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Review Article

AN OVERVIEW ON BURR FORMATION, ITS MINIMIZATION AND DEBURRING PROCESSES

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Abstract: Burr formed in machining is one of the productivity killers of modern era. Formation of burr leads to many hazardous conditions for the workers, and affects the product cost. As deburring is an additional process incurring extra cost, it is preferable to minimize burr formation than deburring; but, in many cases, there is no other option left but to deburr the required machined product to get burr free product. There are several deburring processes available and used according to the need of the desired product.

Keywords: Burr, Burr formation, Burr minimization, Deburring.

1. Introduction

Burr is a plastically deformed material with thin ridges that is attached along the edge of a workpiece formed during machining or other manufacturing processes. It is observed in all kinds of machining. Machining burrs create many problems affecting product quality and assembly automation in industries. Thus, they must be removed through deburring process to allow the part to meet specified tolerances. A number of burr removal processes exist and can be conveniently applied. In the micro-machining process, the burr is very difficult to remove and, more importantly, the burr removal can seriously damage the workpiece [1,2].

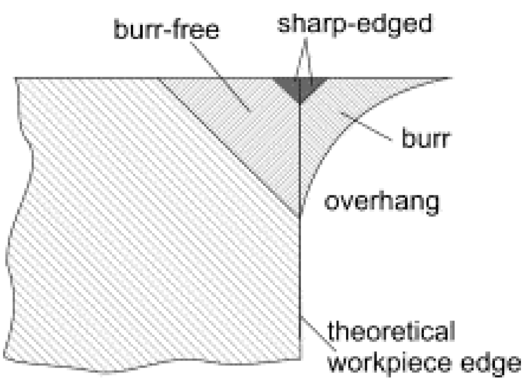


Figure 1. Schematic representation of a burr attached to an edge of a workpiece

Burr is defined as "an undesirable projection of material formed as the result of plastic flow from a cutting or shearing operation."As per the ISO 13715 [2], the edge of a workpiece is burred if it has an overhang greater than zero. Fig.1 shows schematically a workpiece edge having a burr attached.

2. Problems Created by a Burr

In machining and other manufacturing processes, presence of burr on the workpiece might lead to various problems such as:

- Decreasing the fit and difficulty in assembly of parts.
- Damaging dimensional accuracy and surface finish.
- Increasing the cost and time of production due to deburring.
- Chance of injury to an operator.
- Problem of electrical short circuit.
- Poor machinability.
- Poor aesthetics of the component [3,4].

3. Classification of Burr

There exist different burr descriptions depending on the manufacturing process, its shape, formation mechanism and material properties. Kishimoto et al. [5] finds in his tests two types of burr, that is, primary and secondary burr, while Gillespie [2] described four types of machining burrs, such as Poisson burr, rollover burr, tear burr and cut-off burr. Some of these burr types are described in Fig.2.

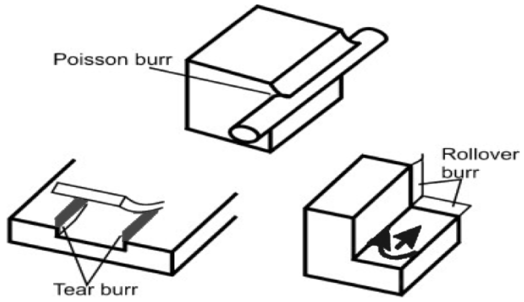


Fig. 2: Schematic diagram of Poisson, tear and rollover burr [7].

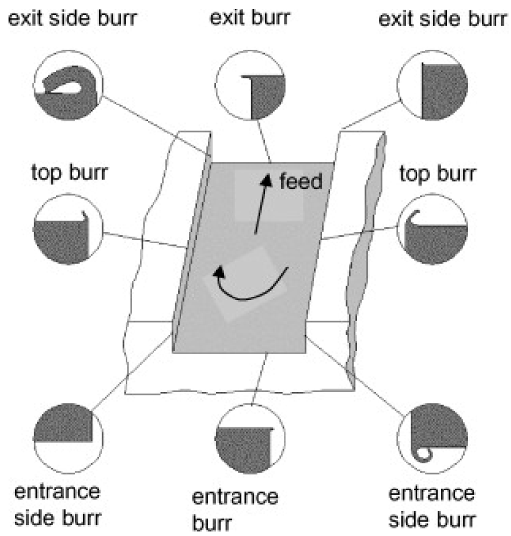


Fig. 3: Types of milling burrs [6]

Hashimura and others [6] classified burrs formed in face milling according to burr locations, burr shapes and burr formation mechanisms. Exit burr is the burr attached to the surface machined by the minor edge of the cutter. A side burr is attached to the transition surface machined by the major cutting edge, and a top burr is a burr attached to the top surface of the workpiece. Different milling burrs are illustrated in Fig.3.

