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SAFBM of Softer Materials: An Investigation into the Micro-Cutting Mechanisms and the Evolution of Roughness Profile

N. K. Francis[1], K. G. Viswanadhan[2], and M. M. Paulose[3]

[1]*Karpagam University, Coimbatore, Tamil Nadu, India*
[2]*NSS Engineering College, Palakkad, Kerala, India*
[3]*MBITS, Kothamangalam, Kerala*

Swirling Fluidized Bed Machining (SAFBM) is a nontraditional machining process and novel variant of Fluidized Bed Machining (FBM) in which the former has overcome certain drawbacks of the latter such as roughness variation and shading effect. SAFBM generates significant material removal and surface finish on the workpiece surface during the machining process with consistency and flexibility. The present detailed study emphasizes on the machining of softer materials such as brass and aluminum using abrasive particles such as silicon carbide in order to analyze the effect of various micro-cutting mechanisms on the generation of surface texture. This study examines the evolution of surface roughness profile after progressive machining with abrasives ranging from coarse, medium and fine grades of SiC with the help of optical microscopic images of the machined surface. The research concludes that using SAFBM, flat and uniform surface finishing with *modification ratio* in terms of roughness parameters ranging from 5 to 7 is possible within 7–8 hours of processing.

Keywords Distributor; Embedding; Fluidization; Hardness; Metal erosion; Modification ratio; Refinement; Roughness; SAFBM; Swirling; Texture.

Introduction

Swirling Fluidized Bed Machining (SAFBM) is a variant of conventional Fluidized Bed Machining (FBM) in which the blower generates sufficient air supply to the porous distributor with evenly placed angular openings (Fig. 1) through the plenum chamber. Compressed air surging out of the distributer with horizontal and vertical components of velocity due to the inclination of the holes fluidizes the silicon carbide grits lying settled on the distributer plate. The particles in fluidized state hence move up in the container, swirl vigorously and hit on the metallic specimen surface, causing wear and surface finish (Fig. 2).

The workpiece surface that is away from the bottom face is subjected to *shading effect* and hence this prevents uniform machining in the case of FBM [Fig. 2(a)] as observed by Barletta [1]. Rising fluidized abrasive particles in FBM strike the bottom portion more vigorously than the top portion of the job because of its closeness and hence results in significant machining variation vertically. However, a major difference is visible in the case of Swirling Fluidized Bed motion as in Fig. 2(b), in which the air–solid mixture circulates in the bottom section of the container as observed by Sreenivasan et al. [13]. As a result the air–particle mixture circulates with more grain concentration and increased speed than in the case of the former owing to the smaller angle of inclination ($\alpha = 15°–20°$) of the distributer holes. SAFBM can thus perform much rapid machining and surface refinement (Table 1).

Figure 2(b) depicts the flow pattern of the air–particle mixture in SAFBM. The horizontal and vertical velocity components of the swirling fluidized charge evenly strike the surface and machine the contours of the metal specimen up and down and guarantee surface finish with minimum variation. Moreover, the particles follow a chain-like pattern on the metallic surface during SAFBM. Each of such numerous high-speed-flowing abrasive chains behaves like a cutting tool and performs rapid metal removal compared with FBM. It is evident that SAFBM compensates the *shading effect* and guarantees uniform machining compared to FBM.

It was Francis et al. [2] who first conducted experiments on Swirling Abrasive SAFBM as an alternative form of FBM using a porous air distributer with inclined holes. The research focused on the comparative study with the FBM and testing the effectiveness as a nonconventional surface modification process. The operational parameters such as machining duration, particle impact speed, abrasive particle size, workpiece material hardness, positioning and geometry of the workpiece and abrasive shape and type play a major role in determining the degree of the roughness achieved and the metal removal rate (MRR). The research investigated the influence of velocity of striking and abrasive mesh size (MS) on a copper (HV 49) specimen. The analysis underlined that the particles with coarse grit size and with higher impact speed will result in faster surface modification with a high value of R_a. On the other hand, finer-sized abrasives with

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Address correspondence to N. K. Francis, Karpagam University, Coimbatore, Tamil Nadu, India; E-mail: francisnk123@gmail.com
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