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ScienceDirect

Procedia Engineering 207 (2017) 419–424

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom

Al-SiC Metal Matrix Composite production through Friction Stir Extrusion of aluminum chips

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Abstract

The production of most mechanical component requires machining operation, thus usually implying the cut material to be wasted as scrap. Traditional recycling techniques are not able to efficiently recycle metal chips because of some critical aspects that characterize such kind of scraps (shape, oxide layers, contaminating residues, etc). Friction Stir Extrusion is an innovative solid state direct-recycling technique for metal machining chips. During the process, a rotating tool is plunged into a hollows matrix to compact, stir and finally, back extrudes the chips to be recycled in a full dense rod. This process results to be particularly relevant since no preliminary treatment of the scrap is required. Experimental campaigns have been carried out in order to investigate the effects on process mechanics of the introduction of silicon carbide micro powders.

Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.

Keywords: Friction Stir Extrusion; Recycle; Chips; Metal Matrix Composites; Silicon Carbide.

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1. Introduction

The production of most mechanical component requires machining operation, thus usually implying the cut material to be wasted as scrap during in traditional cutting processes [1]. The recovery of these materials results to be nowadays a crucial challenge in order to obtain both environmental and economic advantages thus leading many researchers and

1877-7058
Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.
10.1016/j.proeng.2017.10.798

industries to look for innovative and effective recycling technologies. Unfortunately, machining chip is one of the most difficult kinds of scrap to be processed because of some critical characteristics as elevated surface/volume ratio, the presence of oxide layers and different types of contaminants residues i.e. lubricants used during the cutting process. The conventional melting recycling technologies may be applied with many different drawbacks in terms environmental issues (fumes and gas formation), energetic/economic issues, (low efficiency in terms of obtained material and high energetic cost) and technological issues (defectiveness in the final product). In the last years, the recycling by melting of aluminum and magnesium alloys has been deeply investigated by many researchers [2, 3] showing that usually the overall recovery rate hardly reaches 50%. All the above-cited issues these conventional technologies to be generally inadequate for the modern industrial needs.

Gronostajski and Matuszak [4] first introduced in 1999 the direct conversion method. The metal scraps were separated according to the composition, cleaned, chopped and finally compacted and hot extruded between 500°C and 550°C. The direct chip recycling is a relatively simple technology, providing high recovery efficiency and characterized by lower environmental impact compared to the conventional methods, as showed by Duflou et al. [5].

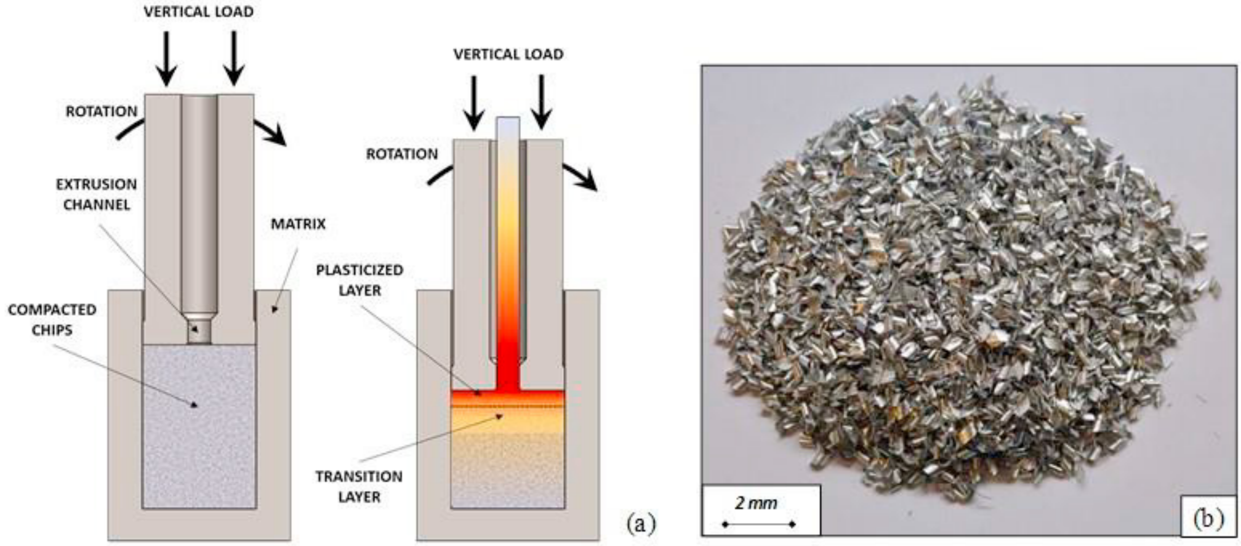

Fig. 1. (a) Sketch of the Friction Stir Extrusion process and (b) AA2024 metal chips used during the experimental campaign

In 1993 TWI patented a new recycling process to be applied to metal chips, named Friction Stir Extrusion (FSE). This technique belongs to the Friction Stir Processing (FSP) technologies, developed following up the “Friction Stir Welding” (FSW). A rotating tool is used to produce heat and plastic deformation through friction between the tool itself and the chips to be recycled (into a hollow cylindrical matrix) by compacting, stirring and extruding the material. In this way, the recycling process takes place in a unique operation, resulting in significant cost, energy, and labor saving with respect to both conventional method and direct method. For this reason, the FSE technique appears very attractive to industry for the recycling of machining chips. Fig. 1a shows a sketch of the process: the chip closer to the tool, i.e. closer to the heat source, rotates together with the tool and plasticizes due to the combined effect of high temperature and stirring. Moving far from the tool interface, a transition layer is encountered, in which the chip is heated but has not been homogenized as a continuum material. The extrusion starts from the rotating plasticized layer and is influenced by the combined action of tool rotation and force on the tool. At the end of the process, the extruded material returns to room temperature by calm air cooling.

After the TWI patent expiration, due to failure to pay maintenance fee in 2002, only very few papers have been published on the process. In particular, Tang and Reynolds [6] produced AA2050 and AA2195 wires from chips using fixed extrusion force and varying tool rotation. The microstructure of the extruded wires is characterized by small equiaxial grains resulting in good mechanical properties of the wires in terms of microhardness and bend ductility. Some of the authors of this paper have already carried out an experimental campaign on the FSE of AZ31 Mg alloy