Evaluating Thermo-Mechanical Stress Due to Surface Grinding on a Sensor Integrated Workpiece

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Abstract

INTRODUCTION: Sensor integration in a workpiece can be used to characterize manufacturing processes but due to integration, a foreign element is added to the material which can alter its material properties [1]. This can lead to a high order of measurement uncertainty. Additionally, the extent of deviation from standard behavior may vary depending on how the sensors are embedded into the material. This report describes the simulation of the thermo-mechanical stress developed on a sensor-integrated workpiece, 'sensorial steel', during surface grinding and compares it with that on a homogenous workpiece. The simulation also includes how the measured stress differs based on the embedding technique used (soldered or glued) on the sensorial steel. Figure1.

USE OF COMSOL MULTIPHYSICS:
The 'Structural Mechanics Module' was used to analyze a 2D model of the workpiece with a rectangular load/heat source on the surface with a width equal to the contact length of the grinding wheel. The source is not considered as a moving heat/load source and hence the stress is measured at that point on the surface where the source, moving in grinding-direction, reaches in one stroke (Figure 2). The depth of cut has also been neglected. The load has both tangential and normal components and the heat source is the total heat flux entering into the workpiece, neglecting the heat flux entering the chip. The parameters used in the model were obtained from previous grinding experiments with sensorial steel [2]. To differentiate between the homogenous and the sensorial steel, the Parametric Sweep function was used on the Young's Modulus and thermal expansion co-efficient of steel, solder, and glue. Hence it is assumed that the solder/glue and the steel differ only in these two parameters.

RESULTS:
The results show the Cauchy stress tensor-depth profile of both workpiece due to combined mechanical and thermal effect of grinding (Figure 3). The deviation at 1.8 mm below the surface where the sensor is embedded is lesser in case of the soldered workpiece than the glued one when compared to the stress measured on the homogenous workpiece (Figure 4). This indicates that the measurement error is higher in case of glued inlays but the distortion of the measurement signal is not significant.

CONCLUSION:

By integrating thin-film sensors into a workpiece, it is possible to characterize abrasive manufacturing processes like grinding to evaluate surface properties or take in-situ process measurements. Due to integration there will be a measurement uncertainty but it will not alter the measurement signal entirely. The extent to which the measured signal deviates from expected behavior also depends on the way the microsensors are embedded in the material. The sensor inlay is embedded into the workpiece either by hard soldering or by using epoxy glue. The latter is simple and cost-efficient but creates a larger measurement error. However, due to minimal distortion, calibrating the measurement signal can produce a reproducible effect and hence glued inlays can be used as an alternate solution for embedding pre-fabricated microsensor inlays into materials.

Reference

1. Walter Lang et.al., From embedded sensors to sensorial materials – The road to function scale integration, Sensors and Actuators A 171 3-11 (2011)

2. Andreas Tausendfreund et.al., CIRP Annals - Manufacturing Technology 64 495–498 (2015)