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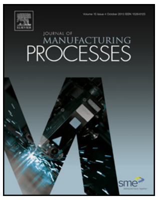

Drag finishing of sensitive workpieces with fluidized abrasives

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ABSTRACT

A new mass finishing technology, namely drag finishing of brass (Cu–30 wt.% Zn) rings with fluidized abrasives, is reported. A new equipment, which combines the typical features of the drag finishing machines to hold the workpiece with the moving abrasives of fluidized beds, was designed. The equipment was validated by performing several experimental tests varying rotary speed and processing time. The evolution of the surface morphology of the workpieces, their mass loss and dimensional accuracy after processing were assessed after each finishing step. The designed equipments allowed to finish with a high level of accuracy and in short time range the brass rings. Material removals and out-of-tolerances of the workpieces could be limited once the appropriate settings of the process were selected. Low energy requirements, lack of any residuals after processing and facile operations make the fluidized bed assisted drag finishing industrially sustainable and very promising in several manufacturing domains.

1. Introduction

Drag finishing is recently imposing in several manufacturing domains as promising alternative to conventional mass finishing processes to finish/polish with a high quality standard sensitive workpieces, which must be processed without coming in touch each other. Thus, drag finishing operations are specifically designed for rounding/deburring of cutting and forming tools, smoothing/polishing of gear wheels, valves and cams in automotive/aeronautic fields, polishing/repolishing of medical and pharmaceutical devices, finishing/polishing of jewels and watches in jewelry and watchmaking industry. Drag finishing equipments are usually based on a *built* ad hoc carousel which is designed to hold and rotate the workpiece, while dipping it inside a stationary abrasive (usually, an abrasive granulate) preloaded in a processing bowl. The equipment features a rotary turntable with one or more rotating satellite station for fixtured workpieces. Uniformity of finishing process is, therefore, ensured by rotating the workpiece around its own axis and allowing it to describe a planetary motion during finishing. In this way, the workpiece surface moving along its prescribed pattern is uniformly impinged by the stationary abrasive. The process can also be controlled through the setting of appropriate variables among which rotary speed of the satellite and dipping depth inside the abrasive bowl are of utmost importance for the effectiveness of the finishing process.

Drag finishing is seldom studied in the scientific literature. It is only mentioned in two technical reports, which are focused on a brief description of the equipments and their potentiality [1,2]. Hence, the knowledge is empirical and it is essentially detained by the equipment manufactures and practitioners [3]. In most case, drag finishing is implemented as wet processing, which means that cooling/lubricating fluids and/or polishing/shining chemical additives are added during finishing process. Fluids/additives are often premixed with the abrasives and preloaded in the finishing container (i.e., processing bowl) prior to the beginning of the operations. This allows to reduce frictions between abrasives and workpiece and, accordingly, lower the power requirements to dip and move the workpiece inside the stationary abrasive. The fluids also decrease the temperature at abrasive/workpiece interface, prevent oxidation and pollution of the processed material and if promoted with acidic/basic additives can contribute to speed up the polishing/shining of the workpiece. However, wet processing involves the formation of humid residuals, which must be dismissed according to stringent and costly procedures.

In contrast, the fluidized bed assisted drag finishing can be always performed as dry processing. The container with the stationary abrasive is replaced with a fluidized bed of abrasive, usually preloaded in the form of loose granulate or finer powder inside a fluidization chamber. The fluidized bed is supplied from the bottom of the fluidization chamber with an airflow, which is able to suspend

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the abrasive granulate. The abrasive is taken in a fluid-like state, thus it is overall motionless with respect to the container while each individual particle can keep on moving along prescribed patterns inside the fluidized bed [4,5]. Hence, the fluidization reduces the resistance the abrasives can oppose when a workpiece is dipped inside them and moved along a prescribed pattern as it happens during the conventional drag finishing process. In this way, the fluidization decreases the amount of energy which is required to bring the workpiece in contact with the abrasive as happens in turbo abrasive machining (TAM) [6–8]. In addition, the fluidized bed is useful to eliminate the residuals at the end of the finishing process. Accordingly, the fluidization is beneficial as it allows significant energy savings to move the workpiece through the abrasive media and, above allow, it greatly simplifies the design of the device to manipulate the workpieces inside the drag finishing equipment.

In this respect, drag finishing of brass (Cu–30 wt.% Zn) rings with fluidized abrasives is here reported. A new equipment, which features the typical device of the drag finishing machines to manipulate the workpiece and a fluidization chamber to fluidized the abrasive, was designed. The performance of the new equipment was studied performing an experimental campaign varying rotary speed and exposure time. The changes in the surface morphology of the workpieces, their mass loss and dimensional accuracy after processing were analyzed. The experimental findings showed how the fluidized bed assisted drag finishing equipment was able to finish the brass rings in short order and with an high quality standard. Material removals and out-of-tolerances of the workpieces could be controller once the appropriate operational parameters were set. Lastly, low energy requirements, lack of any residuals after processing and facile operations make the fluidized bed assisted drag finishing industrially sustainable and very promising in several manufacturing domains where utmost quality and uncompromised performance are stringent requirements.