Kim et al. [7] categorized drilling burrs as uniform burr with or without a drill cap, and crown burr or petal burr according to their shapes and formation mechanism. Two types of burrs, uniform burr (type I: small uniform burr, type II: large uniform burr) and crown burr are seen in stainless steel. Uniform burr (type I: small uniform burr, type II: large uniform burr), transient burr, and crown burr, formed in low alloyed steel are shown in Fig.4, as observed by the authors under different machining conditions.

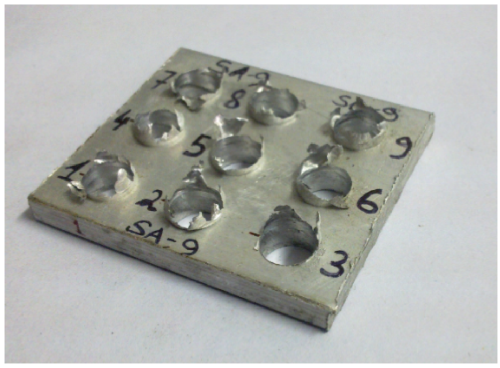


Fig. 4: Typical drilling burr

4. 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 are formed in face milling. They are knife type burr, wave type burr, curl type burr, edge break out and secondary burr [3]. Knife type burr is created by the pushing out of the uncut part near the transition machined surface when exit angle reaches 150^0. The wave type burr is formed when exit angle reaches 90^0 approximately, and curl-type burr is found after machining when exit angle is less than 45^0. Edge break out is observed when metal removal rate becomes very high; sharp burrs are noted along the tool exit edge. The secondary burr is created when fracture causing separation of the primary burr occurs near the root of the burr [8].

5. Burr Measurement

The choice of an appropriate system depends on application conditions, requested measuring accuracy and burr values to be measured like burr height, burr thickness, burr volume or burr hardness, though burr height and thickness are the most frequently and easily measured burr values [7]. However, over 71% of the companies surveyed still use, among other measuring methods, the fingernail test for burr detection [8]. For industrial use, it is important to know the burr parameter that is relevant to assess its harmfulness under production and service conditions. Sometimes for larger sizes of burr and for sampling purpose calipers can also be used.

6. Burr Control Strategies

For effective prevention of burr, the process chain from design to manufacture needs to be considered [9].

Important is the integration of all the elements affecting burrs, from the part design, including material selection, to the machining process.

Efforts to avoid, prevent, and minimize burr formation have been made [9] in machining with respect to:

- *Tool and tooling*: According to the workpiece, suitable tool geometry, material and size are needed to consider to reduce burr formation. Specific tool design, such as a progressive tool, can reduce burr formation remarkably.
- *Coolant*: Application method, coolant type, application location is important to avoid formation of burr.
- *Process parameters*: Proper combination of cutting speed, feed, etc. is needed to be controlled.
- *Process sequencing*: Appropriate sequencing of processes leads to less burr formation.
- *Tool path planning:* Tool path planning in an ordered manner leads to less production time as well as less tendency of burr formation.
- *Edge preparation and variance of in-plane exit angle:* Edge preparation like edge beveling can lead to reduce entrance burr and exit burr. Varying in-plane exit angle also leads to less burr formation [9-13]. In-plane exit angle and beveled exit edge are shown in Fig.5.

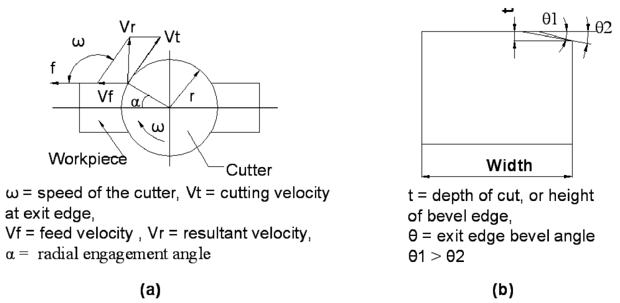


Fig.5: (a) In-plane exit angle in milling operation, (b) Job with the exit edge beveled. [10]

7. Deburring

Deburring includes all operations which are used to remove burrs ranging from simple hand deburring to surface finishing by NC controlled robots. Gillespie [2] proposed the following four main categories in order to group different deburring operations.

- Mechanical deburring operations,
- Thermal deburring operations,
- Chemical deburring operations,
- Electrical deburring operations.

A deburring process should be selected based on its influencing effects on dimension, finish, cleanliness, flatness, plating, soldering, welding, residual stress, surface imperfections, corrosion rate, lustre and colour [14]. Thilow [15] introduced an industrially applicable system for the selection of a deburring process.

Manual deburring is a tedious and exhausting operation. To reduce the work load and to guarantee a constant workpiece quality, robots are applied. Abele studied the application of robots for deburring operations.

