Journal of Materials Processing Technology 209 (2009) 6087–6102

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

Progress in abrasive fluidized bed machining

M. Barletta

Università degli Studi di Roma Tor Vergata, Dipartimento di Ingegneria Meccanica, Via del Politecnico, 1-00133 Rome, Italy

ARTICLE INFO

Keywords:
Abrasive
Fluidized bed
Deburring
Finishing
Polishing
Cleaning
Surface preparation

ABSTRACT

The use of abrasive fluidized bed equipment in a broad range of manufacturing processes is reviewed. In particular, applications in deburring and finishing of complex-shaped metal components, in superfinishing of dies for injection molding, in cleaning and polishing of electronic devices, and in surface preparation of tungsten carbide milling tools are reviewed. Attention is focused on the effects of the most important process parameters, such as machining time, abrasive type and mesh size, and flow or jet speed. The extent of material removal and the change in surface roughness as a function of the process parameters are addressed. Selected numerical and analytical models that are useful for automation and control purposes are discussed. Finally, the industrial sustainability of the processes and equipment investigated is highlighted.

1. Introduction

Abrasive fluidized beds (AFBs) are used for advanced machining processes. They have been recently proposed as cost-effective and environmentally friendly alternatives for a wide range of industrial applications, such as deburring, finishing, polishing, cleaning and surface preparation of metal and non-metal workpieces. Fluidized bed systems were first proposed as a method for finishing of complex-shaped cast aluminum components less than 10 years ago by Barletta et al. (2001). Since then, interest in AFB technology has increased. In 2002, Barletta et al. tried to extend the use of AFBs to components that are difficult to machine (Barletta et al., 2002). They investigated issues related to the finishing of metal matrix composites used in the manufacture of automotive and aeronautic components. Barletta et al. (2004a) furthered the applications of AFB technology by performing finishing of sintered components and evaluating its suitability for cleaning and coating of metal substrates (Barletta et al., 2004b, 2006a; Montesperelli et al., 2006). In particular, cleaning of copper–nickel frames used in the manufacture of electronic devices was investigated and the appropriateness of glass beads as a viable cleaning medium was demonstrated (Barletta et al., 2004b). The growth kinetics of thin alumina films on aluminum alloys and the mechanisms involved were the subject of further investigations (Montesperelli et al., 2006; Barletta et al., 2006a). Such studies demonstrated that well-adhered thin hard films on softer metal alloys can be established by simply exposing them to repeated impacts by hard and brittle media at ambient temperature for a long processing time.

In 2006, Polini et al. were the first to evaluate the possibility of pre-treating tungsten carbide substrates by fluidized bed peening with diamond powder (Polini et al., 2006a). The aim was to corrugate the substrate morphology to improve the adhesion of overlying diamond coatings deposited by hot filament chemical vapor deposition (HF-CVD). Fluidized bed peening also seeded the tungsten carbide with diamond fragments that were found to act as nucleation centers during subsequent diamond deposition. Kumar et al. used a similar technique to corrugate a metallic Cr interlayer used as a Co-diffusion barrier on a tungsten carbide substrate to promote growth of a well-adhered CVD diamond coating, thus avoiding the formation of intermediate carbonaceous layers (Xu et al., 2007).

More recently, Barletta et al. investigated the influence of the main process parameters on the effectiveness of the machining process (Barletta, 2006). In particular, the effects of the impact speed and the media size and shape on the material removal rate and final morphology were determined. This experimental effort was followed by first attempts to model the main phenomena during machining.

The relationship between the machined material and the process parameters was the subject of further investigations (Barletta and Tagliaferri, 2006; Barletta et al., 2007a,b). Barletta et al. demonstrated that long and narrow tubes of aluminum, stainless steel and an austenitic nickel–chromium-based super-alloy could be effectively machined at high speed using a couple of interconnected fluidized beds and different sized alumina as abrasive media. Very short repeated machining cycles yielded impressive finishing on the internal surface of the tubes, with the harder and tougher substrates exhibiting the best morphology after fluidized bed processing.

Finally, the importance of suitable AFB process parameters was addressed by Barletta et al. in pioneering studies on hard

---

E-mail address: barletta@ing.uniroma2.it.

