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The effects of process faults and misalignments on the cutting force system and hole quality in reaming

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Abstract

A chip thickness and cutting force model that considers the deflection of the tool and the regenerative effect resulting from the presence of process faults and misalignments has been developed for the reaming process. Through a series of experiments, the model has been calibrated and validated. The model predicts tool displacement, torque, thrust, X and Y forces, and the average radius of the reamed hole. The developed model is also shown to be capable of being used as a basis for the on-line detection of process faults present in the system.

Keywords: Reaming; Process faults; Hole quality; Force model; Cutting force system; Misalignments

1. Introduction

In reaming, when process faults and misalignments are present, due to the flexibility of the tool, the reamer has a tendency to deflect towards the initial hole axis as it passes through the hole. This deflection changes the value of the process fault parameters and introduces additional forces into the system that can influence the quality of the reamed hole. In order to accurately predict final hole quality, the influence of all these factors need to be better understood.

In an earlier paper [1], a static force model was developed that accurately predicts torque and thrust in reaming in the presence of process faults. However, the tool was assumed rigid and the chip load model did not consider the effects of tool deflection and regeneration. Though this model is quite useful for torque and thrust predictions, in order to be able to predict X and Y forces and consequently hole quality, the effect of process faults on tool deflection and regeneration [2,3] of the chip load must also be taken into account. Therefore an objective of this research is to extend the model developed by Bhattacharyya et al. [1] and incorporate the effects of tool deflection and regeneration due to process faults. A further objective of this paper is to better understand the effects of process faults and misalignments on reamed hole quality.

The contents of the paper are as follows. First, the nature of the tool deflections resulting from process faults and misalignments will be experimentally investigated. The next section describes the development of the extended chip load and force model that incorporates the effects of tool deflection and regeneration. This is followed by the model validation section that details the experiments conducted. Finally, a section on hole quality is presented where the experimental process for measuring the hole quality is first described followed by the use of the extended deflection and force model to predict hole quality.

2. Reaming process in the presence of process faults

In reaming, the reamer will have a tendency to follow the initial hole. This causes deflection of the tool when process faults and/or misalignments are present. This also causes a change in the net runout characteristics and additional forces due to this deflection will act on the reamer as it passes through the hole.

In order to observe the effects of reamer deflection, experiments were conducted using a Mori Seiki TV-30, a light milling, drilling, and tapping center. During these

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experiments tool deflections and process faults were measured using a C1-A Lion Precision capacitance sensor, with 500 μm range and 0.1 μm resolution. A 4-component Kistler dynamometer, which measures torque, thrust, X, and Y forces, was used to measure cutting forces. Fig. 1 shows the experimental setup used. The parallel offset runout, spindle tilt, parallel offset runout locating angle, and spindle tilt locating angle [1] were measured by the capacitance sensor to be 0.0376 mm, 0.08°, 67.78°, and 80.18°, respectively. The feed and speed were 0.19 mm/rev and 19.79 m/s, respectively. There was no spindle/hole axis misalignment present during the test.

Fig. 2 shows the force profile and the tool displacement from one of the experiments. The amplitude of the signal measured by the capacitance sensor prior to engagement, seen in the displacement profile in Fig. 2a, corresponds to the runout that the tool is experiencing at the point of measurement. This runout occurs as a result of a contribution of the effect of four runout parameters: parallel offset runout, spindle tilt, and their respective locating angles [4]. From Fig. 2a it can also be seen that when the tool becomes engaged in the hole, the runout decreases significantly as seen by the decrease in the amplitude of the signal measured by the capacitance sensor. But the runout of the reamer during engagement is still significant, suggesting that this runout will have an effect on both the cutting forces and hole quality.

Fig. 2b shows that during engagement/cutting, the X and Y forces are non-zero as expected due to the presence of net runout [1]. Fig. 2b also illustrates that after cutting is complete, while the tool is still rotating in the hole, the X and Y forces have non-zero magnitudes essentially identical to the X and Y forces during cutting. This indicates that the presence of a reaction force acting on the tool is the major component of the X and Y forces and emphasizes the need to take this phenomenon into account in the modeling of the reaming process.

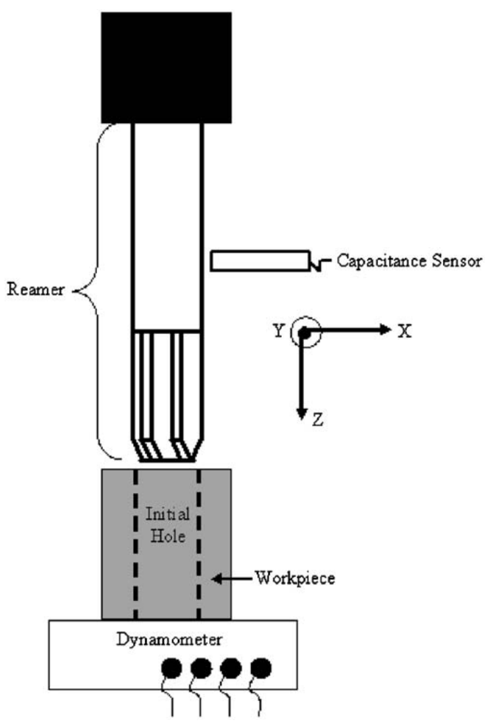

Fig. 1. Experimental setup for tool displacement measurement.

3. Modified chip load and force model formulation

It has been shown for related processes [4,5], the X and Y forces have a strong influence on final hole quality. Therefore, for accurate prediction of hole quality, the effects of tool deflection and regeneration must be incorporated due to their significant impact on the X and Y forces. Furthermore, X and Y forces have been shown to be useful in the on-line detection of process faults in tapping [6], suggesting that the same may be true for reaming. Therefore, the chip load model formulation of [1] should be extended to incorporate the effects of tool deflection and regeneration. In this section, the definition of process faults is given first. The tool deflection is then expressed as a function of the process faults present. The radius of rotation for each flute is modified to include this deflection, and the chip thickness taken by each flute is extended to consider the effect of regeneration. Finally, the formulation of cutting force model is presented.

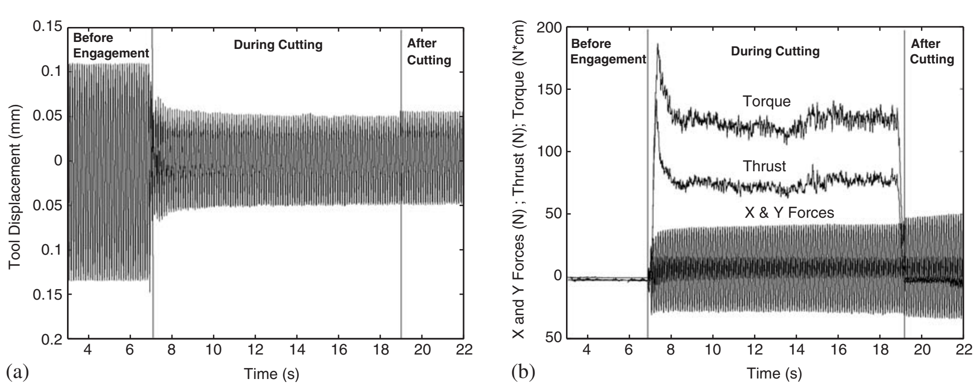

Fig. 2. Force and tool displacement profile.