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Aspects of burr formation in bandsaw teeth manufactured by milling operation

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ABSTRACT

Steel manufacturers and stockholders prefer bandsawing for cutting off raw materials compared to other techniques as it enjoys competitive advantages of higher accuracy of cut, better surface finish, lower kerf loss, better straightness of cut, long tool life and high metal removal rate. Along with the geometries of the bandsaw tooth, bandsaw cutting edge condition (e.g., edge sharpness and burr) significantly affects the cutting performance of a bandsaw. Currently the production of bandsaw is largely done by milling operation due to the scale of manufacturing and the economics of milling compared to other processes (e.g., grinding). Ideally, the bandsaw teeth should possess sharp cutting edges with no burr. In general, two types of burr are commonly seen in the bandsaw teeth manufactured by milling operation namely tooth tip burr and side burr. Current research undertaken at Northumbria University in collaboration with a major bandsaw producer is focused on the mechanism of burr formation in the bandsaw teeth. This paper briefly outlines the factors affecting the burr formation in bimetal (High Speed Steel edge wire and soft steel backing material) bandsaw teeth manufactured by milling process and suggests the necessary steps to be considered for manufacturing burr free bandsaw with sharp cutting edges. The investigation showed that flank wear in the milling cutter has a major influence on the side burr formation in the bandsaw teeth, whereas tooth tip burr was influenced by both flank wear and "V" type notch wear found at the crossover point on the flank face. It was also concluded that TiN coating on the milling cutter could control the burr formation in bandsaw teeth to some degree.

1. Introduction

Technically, burr in machining process is defined as an undesirable projected material generated on the edge of a machined workpiece as a result of plastic deformation. Burr could be generated in any machining process such as turning, milling, drilling and grinding. Burr formation on the edges of machined components causes various problems in manufacturing. For example, if a machined part goes through various manufacturing steps, the presence of burrs on the edges of the part causes misfit problem in subsequent assembly operation hence, strongly affecting the productivity. In automated production environment, burr could give erroneous measurement due to dimensional inaccuracy, thus affecting product quality. The performance of a final precision product could degrade due to the burr. Therefore, in most of the cases, costly (up to 30% of the total product price [1]) and time-consuming deburring processes need to be incorporated in the production line. Furthermore, in some cases conventional deburring techniques might not be suitable to eliminate the burr completely. Consequently, burrs represent a serious bottleneck in machining operations in terms of productivity, product quality and production cost. Thus, urgent attention is necessary to control the burr formation in the machined parts, thereby saving production cost and time.

Material removal by milling process is considered as one of the most multipurpose and extensively used machining processes. Theoretical and experimental studies have been performed to understand the mechanism of burr formation on machined parts in milling operation [2–6]. During the milling operation, burrs are created mainly where the milling cutter exits the machined part. Burr generation in bandsaw teeth produced by milling operation is also a serious concern because the presence of burr on the bandsaw cutting edges could significantly affect the cutting performance. A clear understanding of the burr formation mechanism would be of great value in minimising the burr and hence, improving the manufacturing precision of bandsaw teeth. The aim of this paper is to provide valuable insight for better understanding of the burr formation in bandsaw teeth produced by milling operation.

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2. Bandsaw manufacturing process

The manufacturing process of bandsaw involves the packing of long bimetal strips in a milling machine and forming the teeth in the band strips using a specially designed milling cutter (Fig. 1). In a milling pass, the cutter traverses across the stationary band pack at a certain feed, speed and depth of cut. After completing one milling pass, the band pack is transferred forward and milling in the next pass continues. The milled bandsaw teeth are set in left- and right-hand directions using different set patterns and then hardened to give the required hardness and toughness in the bandsaws. Band loops are prepared with pieces cut from a long bandsaw to use in bandsawing machine.

The cutting tool in this case is a form milling cutter in which the flutes are arranged in a spiral manner. Helical teeth are formed on each flute to produce the required cutting edges. The cutting edge profiles are usually specified according to the cutting edge profiles of the bandsaw to be manufactured. Setting the flutes at an angle allows the teeth to enter into the workpiece material gradually hence, reducing vibration. Sharp bandsaw teeth are formed by the complex cutting action of the two teeth in successive flutes of the milling cutter (Fig. 2). Interrupted cutting action takes place in milling operation. As the workpiece material is not a solid block, rather a stack of many thin strips, the interrupted cutting characteristics are even more pronounced in the milling process. The milling of bimetal strips even complicates the machining process as the milling cutter encounters different materials (HSS, weld and spring steel) along the depth of cut.

