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Analysis of Metallic Waste from Laser Cutting for Utilization in Parts Manufactured by Conventional Powder Metallurgy

José de Souza[1], Clayton A. Oliveira-Motta[2], Tiago Gonçalves Machado[3],Alexandre Giacomin[4],Hamudy Munir Abou Arabi[5]

[1,2,4]*(Fundação Liberato – FETLSVC – Diretoria de Produção ePesquisa Industrial, DPPI –Novo Hamburgo/RS – Brasil)*
[3]*(Universidade do Vale do Rio dos Sinos – UNISINOS –Engenharias – São Leopoldo/RS – Brasil)*
[5]*(Pontifícia Universidade Católica do Rio Grande do Sul – PUCRS – FENG – Porto Alegre/RS– Brasil)*

Abstract: This study aims to evaluate the utilization of the waste coming from the laser cutting process for use in the manufacture of metal parts. The Powder Metallurgy Process was chosen as agent for this purpose. In this development was considered the state of supply of residues, which are particles of metallic material that has been cut by the laser process. To evaluate the residue behavior, chemical analysis of the material were performed, as well characterization by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). Analyzes showed that the base metal constituent in residue is iron, being observed also the presence of carbon and oxygen. The metal residues can be used as raw material in generating parts by the conventional powder metallurgy process. This is due to the fact the base metal present temperatures necessary for the formation of "sintering necks" within the values practiced by the ovens regularly traded.

Keywords: Laser Cutting Waste, Conventional Powder Metallurgy, Design for Environment.

I. INTRODUCTION

The growing concern for the fate of waste generated by all national and also international production chain has led authorities to request from companies that have greater control and transparency on its generation and destination. In Brazil there are laws and guidelines to be followed for the disposal of waste generated by legal entities and individuals. The National Solid Waste Policy, updated in 2012, is one of those directives. Due to these factors, companies are taking measures to prevent waste generation and conducting studies on the reuse of the same [1]. To that end, an analysis for use of waste generated by the laser cutting process was carried out through the identification of the constituents present in the waste and the study of their potential use by the processes of powder metallurgy.

Wastes in solid and semi-solid state are considered those resulting from industrial activity origin, as well from home, hospital, commercial, and agricultural, among others [2]. Solid waste can be classified according to their constituents, characteristics and type of process that were generated. The originating scrap from metal manufacturing processes such as laser cutting are classified as “non-inert waste" and are resources that can be reused [3].

The welding and cutting process using laser energy as a heat source are processes that are based on electromagnetic energy from a monochromatic and collimated current [4].

Technological workshop Design for Environment defends sustainability from product design with a view to their life cycle. Such a premise considered by sustainability tool seeks project contributions that reduce the use of non-renewable resources as raw materials or aretoxic and carbon emitters in the atmosphere. The global concern for the environment through the recycling of solid waste is growing [5].

Powder metallurgy is a process that satisfies the concept of product life cycle while meeting productivity. It consists of a method of manufacturing metallic parts from metals and alloys, reduced to a powdery state. In the powder metallurgy process, the materials that will make up the alloy are balanced, mixed and then compressed. The compression of the material in powder metallurgy is typically made in suitable presses for this type of manufacturing [6]. Products manufactured by the powder metallurgy process depend essentially on the correct mixture of powders, the applied pressure and temperature [7]. The metal powders can be generated using several techniques. However, the feedstock for powder metallurgy is a factor of paramount importance [8]. The characteristics of a metal powder must be known and determined with the greatest possible depth. There are several powder generation techniques for application in the process, each resulting in a powder with specific characteristics. Among these powder processing techniques, there are the physical and chemical processes, electrolytic processes and atomization processes [9]. The physical-chemical process in particular has as main feature the reduction of oxides [10]. There are also more modern techniques, such as those using high energy milling [11]. Many waste recovery techniques have been applied and the powder metallurgy process is inserted in this context of clean production. Studies with the use of stainless steel AISI 316 chips to generate parts with the Powder Metallurgy Process [12] showed that there are real possibilities of success in the reuse of this waste by such production technique. Thus, studies for use of waste coming from the laser cutting processes or other types of cutting metal materials aiming at cleaner production and the life cycle of products are valid.

II. MATERIALS AND METHODS

To carry out the proposed study were used residues of low carbon steel and low alloy processed by laser cutting process of a TruLaser CNC machine 3030. This waste is collected at the bottom of the equipment as shown in Fig. 1.

