Optimization Of Microfabricated 2D Planar Spiral Microcoils For The Micro NDT Of Grinding Burn

Isman Khazi[1], Andras Kovacs[1], Rui Zhu[1], Ulrich Mescheder[1]

[1]Institute for Microsystem Technology(iMST), Furtwangen University, 78120 Furtwangen, Germany

Abstract

Cylindrical grinding has become an integral part of machining of workpieces with an ultra-high precision and higher throughput. The grinding process involves the mechanical interaction of the grinding blade with the workpiece at relatively higher rotation speeds, with a higher energy input to remove a unit volume of material from the workpiece. The applied mechanical energy is dissipated in form of heat energy at the contact zone, which leads to grinding burn. Therefore, an early detection is desired to avoid the occurrence of it. Hence, in this work microfabricated 2D planar electromagnetic eddy-current microcoils (µcoils) are simulated for the non-destructive testing (NDT) of the grinding burn quality during the grinding process, with a higher detection resolution.

COMSOL Multiphysics® is used to describe the experiment conditions using a 3D model, involving the workpiece with grinding burn and the eddy-current microcoils in its vicinity for NDT of grinding burn (Fig. 1a). A 3D model is built using COMSOL Multiphysics® solver using the AC/DC Module with "Magnetics and Electric Fields" physics interface involving a frequency domain study. The geometrical construction of the simulation included defining a spiral µcoil (variable number of turns), glass substrate, air environment, iron workpiece and the grinding burn (Fig. 1b). The major challenge in the simulation work was the definition of the grinding burn, because as compared to other material defects such as microcracks, pores, etc., which can be easily defined as air gaps, the nature of grinding burn is more complex. The occurrence of the grinding burn in the contact zone influences the microstructure of the materials, thereby altering the mechanical, electrical and magnetic properties within the contact zone within grinding burn. In terms of modification of mechanical properties such as the internal stress, hardness and microstructure are affected, while in case of electrical properties the electrical resistivity is affected. In case of the magnetic properties predominantly the relative permeability (µr) is affected. Considering the use of the ferromagnetic materials for the cylindrical grinding, the electromagnetic nature of the NDT approach using eddy-current µcoils, the relative permeability is used as the physical parameter defining the presence of the grinding burn in the workpiece (for e.g. µr=28 for workpiece and µr=20 for the grinding burn). Following, a frequency domain study was conducted within the frequency range of 100 kHz - 1000 kHz to investigate the impedance of the µcoil as function of frequency in presence and absence of grinding burn.

The following parameters of the µcoil were varied and studied to achieve a higher sensitivity (i.e. higher change in impedance of µcoil): the number of turns of the µcoil, the width, height and the distance between the conductive tracks of the µcoil, and also the distance between the µcoil and the workpiece. Sender and receiver µcoil with transformation principle is also simulated. The simulation results show a clear change in the impedance of the µcoil (Fig. 1c and 1d) as function of the grinding burn and thereby, showing the feasibility of using µcoils for the NDT of the grinding burn.

Figures used in the abstract

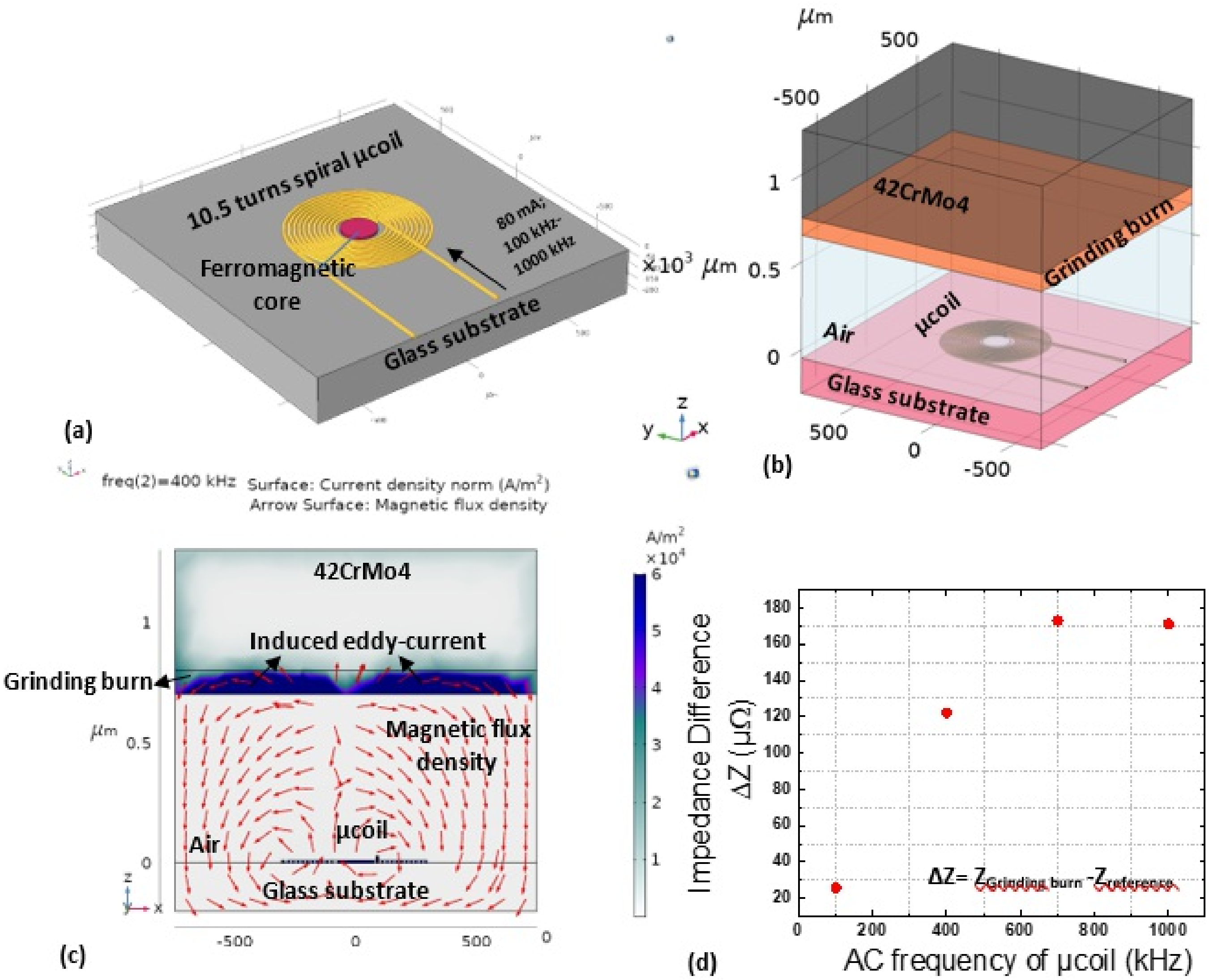

Figure 1 : Fig.1 (a) Geometrical construction of circular spiral µCoil with a ferromagnetic core on a glass substrate, (b) the complete simulation setup with 42CrMo4 workpiece and grinding burn, (c) simulated cross section profile showing the induced eddy-current in