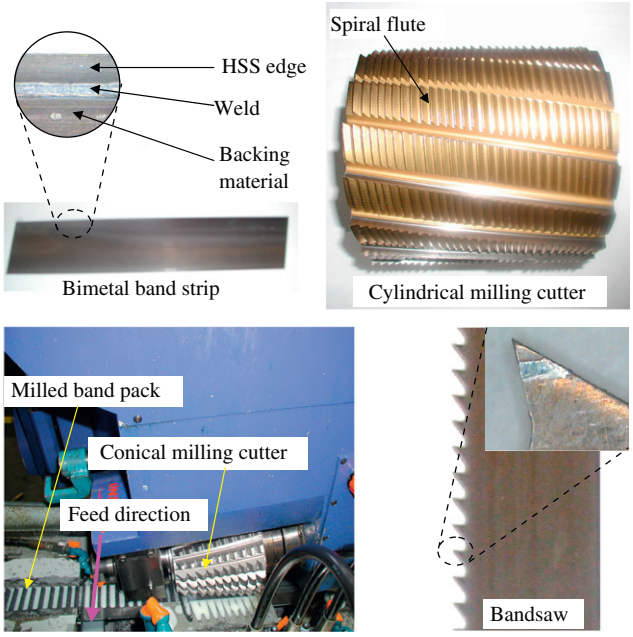

Fig. 1. Bimetal band strip, milling cutter, milling machine and generated bandsaw teeth in the strip.

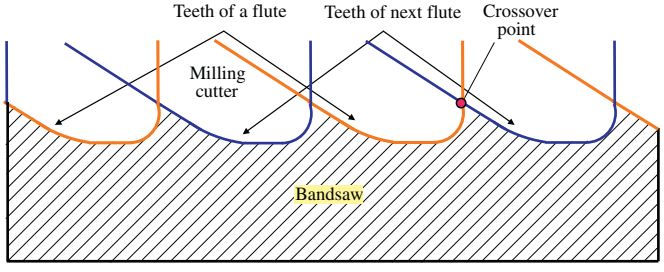

Fig. 2. A schematic diagram of bandsaw teeth generation by a milling cutter.

3. Materials, cutter and milling machine

The workpiece used for manufacturing bandsaws is long bimetal steel strip, in which M42 HSS edge wire (250–330 $HV_{1.0}$) is welded to D6A backing material (180–260 $HV_{1.0}$) as shown in Fig. 1. Width (13–80 mm) and thickness (0.6–1.6 mm) of bimetal strips vary depending on the size of the tooth pitches. Typical elemental compositions of the bimetal steel are presented in Table 1. Powder Metallurgy High Speed Steel (PM HSS; 900 HV) is used for the solid milling cutter, which was hardened and tempered at different stages of manufacturing to give the maximum strength at the cutting edges. The shape of the milling cutter could be either cylindrical or conical depending on the rake angle to be produced in the bandsaws. Bimetal bandsaws are manufactured in CNC milling machines (Fig. 1), where feeds and speeds can be continuously varied. The milling operation is carried in wet condition with water soluble coolant. The feeds and spindle speeds of the milling cutter are selected on the basis of optimised feed per tooth and surface speed within the capability of the milling machine. Bandsaw cutting edges and milling cutter wear were examined in a Compact Video Microscope (Allen CVM; magnification 50 ×) and optical microscope. The bandsaw tooth quality (Burr and back to tip height) was measured in a Shadowgraph (BATY International Ltd. P14 XLQC) having a magnification of 25 × .

4. Types of burr in bandsaw teeth and its consequences

Researches on burr formation in milling process [2–5] have identified different kinds of burr depending on the type of operation (face milling, end milling or slot milling), shape of burr and location of burr in machined workpiece. Manufacturing of bandsaw teeth by milling is a unique machining operation where two distinct kinds of burr are generally observed namely, side burr and tooth tip burr. Burr does not appear in the bandsaw teeth in controlled production environment where the level of burr is continuously monitored and controlled. Fig. 3 shows the perfectly formed bandsaw teeth in which no burr appears. Side burr generally appears around the gullet and along the sides of rake and clearance faces; whereas tooth tip burr appears in the bandsaw tooth tip (Fig. 4). The existence of burr is sometimes hard to recognise by naked eyes, but clearly appears under microscope or in shadowgraph. Side burr can be felt by the fingers when rubbing the machined edge.

Table 1
Typical elements in bimetal (M42 HSS and D6A) steel.

Band materials/weight (%)	C	Si	Mn	P	S	Cr	Mo	W	V	Co	Ni
M42	1.05–1.11	0.40 max	0.40 max	0.025 max	0.010 max	3.30–4.20	9.20–9.80	1.30–2.00	1.00–1.30	7.50–8.50	–
D6A	0.42–0.55	0.10–0.30	0.60–0.90	0.025 max	0.010 max	0.90–1.20	0.85–1.10	–	–	–	0.40–0.70