0924-0136/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2009.04.009

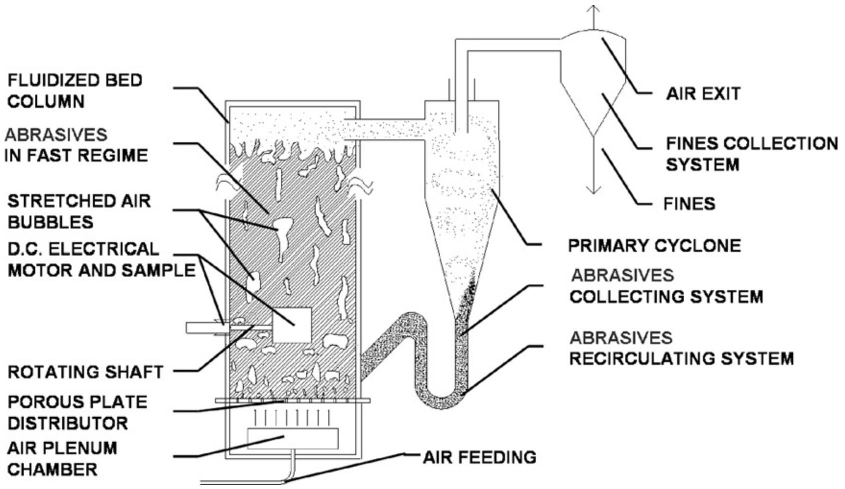

Fig. 1. Sketch of a typical fluidized bed apparatus.

ceramic and metallic thermally sprayed coatings on metal substrates (Barletta et al., 2008a,b). The experimental findings revealed that a sufficient processing window for practical purpose is easily identified using fine-sized alumina as the abrasive medium and rotating the parts inside the AFB at high speed to enhance the machining effect.

2. Equipment

AFBs are based on fluidization theory, which was described in detail by Davidson et al. (1985). Workpieces can be processed by simple dipping or rotation within a tank of fluidized (i.e. suspended) abrasives or, alternatively, by flowing or jetting loose abrasives at relatively low or moderate pressure onto or across the surface to be machined. In this way, even complex-shaped components or partially obstructed surfaces can be processed to a high standard.

Fig. 1 shows a fluidized bed apparatus comprising four main sections. (i) A blower supplies fluid to the bed and fluidizes the abrasives. (ii) An air chamber allows homogenization of the flow of incoming fluid (mostly, air) to generate smooth fluidization regimes of the abrasives in the main chamber. (iii) The main chamber or fluidization column where machining is performed has a porous plate distributor at its bottom to ensure that fluid is supplied uniformly across the whole column section column and that holds the abrasives when they are not fluidized. (iv) A recirculation system (i.e. cyclones) allows both recovery of abrasives entertained in the fluid flow at the highest fluidization speeds and collection of most of the fines produced during processing.

An air supply at low or moderate pressure, generally approximately 100 mbar or less and well below 1 bar, is the driving force for fluidization of generally small (0.02–2 mm) round or angular (factor shape 0.5–0.95) abrasives. Ceramic abrasives are the most widespread, but metal, plastic and wood abrasives are also widely used. Material loss from a workpiece due to repeated impacts by abrasive particles is typical evidence of an effective machining process.

The relative impact speed and the number and angle of impacts of fluidized abrasives on the workpiece surface characterize the machining process and dictate the speed at which it is performed. Therefore, choice of these parameters also affects the mechanisms by which material is displaced or removed from the workpiece during the processing, particularly the extent and speed of material loss, thus influencing the final performance of the end products. The flow rate plays a crucial role as it dictates the fluidization regime within the bed and thus is a measure of the machining speed for a particular workpiece. The flow rate is also a measure of the energetic absorption of the system, which greatly depends on the air amount and pressure fed to the fluidized bed.

Workpieces can be dipped into the fluidization column and exposed to repeated impacts by fluidized abrasives in many different ways. Pieces can be housed on a rotating shaft that both holds the workpiece and allows its rotation during machining for more uniform processing (Fig. 2a). Workpieces can also be placed inside a rotating barrel (Fig. 2b) or left loose inside the fluidization column when impacts between pieces do not affect the final machining performance or cause significant equipment damage (Fig. 2c). Workpieces can also be placed on top of a conveyor belt (Fig. 2d) specifically designed to allow the passage of fluidized abrasives but retaining the pieces within the column. Even in the latter cases, workpieces can be secured in a fixed location or left

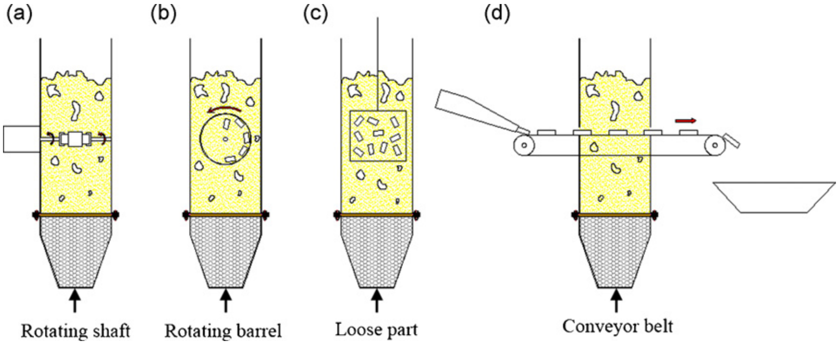

Fig. 2. Technological solutions to hold workpieces within a tank of fluidized abrasives during processing: (a) rotating shaft, (b) loose parts inside the fluidization chamber, (c) rotating barrel, and (d) conveyor belt.