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DEM simulation of centrifugal disc finishing

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Abstract
The finishing of small components with complex geometries is a major industrial challenge. One process that is suitable for targeted post-processing is centrifugal disc finishing with wet and dry media. In this process, the workpieces float as bulk material together with the abrasive particles in a container and are completely surrounded by the abrasive medium. As shown in previous studies, the Discrete Element Method (DEM) is suitable for investigations of grinding processes with specified workpiece motions. To simulate unpredictable workpiece motion, a new approach is being tested in which the workpieces themselves are treated as particles. Within this research paper, results for the post-processing of centrifugal disc finishing with the software ROCKY DEM are presented. The investigation results show good correlation between the numerical determined pressures and the analysis results of the rounded workpiece edges on test components made of mould-steel X13NiMnCuAl4-2-1-1.

Keywords: immersed tumbling, centrifugal disc grinding, discrete element method

1. Introduction

In order to meet high quality requirements for parts and components with surface roughness of Ra ≤ 0,1 µm and burr free edges finishing processes are increasingly used at the end of the process chains. For rounding, deburring and surface improvement, a wide range of processes can be used depending on the requirements [1]. A technology which is particularly suitable for small and complex components and their mass finishing is centrifugal disc finishing [2]. Thereby, the workpieces are completely surrounded by the abrasive grains. Through the specific process simulation with the Discrete Element Method (DEM) it is possible to improve the process understanding and to analyze the particle behavior. In particular, the software ROCKY DEM from the company ESSS, Florianópolis, Brasil, offers new possibilities for the simulation of moist particles and thus an analysis of the disc centrifugal grinding. In addition to the use of complex particle geometries, the software enables a high number of particles through improved computational algorithms of the contact mechanics. Furthermore, moist particles and their contact conditions can be calculated by an implemented liquid-bridge model [3]. Uhlmann et al. [3, 4, 5] as well as Zanger et al. [6] were able to demonstrate potentials for the analysis of different drag finishing technologies with the software ROCKY DEM and the simulation of dry and wet particles through their research work. In the following, the numerical approaches are to be applied for another process and thus the field of application is to be extended.

2. Centrifugal disc finishing

A centrifugal disc machine tool consist of an open process container, wich is filled with moist or dry abrasive medium, shown in Figure 1. A toroidal stream is generated inside the stationary process container via the rotation of a disc attached to the bottom. In this process, the workpieces (e.g. screws, wire guides, springs or jewelry) float as bulk material together with the abrasive particles in the container.

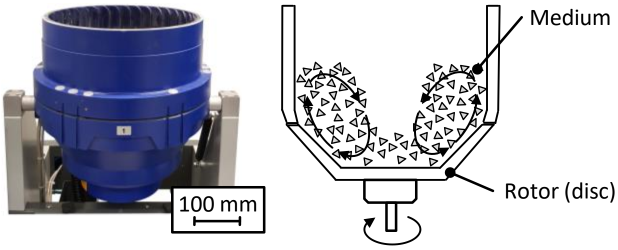

Figure 1. Centrifugal disc machine tool

3. Setup

A CF 2x18 centrifugal disc finishing machine tool with a container volume of 18l was used for the study. The system of the company OTEC Präzisionsfinish GmbH, Straubenhardt, Germany, has a disc speed of up to n_d = 330 1/min. A moist abrasive medium of the type KM10 with a conical particle geometry and height of h_c = 10 mm was used. A mould steel of the type M261 extra, X13NiMnCuAl4-2-1-1, of the company Böhler Edelstahl GmbH, Kapfenberg, Austria, was set for the rectangular block workpieces with dimensions l_w = 50 mm, w_w = 20 mm and h_w = 3 mm. The blocks were machined with a process time of t = 15 min and t = 30 min. After the finishing process the radii of the workpiece edges were measured with the optical measurement device InfiniteFocus of the company Alicona Imaging GmbH, Graz, Austria.

4. Discrete element modelling

The software version 4.5.2 of ROCKY DEM was used for the process simulation. A CAD-model of the centrifugal disc machine tool was designed and filled with the wet KM10 granulate. As shown in previous work, ROCKY DEM provides a sufficient representation of flow and contact behaviour of non-spherical particles as well as realistic simulation of moist particles given by the built-in liquid-bridge module [3, 4, 5]. For the experiments a homogenous moisture distribution was chosen with physical parameters of water and mass of $m_w = 10$ mg per particle resembling the experimentally weightened mass of water carried by each particle. The particles were meshed with $n_{c,KM10} = 300$ cells. Contacts are modelled with hysteretic linear springs for normal forces F_N and linear coulomb springs for tangential forces F_T.

