere [11].

5. CONCLUSION

The following conclusions can be drawn from the experimental investigation done –

- It was found that for both cutting velocities and feeds, minimum burr formation occurs at an edge bevel angle of 15^0 and results in good surface quality.

- But the tendency of minimum burr formation has been varied with the edge bevel angles in our experiments. To optimize the edge bevel angle for minimum burr formation, there is a need to extend our experimental work to more cutting parameter and tool geometries.

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