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Magnetic Property Changes by Machining Ferromagnetic Materials

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Abstract

The higher the demands concerning the cleanliness of the component and the surface qualities, the more the change of the magnetic surface characteristics influenced by machining comes into focus. The influence by machining has to be examined under different aspects to meet the complexity of the subject matter. This paper focuses on the correlation between the process parameters, the batch of the material and the change of the magnetic surface characteristics. The findings concerning the correlation of magnetic characteristics of a workpiece and the machining lead to an optimized approach to the planning of process chains.

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Keywords: Bearing, Machining, Surface analysis, Magnetic properties

1. Introduction

The higher the demands concerning the cleanliness of the component and the surface qualities, the more the change of the magnetic surface characteristics influenced by machining comes into focus. The revision of the VDA 19 shows clearly the growing focus on the field of the cleanliness of components [1]. It thus demands need for action. A related field of study is the adhesion of chips to components and tools, inter alia through the change of magnetic properties of the component. Figure 1 shows the dependence of the size of particles to the existing magnetic field on the surface of a workpiece, assuming idealized steel particles. Diverse boundary conditions influence the magnetic surface properties of a workpiece. This paper aims to demonstrate systematical effects and to analyze influences on these effects.

For this reason, machined steel 1.7225 with varied predefined machining parameters was analyzed. Here, milling was used for its excellent repeatability properties, aiming to produce a preferably even surface. So it is possible to apply nondestructive test procedures to measure the magnetic properties. The possible influencing variables can be detected by a statistical Design of Experiments (DoE). Thus, qualified measurements can also detect a possibly minimized change in the magnetic flux density.

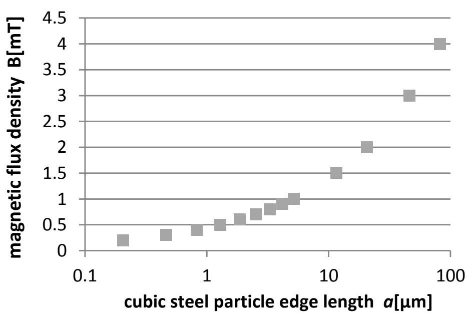

Fig. 1. Required magnetic flux density *B* in mT for adherence of idealized cubic steel particle, edge length *a* in µm.

2. State of the Art

The change in magnetic properties near to the surface of materials is a long-known side effect of machining that has been researched since the 1970s. Schreiber [2] investigated primarily the change in hardness and residual stress. Those

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values were mainly produced by thermal effects through machining. Besides Schreiber, also Byrne [3] investigated the effects of machining on magnetic properties. His research approaches the process parameter milling, turning and drilling. In his experiments he uses the *one factor at a time*-method. As a result, no interdependencies between single factors can be found. [3] Hence, it is rather difficult to compare the results.

Subsequently, Eyrisch et al. [4] indicate the changes of magnetic properties while machining using their methods. They come to the conclusion that there is a low influence of machining to magnetic properties of the material. This influence is not strong enough to have a significant effect on metallic particles. Further research on the topic has been conducted by Bähre et al. [5,6]. There, they show the relation between influences of parameters and magnetic fields.

Influencing factors are external magnetic fields like the electromagnetic fields of the machine drives, the terrestrial magnetic field or magnetic clamping. The latter has been researched by Grimm [7]. There, he describes the development of magnetic clamping systems, which include an electronic pole reversal control unit. Furthermore, Bähre et al. [6] assume that the ductile plastic deformation of a workpiece is an influencing factor on the change of magnetic properties. Moreover, the thermal influences on the workpiece during the machining process as well as the Villari-effect represent an important factor on the change of magnetic properties. Trapp et al. [8] also show the impact on the change of magnetic properties through certain parameters during machining. Examples for these parameters are depth of cut, feed speed and batch. The results depict on one hand the significant effect of the batches and the feed speed. On the other hand the paper identifies the effect of the depth of cut to be rather low. With its statistical DoE, this paper is a valuable continuation of [8], where a statistical base has not been applied.

Furthermore, Trapp et al. [8] investigated the measurement distance between Hall sensor and surface of the sample. As a result, they stated that the distance between Hall sensor and surface of the sample should be minimized. This arrangement helps providing significant and reproducible values. Likewise, Su and Chen [9] conducted experiments on the distance between Hall sensor and surface of the sample. In their work, they also observe the most significant values with a minimized distance between Hall sensor and surface of the sample.

3. Effect Analysis and Experimental Procedure

3.1. Effect Analysis

In a DoE a system is analyzed which can be influenced by various factors. In this paper, the system analyzed is the machining process. Exemplarily, Figure 2 shows the influencing variables of the workpiece and of the machine used. The variables induce changes in the considered quality features, which are defined as magnetic properties in this paper. They can be described as an impact of the machining on the workpiece. Other quality features as surface quality are not investigated here. The listing of influencing variables is not exhaustive and can be completed by multiple factors, for example the surrounding conditions or human impacts. In order to give valuable input on the statistical DoE, some factors were chosen amongst the influencing variables and then connected with defined factor levels of the DoE.

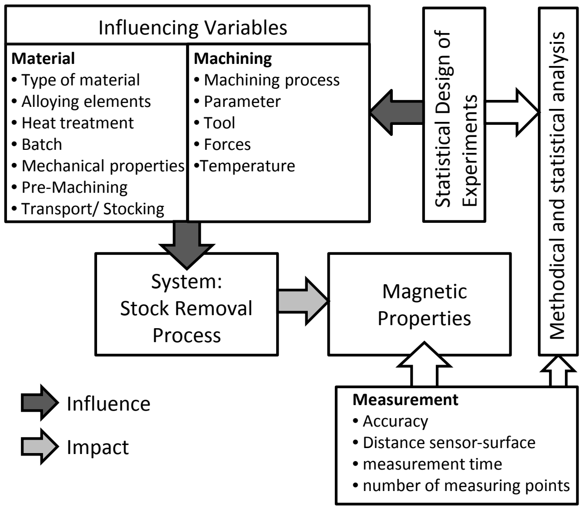

Fig. 2. Influence and impact analysis between machining process, influencing variables, magnetic properties and statistical DoE.

3.2. Experimental Procedure

The workpieces made of 1.7225 steel are sawed on a length of 200 mm from a rolled bar stock with a cross section of 40 mm x 60 mm. The main difference of the two batches are shown in the chemical analyses by sulfur (A:0.0072 wt%, B:0.022 wt%) and phosphor (A:0.0171 wt%, B:0.0131 wt%). The DoE defines the machining, using values, factor and factor level, from table 1. The milling process appears either parallel or perpendicular to the direction of rolling. The quality feature is characterized by the magnetic flux density *B* which is measured via a Hall sensor and is conducted over the whole sample in all three components of spatial dimension as 2D and 3D scan. The setup can be seen in Trapp et al. [8]. In this work, the Hall sensor *metrolab* THM 1176-LF with an accuracy of 1% of the measured value has been used.

Table 1. Experimental setup parameters during milling.

Tool	45° plane milling head with five cermet edges and 80 mm diameter	
Milling conditions	non coolant fluid	
Milling Direction to rolling direction	parallel ∥	perpendicular ⊥
Workpiece material	automotive steel 1.7225	

Factor	**Factor Level**	
Rotation speed n	625 min^{-1}	833 min^{-1}
Feed per edge f_z	0,05 mm	0,15 mm
Depth of cut a_p	0,5 mm	1 mm
Batch	A	B
Milling Direction to rolling direction	parallel ∥	perpendicular ⊥