7.1 Mechanical deburring operation

Machining based deburring processes are listed below [2,3,16,17]:

- *Belt sanding*: In this process, the workpiece is held against a moving abrasive belt until the desired degree of finish is obtained [17].
- *Vibratory conveyor* : This type of conveyor is used for flat surfaces for removing top burr.
- *Manual deburring*: It is done for swift corners and is almost a final finishing process.
- *Wheel blending*: This process is used for flat and round objects for finishing of corners.
- *Edge rolling*: Mainly done for rectangular objects to get rid of entrance, exit and top burr.
- *Wire brushing*: High speed rotary wire brushing is used to deburr surfaces from top, entry or exit burrs [17] as shown in Fig.6.

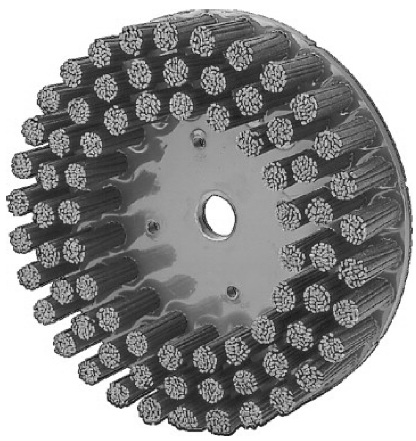


Fig.6: Wire brush used for deburring

Mass finishing processes include [2,3,16,17]:

- *Barrel tumbling:* Used for deburring large number of small objects inexpensively.
- *Cryogenic barrel tumbling*: Here, cryogenic liquid is used.
- *Vibratory deburring*: This type of deburring operation is done in open barrels where the workpiece and media are vibrated at frequencies between 900-3600 cycles per minute.
- *Centrifugal barrel finishing*: In this process, the barrel is fitted at one end to accelerate the process by 25 to 50 times.

Other deburring processes consist of:

- Liquid Abrasive Flow,
- Semi-solid Abrasive Flow,
- Abrasive Jet,
- Cryogenic Abrasive Jet,
- Water Jet,
- Lapping,
- Ultrasonic Slurry.

In mechanical deburring operations, burrs are reduced or removed by mechanical abrasion. Influence of burr thickness and length on vibratory deburring time is analyzed, and dimensional and weight changes are recorded during deburring.

7.2 Thermal deburring operation

In this process, thermal energy is used for deburring various forms, such as:

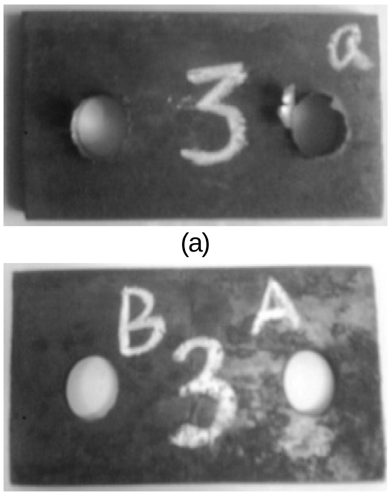
- *Thermal energy method:* Here formed burr is removed through application of heat.
- *Laser deburring*: In the process, focused laser is used to get rid of burrs by melting and vapourisation.
- *Electronic discharge machining (EDM):* Through spark erosion, burrs are removed in this process.

7.3 Chemical deburring operation

In this process, chemical reaction is involved. Various processes under this category are:

- Chemical Barrel Finishing,
- Chemical Vibratory Finishing,
- Chemical Centrifugal Finishing,
- Chemical Magnetic Finishing,
- Ultrasonic (Chemical),
- Chlorine Gas Deburring [17].

Fig.7: MS plate deburring by nitric acid solution [13]



(a)

(b)

Fig.8: MS plate (a) before and (b) after deburring [13]

Merritt and Schein studied the application of electromechanical deburring operation, and enhanced advantages of electrochemical deburring (ECD) by employing a system of automatic loading and unloading. Factors that influence the process including the electro-chemical properties of both the workpiece material and electrolyte along with component geometry, process parameters, tooling and machine characteristics need be considered while considering deburring operation.

7.4 Electrical deburring operation

Mainly it is the electrolysis process [17] such as:

- Electrochemical Barrel Tumbling,
- Electrochemical Vibratory Finishing,

- ➢ Electrochemical Moving Electrode,
- ➢ Electrochemical Deburring.

8. Conclusion

Following conclusions may be drawn from the above paragraphs.

- Burrs are formed due to various factors including geometry of job, tool exit angle, environmental condition, speed, feed, depth of cut, tool path planning, etc.
- Reduced burr height is obtained using coolant over dry machining in many cases.
- As deburring is an additional process, it is needed to minimize burr formation than deburring.
- However, extensive use of deburring may either be eliminated or reduced substantially, if appropriate burr minimization strategy is adopted.
- Scope of future work remains to explore effective burr minimization technique for different materials under different processes.

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