2. Experimental

2.1. Materials

The workpiece was manufactured from a 6 m long pipe in brass (Cu–30 wt.% Zn). The pipe featured an inner and outer diameter of 21 and 25 mm, respectively. The pipe was first cut off to achieve rings 10 mm long. Then, the ring was turned to achieve a customized surface morphology characterized by an approximately constant and well known starting roughness profile, whose average roughness R_a was very close to 3 μm. For such purpose, feed rate, depth of cut and cutting speed during turning were set at 0.18 mm/min, 0.25 mm and 250 m/min, respectively.

The abrasive media were prepared by impregnating a carrier, walnut shell granulates with two different sizes, with an abrasive paste. The smaller carrier, namely Nutshell L003 (Pai Cristal, Domegge di Cadore, Italy), featured an average diameter of the granulometric distribution of approximately 0.6 mm (range 0.4–0.8 mm). The bigger carrier, namely Nutshell L099 (Pai Cristal, Domegge di Cadore, Italy), featured an average diameter of the granulometric distribution of approximately 2.6 mm (range 2.2–3.0 mm). The carriers were impregnated with a grinding paste (MS, Pai Cristal, Domegge di Cadore, Italy) which conferred the abrasive potential to the carrier surface. The impregnation process was preventively performed inside a rotating barrel, where the paste was thoroughly premixed (10% volume paste/volume carrier) to the carriers. The high shear forces the rotating barrel imparts enforce the viscous paste to uniformly spread over the carrier surface and adhere pretty firmly. Indeed, the surface adhered paste remained soft and flexible. The manufacturer claims the paste is suitable for finishing of ductile metals of intermediate hardness. The paste is composed of medium sized angular SiC grains (9 Mohs scale of mineral hardness, approximately 10 μm average diameter) with high abrasive power dispersed in concentration up to 30% in a synthetic wax of high viscosity which only acts as binder. The wax is necessary to ensure the good adhesion of the paste on the carrier surface and the appropriate retention grade of the SiC grains during the finishing process. In this way, the SiC grain will be retained on the carrier surface an appropriate time range, that is, until it will lose most of its cutting capability. After that, it will be released and elutriated in the form of fines form the top of the finishing equipment.

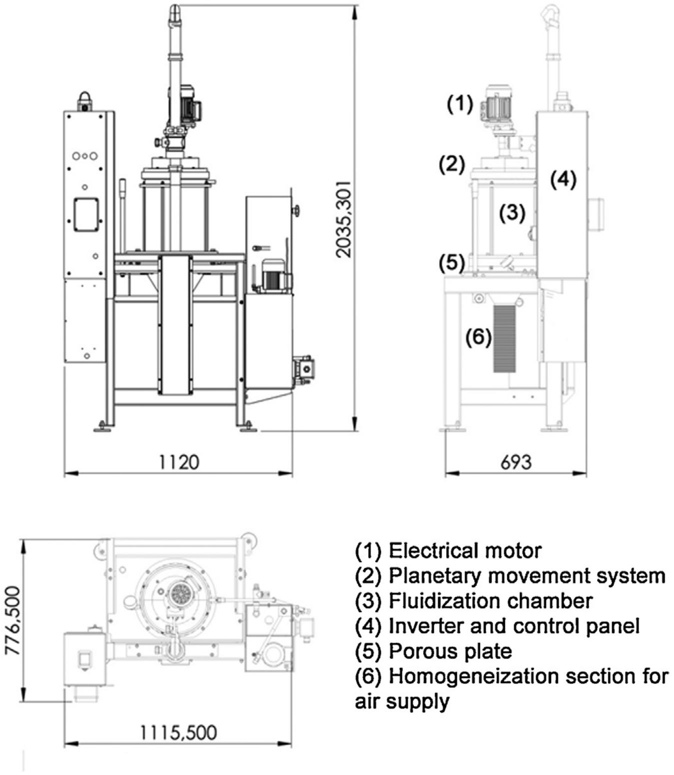

Fig. 1. Design of the fluidized bed assisted drag finishing (all the dimension are given in mm).

2.2. Equipment

The equipment for drag finishing assisted by fluidized bed is reported in Fig. 1. The system is essentially composed of two main sections: (i) the device to implement the planetary motion of the workpiece necessary for the drag finishing operations; (ii) the processing bowl which is substituted by a fluidization chamber. The former device is depicted in Fig. 2. It is composed of a rotary turntable with three rotating satellite stations. Each satellite features a vertical shaft with a workpiece clamp (i.e., a hook for holding one or, potentially, more brass rings) (Fig. 3). Drag finishing is, therefore, performed by allowing the workpiece to describe a planetary motion during finishing. Indeed, when the rotary turntable is switched on, the belt-pulley system transfers the motion to the satellite stations (∼2.2:1, multiplication). The workpiece anchored to the clamping system of the vertical shaft of the satellite stations gets the processing position (i.e., ring vertical axis parallel to the vertical shaft of the satellite) under the action of the centrifugal force. In particular, the ring is quasi-static with respect to the clamping system (i.e., it can only vibrate or rotate at negligible speed around its own axis). Under such circumstance, the pattern of

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