Cutting process impact on machine tool thermal errors

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Abstract

Achieving high workpiece accuracy continues to be a long-term trend among machine tool designers as well as customer requirement. There are many causes of workpiece inaccuracy. However, thermal errors are the most dominant and have been affecting the accuracy of production machines for a long time. Compensation of thermally induced errors is promising strategy how to reduce thermal errors of machine tools. Although real-time thermal compensations exist, these compensations have a number of serious drawbacks. One of the most significant is that the majority of these models only presume machine tools under load-free rotation of the main spindle without any reference to rough machining. The cutting process is completely neglected in spite of the fact that the machining process represents a significant cause of workpiece inaccuracy. Thus, the accuracy and reliability of the estimated thermal deflection by using air cutting compensation models is generally poor.

The challenge to be addressed by this paper is to extend the machine tool thermal compensation models considering only internal heat sources to include the effects of the cutting process. In order to include the cutting process impact into the existing air cutting model using transfer functions (TF), a series of technological tests were carried out (see Fig.1).

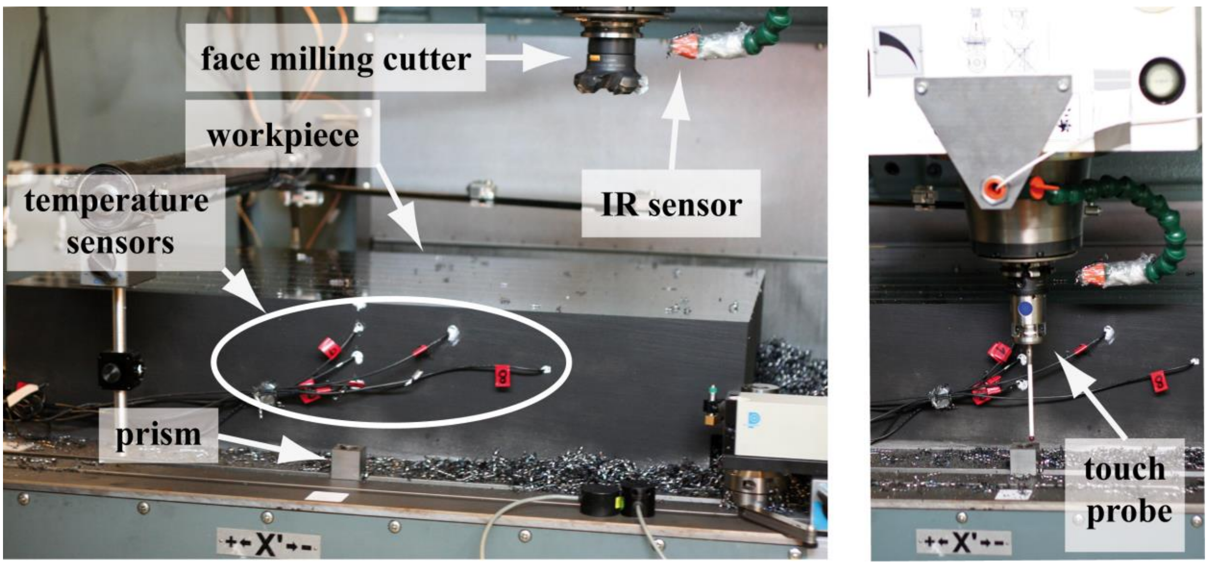

Figure 1: Experimental setup

Subsequently, a robust compensation of thermally induced displacements at the TCP due to the complex cutting process impact was developed based on performed steel cutting tests. Further, the model was implemented into a standard CNC controller of a three-axis vertical milling centre to compensate for thermal errors in real time. The inputs of the compensation algorithm are the spindle rotational speed, the 5 temperatures of the machine structure and spindle power.

Finally, specially designed test worpiece have been developed to determine the machine tool errors under real operating conditions. Test workpiece is divided into three sections which represent thermal error in case of uncompensated machine, machine equipped with widely used MLR compensation model and machine equipped with developed thermal error TF model including cutting process impact to compare machining accuracy. A reduction of thermal errors achieved by using the new approximation TF model including cutting process impact is up to 79% (fit) for steel cutting tests with different cutting conditions (see Fig.2).

Experimental results confirmed the great importance of the cutting process impact on thermally induced displacements at the TCP. Therefore, ïn order to enhance machine tools precision deteriorated by thermal causes in future, the thermal compensation models should be based on real machining tests (thermal compensation algorithms should include cutting process influence).

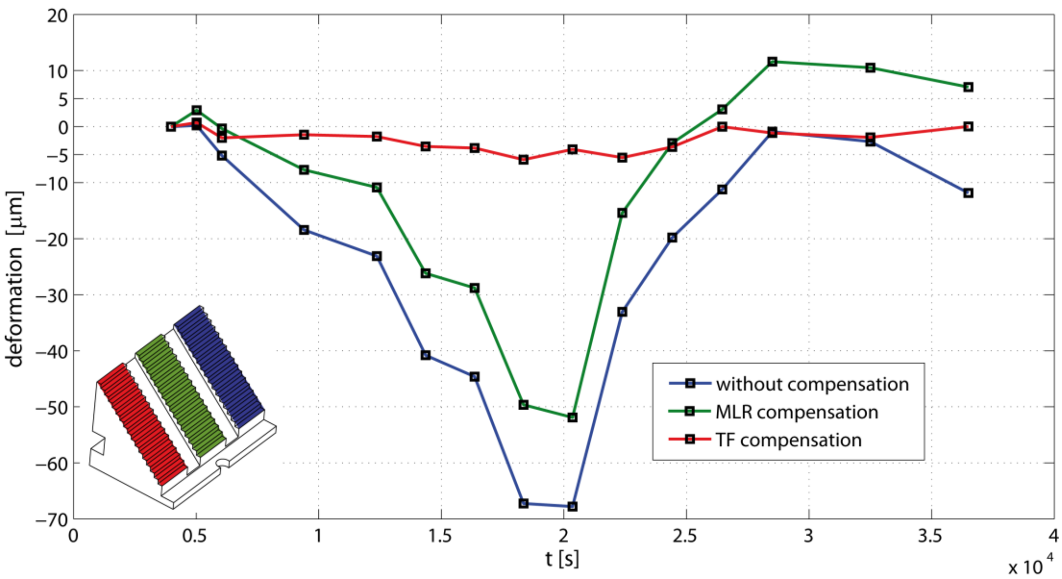

Figure 2: Comparison of thermally induced displacements at the TCP in Z direction.

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