CUTTING DEVIATIONS IN BANDSAWING OF CYLINDRICAL METAL PARTS

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1. Introduction

Horizontal bandsawing is a highly material efficient manufacturing technology for cutting bar stock to length mainly due to its narrow kerf [1]. The aim of modern metal bandsawing is to produce semi-finished parts with cut surfaces so straight that face milling as a subsequent operation is no longer necessary. Avoiding this chipping-intensive process would mean a drastic reduction of material loss and cutting time in the roughing stage of many manufacturing applications. However, bandsawing technology has not yet reached this goal. The first step necessary for improving straightness of cuts is to investigate the current capability of the bandsawing process. This work is therefore concerned with examining the variety of different occurring types of non-straight cuts through experimental means.

2. Experimental Set-Up

For experimental investigation, Inconel 718 was selected as an exemplary material. Since it is difficult to machine [2], it poses a great challenge to the bandsawing process. Therefore, it can be assumed that characteristic non-straight cuts appear very distinctly. Additionally, its high material value [3] makes investigations into reducing wasteful machining operations relevant.

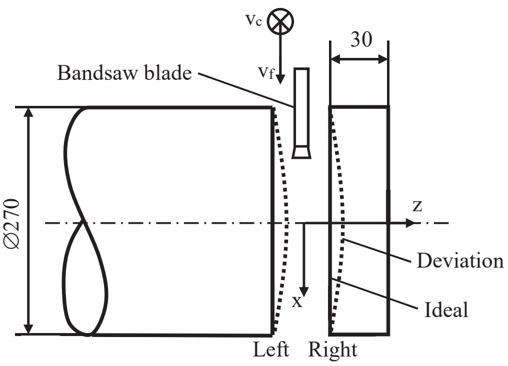

Fig. 1. Cutting of specimens for measurements

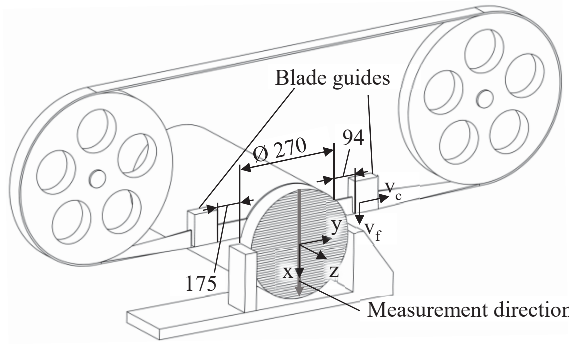

Fig. 2. Bandsawing process: Measurement and cutting directions. Dimensions in mm and measured parallel to the y-axis.

Cylindrical stock with a diameter of 270 mm was sawn into disc-shaped slices with a thickness of 30 mm (see Fig. 1 for schematic and terminology). A carbide bandsaw blade (Wikus Futura 718, 2-3 TPI) was used in a horizontal bandsawing machine (Behringer HBM540A) with a range of different cutting parameters: The cutting speed v_c was varied between 28 and 36 m/min, feed rate v_f between 3 and 8 mm/min. Using a ZEISS Duramax coordinate-measuring machine, the centerline elevation z of each probe's cut surfaces was measured with an average x-resolution of 0.1 mm (directions see Fig. 2). The z-axis lay in the measured cylindrical axis of the probe with the xy-plane defining the ideally straight cut. The $z = 0$ reference was set at the minimum x-value (blade entrance).

3. Results

The measurements of both cut surfaces of the probe can be recombined to form the left and right side of each cutting channel. With the bandsaw blade teeth being symmetrical to the xy-plane, the path of the teeth through the workpiece can be assumed to be the mean value of the left and right cut surfaces resulting in the deviation curves in Fig. 3. Two deviation characteristics can be defined: Total Deviation is the difference between the maximum and minimum elevation of a cut surface. It determines the amount of material that has to be removed in successive machining steps to achieve a perfectly plane surface. It can therefore be regarded as a measure of waste in terms of material and chipping effort. Deviation Rise is the z-difference between end and start of a cut and constitutes an overall cut inclination.

Over all parameter sets investigated, 3 different variants of crooked cuts could be identified, see Fig. 3. Parameters given correspond to the respective measurements shown but may not always result in the same deviation characteristic. The extremum of **Mode 1** lies in the center of the cut (x = 0) and the Rise can be either negative or positive. **Mode 2** has an extremum well before the center with a Rise to the opposite side of the extremum. **Mode 3** has two extrema leading to an almost sinusoidal cut. In the experiments conducted, both Total Deviation and Rise were at their lowest in Mode 3.

Mode 1: v_f = 3 mm/min	 f_z = 1.07 µm	*Cutting speed:* v_c = 28 m/min
Mode 2: v_f = 5 mm/min	 f_z = 1.79 µm	*Blade tension:* 300 MPa
Mode 3: v_f = 7.5 mm/min	 f_z = 2.68 µm	*Coolant:* 10% emulsion

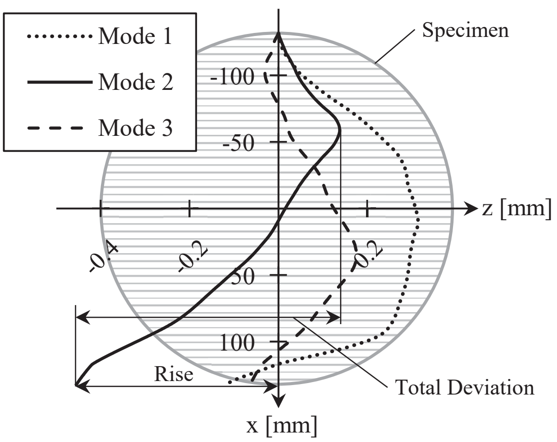

Fig. 3. Identified modes of deviation. f_z...calculated average feed per tooth. Illustrative view of the specimen rotated 90° around x-axis.

4. Discussion

Reng [4] reported deviation measurements for cutting cylindrical pieces that are similar to Mode 3 with a Rise to the right side of the cut. Total Deviation and Rise are in the same order of magnitude as in this work.

The circular cross-section of the cut results in a cutting width that varies over the feed path x. This likely influences the deviation behavior. The zero-crossing of Mode 1 and the extremum of Mode 2 coincide with the widest part of the cut. Notably, no measurements showed mirrored versions of the modes displayed in Fig. 3. Since the teeth of the bandsaw blade used are symmetrical in respect to the xy-plane, this could not be explained at the chipping process level. One reason could be the pre-torsion of the blade caused by the blade guides. Also, the exact set-up and manufacturing tolerances of the bandsawing machine may play a role. Repeating the experiment using a different machine could yield opposing (mirrored) trends.

The underlying mechanisms of bandsawing deviation constitute a complex elasto-mechanical problem including stability considerations and dynamic effects under stresses arising from the chipping process. Further investigations with a coupled FE-simulation approach are necessary.

5. Conclusions

3 different modes of deviation could be identified. Their occurrence as well as the deviation magnitude appears to depend on cutting parameters, in particular on feed per tooth f_z. Mode 3, which seems to be overall favorable, coincides with an increased value of f_z. It has to be noted, though, that trials with an even higher f_z again led to Mode 1 with an increased deviation magnitude.

This work provides the basis for further investigations into bandsawing deviation behavior and shows the status quo that deviation-reducing measures need to improve upon.

References

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