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Compensation of the deviations caused by mechanical deformations during machining of threads

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Abstract

In the paper deviations during threading caused by mechanical deformations are analysed. Machining with full and partial profile of the cutting insert is investigated. A new method for inspecting the machined thread profile is suggested where the profile deviations caused by mechanical deformations can be compensated. The method is based on a workpiece-cutting tool touch probe inspection system. A detailed description is given on the cutting tool setup and monitoring algorithm for threading inserts with both full and partial profiles. The method can be applied to all types of internal or external threaded surfaces.

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1. Introduction

Profitability of parts manufacturing under the conditions of high competitiveness can only be achieved by applying effective manufacturing technologies. High competitiveness in many cases requires operations under extreme conditions near the limits of their reliability and search for rational technological solutions for assuring accuracy. Under these circumstances, machining processes are characterised by heavy cutting conditions [1,2] which lead to extensive machining errors and increased time for operational inspection necessary for reliable quality

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control. The cost of inspection connected to in-line measurements is especially high at high-accuracy machining and multi-tool arrangements where it is necessary to ensure not only the final dimension but also the intermediate ones [3,4].

Machining accuracy of threading is mainly defined by the dominant influence of mechanical deformations. These deformations are the result of the increased contact length between the cutting tool and workpiece during the final stage of the thread profile formation and the wear of the cutting edges. Cutting insert wear may cause deviation of the profile, but its contribution is small compared to errors caused by the fluctuation of the mechanical deformations. When machining internal threads, due to the low strength of the cutting tool this negative effect is increased. Under these circumstances assuring accuracy requires increased operational inspection. It is usually achieved by using gauges and micrometre callipers for external threads, and gauges only for internal threads. In order to be able to correct profile deviations, operational inspection has to be performed directly on the machine tool. In job-shop and low-batch production the use of gauges for inspection increases the production cost and lead time. Another problem is the lack of quantitative information. Due to these problems, during machine tool setup and re-setup, in order to define the value of compensation without producing scrap, it is necessary to perform a number of trial cuts [3,4,5]. There is an additional problem when machining threads with large diameters due to the necessity of gauges with large dimensions and weight. When machining threads on parts that are clamped between centres the use of gauges makes the inspection even more complicated because it requires the removal of the workpiece from the machine tool to perform the inspection and its subsequent re-installation. This process has to be performed several times until the required accuracy is achieved.

The usage of gauges is a reliable way of thread inspections but it leads to increased manufacturing costs due to increased processing times and does not allow automation of inspection and machine tool setup. Also, the cost of threading gauges has to be taken into account when defining unit costs, especially at low production volumes.

2. Inspection Methodology

In order to eliminate the shortcomings of inspection using gauges, a new method for automatic inspection of machined threads is developed. It is based on the registration of electrical contact between the cutting tool and workpiece without the necessity of their electrical insulation [3-5]. The cutting tool is the touch probe and when a contact between the tool and the workpiece is made a contact signal is generated that registers the dimension at the time of the contact. This eliminates the need for an additional measuring device. The tool-workpiece touch probe system includes a high-frequency generator which is connected through wires to two selected points on the machine tool body. The voltage in the generator creates eddy currents in the body of the machine tool. When the cutting tool, installed in the turret, makes contact with the workpiece, an electrical loop closes, which redistributes these currents. A sensor is fixed to the slide of the machine tool in a position where this current redistribution induces maximum voltage in it.

Inspection performed directly using the cutting tool itself is highly sensitive to dimension deviations of the machined surfaces and to mechanical deformations. This makes the method effective for automatic operational inspection of threaded surfaces.

3. Inspection Methodology

Inspection using gauges is complex; it is necessary to measure the pitch diameter, pitch, and profile angle. On CNC machine tools, thread pitch errors are relatively low due to the high positional accuracy of the machine. Since in most cases the thread is machined using carbide inserts, the initial accuracy of the thread profile is also guaranteed. Therefore, on CNC machine tools thread inspection can be limited to the measurement of the external and pitch diameters and profile deviation due to cutting insert wear. Thread inspection on CNC lathes depends on the two types of threading inserts: with full and partial profile (Fig. 1).