
13 Al Aliminum
12 Mg Magnesium
22 Ti Titanium
4 Be Beryllium
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Fabrication of Porous Steel using Machined Chip Waste

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Abstract

In the last few decades there has been rapid increase in the waste materials and by-production due to the exponential growth rate of population, development of industry. Steel industry represents one of the major constituents of industrial solid waste. In this study; a new technology has been used to produce porous steel from low cost machined chip real wastes which came from some company instead of steel powder. Thus, metal loss prevention will be provided, production costs will be reduced and less waste will be released to the environment. The present study is aiming at investigating the possibility of producing a porous steel from machined chips with various shape by powder metallurgy. The effect of chip utilization and shape on the pore properties was evaluated from the characterization studies.

Keywords: Steel chips, waste, sintering, milling scraps.

1. Introduction

Porous steels are known to have many interesting mechanical and physical properties, such as high energy absorption and damping capacity with very low specific weight. In recent years, metal powder containing a space holder sintering technique in powder metallurgy (PM) has been used to manufacture porous steels [1-2]. The aim of the present work is to investigate the possibility of producing a porous steel from low cost machined chip wastes instead of steel powder. When metal products are manufactured, considerable amounts of waste in the form of chips and discards are produced. These waste and scraps are returned to smelters, whereby some of the metal is recovered and reutilized in production processes. During the recycling of the waste a lot of the metal is lost as a result of oxidation, and the costs of labour and energy as well as the expenditure on environmental protection raise the general cost of such processes. For the cost reduction, some researchers have developed new process to produce highly porous steel from machined chip waste by powder metallurgy technique. At the same time, ın that way metal loss prevention will be provided, and less waste will be released to the environmental [3-4].

INCONEL nickel-chromium-iron alloy is a general-purpose engineering material for applications that require resistance to heat and corrosion. An outstanding characteristic of this alloy is its resistance to high temperature oxidation. The alloy also has good resistance to aqueous corrosion, has high mechanical strength, and is readily formed, machined and welded. In the past years, several researchers worked on obtaining porous aluminum and magnesium by PM technique from scraps and determined the mechanical and microstructural properties of the specimens [4-6]. However, there is no study on porous INCONEL steel in the literature and in this study, porous metal have been obtained from this steel milling scraps by PM technique; hence it can be described as a novel method among the other researches. The aim of the present study is to investigate the possibility of producing porous steel from low cost machined chip waste instead of steel powder via solid-state consolidation process. This new method is environmentally friendly and gives saving in material, labour and energy.

2. Experimental Procedure

Machined small thin and long string types chips of INCONEL alloy (UNS N06601/W.Nr. 2.4851) as shown in Fig. 1 were used to produce porous steel materials by powder metallurgy technique. The manufacturing process of porous metals from milling scraps includes four stages: cleaning of the chips from surface contamination like oxides and oil, mixing of the chips and the binder, compaction of this mixture and sintering. Chips were firstly cleaned and then mixed with hot paraffin wax solution. This mixture was compacted into cylindrical form of 10 mm in both height and diameter under 400 MPa pressure and then these green specimens were sintered at 1170 °C for 30 minutes under cracked ammonia atmosphere. Density and porosity content of the sintered porous steel specimens were measured by an Archimedes method, and the pore morphology was observed and evaluated. Mechanical properties were investigated at room temperature using the Zwick-Roell Z050 Testing Machine fitted with 50 kN load with a strain rate of 0.5 mm min-1. Each test was repeated three times to provide the repeatability of the results.

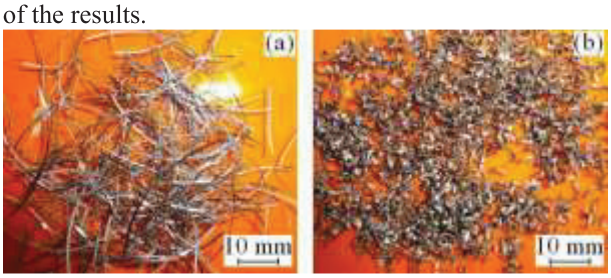


Figure 1. INCONEL alloy machined chip waste with different types of shape.

3. Results and Discussion

Sintered specimens with porosities in the range of 28.8-31.6% were produced by PM technique from milling scraps with different shape chips as show in Fig. 2. Pore size of the specimens is strongly related to the chip size. The obtained porous specimens possess wide macropores because chips were used instead of powders. It can be seen that the pore shape of all specimens replicated the initial shape of the INCONEL chips. They have different pore morphology. The small thin ships has smaller pores than that of long chips. The size and shape of the pores were uniform and its porosity was very high as for porous steel made from the metal powder alloy [3]. In contrast, as for porous structure made from the machined chips, the size and shape of the pores were very irregular and its porosity was very low. The porous steel made from the chip precursor has similar porosity and pore morphology as that from a powder precursor. No cracks were observed in these porous structures. A detailed microstructure investigation in terms of bond formation between pore walls of the chips is out of the scope of this study and will be carried out in the further researches. Many chip boundaries were observed in a centre part of the specimen, though firm consolidation with well-bonded chips was fabricated in a peripheral part. Surface thin oxide films on the steel chips would be broken and each chips would be well bonded all over the specimens by the repeated large shear deformation.

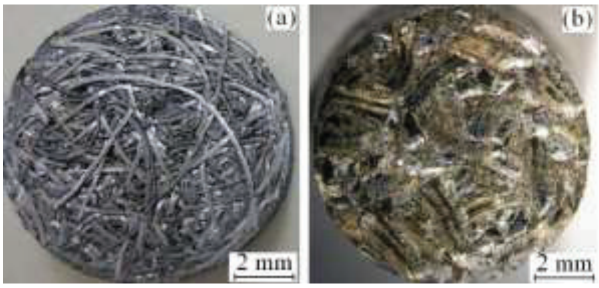
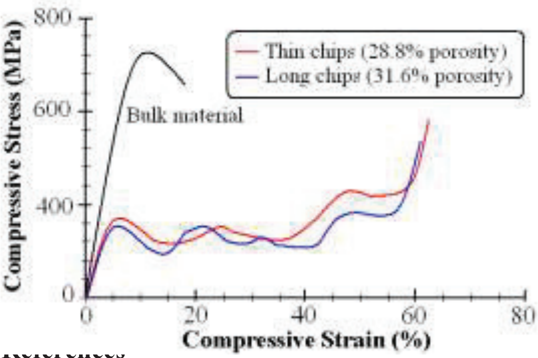


Figure 2. Sintered porous specimens made from different shape machined chips.

Fig. 3 shows the stress-strain curves of porous samples of INCONEL and that of the bulk material shown for comparison. The compressive behaviour of the porous samples is completely different compared to the bulk material. In fact, there are plateau regions with nearly constant flow stresses in the case of the porous parts. That is it absorbs impact energy until the stress rapidly increases. Thus in comparison with the bulk material, the ability of the porous parts to absorb impact energy is greatly improved. The same results were also obtained by Okumura et al. [7]. It can concluded that the plateau stress increases with decreasing pore ratio. It can see that the small thin chips exhibit the highest strength as compared with the long string chips.



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