In this study, the examined workpieces do not perform deterministic movements, but must allow free body movements as well as free body rotations. For that matter the steel workpieces are implemented as secondary particles with $n_{c,w} = 9{,}122$ cells and two workpieces are dumped into the container. The collected intra-particles and inter-particles-contact data are then analyzed and compared with the experimental results. The simulation environment is presented in Figure 2.

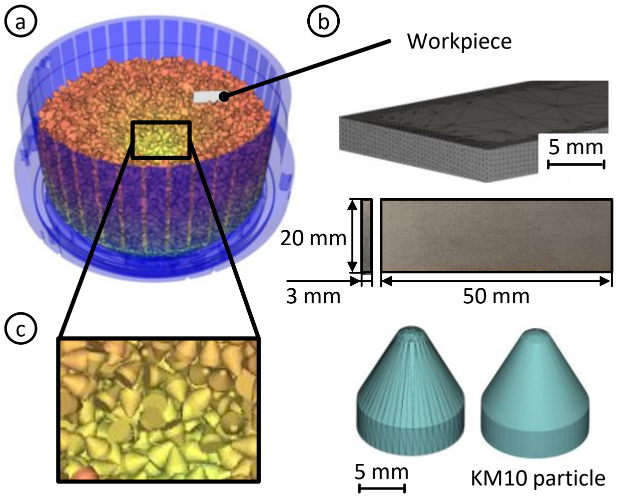

Figure 2. Simulation environment and components;
a) process model with particles, b) meshed workpiece, c) KM10 particle

5. Results and discussion

The corners as well as the edges of the longitudinal axis were measured on the unmachined workpieces and the machined workpieces after varied process times of t = 15 min and t = 30 min. Furthermore, images were made and the results were compared with the simulation results consisting of the duration time t_d, tangential stress τ, normal stress σ and frequency f of the contacts. Figure 3 shows the mean values of the experimental results presented by the radii r as well as the calculated average of normal stress σ_a in the simulation. It can be assumed, that first effects on the edges and corners of the workpieces, in consequence of the particle contacts, can be mapped simulatively. Due to the high computing times, only a few seconds are calculated in the simulation and the result is scaled. Due to a longer simulation time t_s, an increase of the processing intensity can be detected similar to the real process. The number of contacts increase and higher tangential and normal stresses are achieved. In the real process, an increased machining of the corners is visible, which could also be determined simulatively by higher stresses.

While contact points between the workpiece and abrasive particles are distributed everywhere on the surface of the workpiece, significant stresses occur only at the corners and edges. The results show a clear correlation between the simulated machining peaks and the areas of maximum geometry change from the experiments. This is also confirmed with different process times t. These conclusions show that the evaluation of collision statistics on particles is possible and realistic, and that it is advisable to use this for bulk materials with under-mixed particulate workpieces.

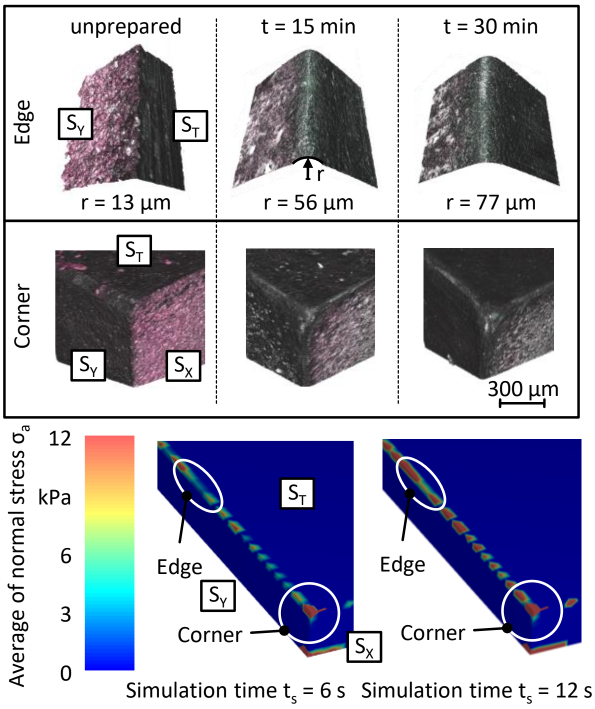

Figure 3. Preparation and simulation results of the edges and corners

6. Conclusion

The given study provides a numerical modelling of the centrifugal disc finishing with a moist medium. By using the software ROCKY DEM, free moving workpieces could be realistically simulated by treating them like particles themselves. Flat workpiece samples were finished and the radii of the machined edges were measured. The experimental results were then qualitatively correlated with those obtained from the simulatively determined average of normal stress σ_a.

In further investigations, the model will be used for simulation of workpieces with higher complexity and the surface quality will be considered as a further target variable as well as its simulative predictability.

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