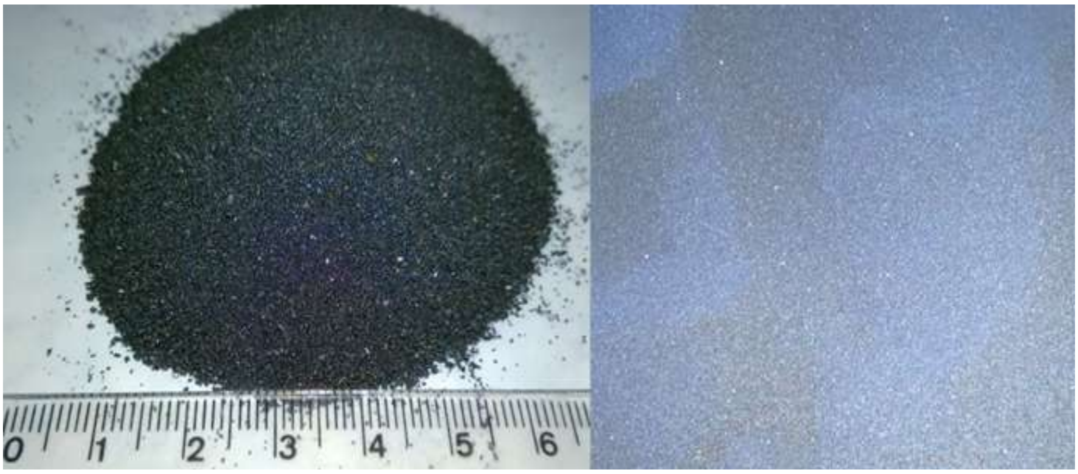

Figure 1. Metallic waste from laser cutting.

To determine the chemical composition and to verify the metallographic distribution of material collected for study were applied chemical analysis tests, scanning electron microscopy and dispersive x-ray detector. To perform the chemical analysis, the material was compacted and then subjected to a process of sintering at 1120ºC in a conveyor belt furnace with controlled atmosphere with argon. The powder blend to be sintered consisted of 20% residue + 79.8% Fe + 0.2 % graphite.

Metal waste collected from laser cutting processes revealed in its matrix, after sintering in 1200°C, a heterogeneous microstructure with various metallic constituents. Fig. 2 shows the sintered part with the metal waste coming from the laser cutting. This part provided the samples for the tests applied in this study. The same parameters sintering the low carbon steel were used.

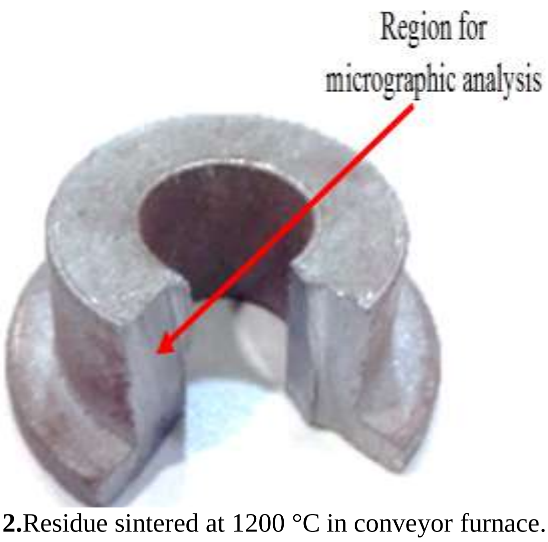

Figure 2. Residue sintered at 1200 °C in conveyor furnace.

Fig. 3 also shows in detail the microstructure revealed.

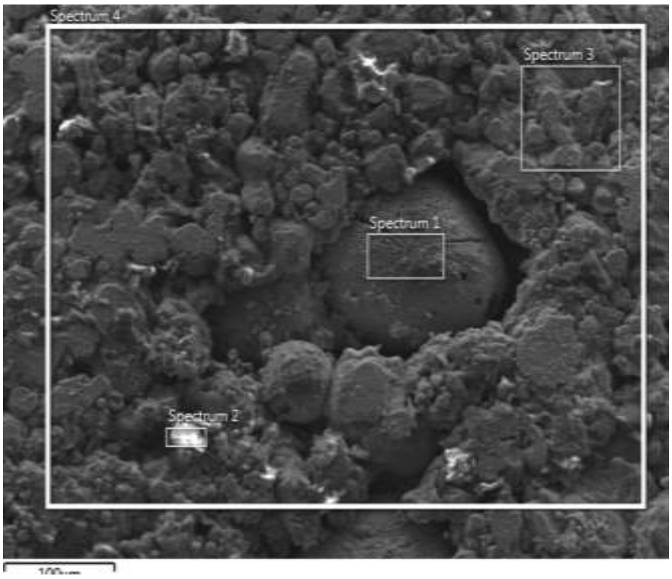

Figure 3. Micrograph of metallic waste.

The micrograph held in generated part identified four (04) regions of chemical aggregates. These regions, identified as Spectrum, were important in qualitative and quantitative determination of the elements present in them.

With the help of chemical analysis, it can be revealed the presence of the following items shown in Table 1.

Table 1. Chemical analysis of the elements identified in Spectruns 1, 2, 3 and 4.

Spectrum Label	Spectrum 1	Spectrum 2	Spectrum 3	Spectrum 4
C	29.86	57.51	24.94	36.68
O	9.94	19.07	13.04	15.35
Na	-	-	4.51	2.26
Mg	-	1.60	0.32	-
Al	0.14	0.46	0.16	0.17
Si	0.25	0.96	0.22	0.26
P	-	-	0.30	0.15
S	-	-	0.20	0.19
Cl	0.14	0.42	0.14	0.29
K	0.11	0.39	-	0.21
Ca	0.17	1.60	1.22	0.56
Ti	-	4.48	-	-
Fe	51.32	12.03	41.98	36.40
Zn	8.07	1.51	12.96	7.49
Total	100.00	100.00	100.00	100.00

Scanning Electron Microscopy using the electron secondary detection (SE) was used to better understand the structure present in the formulation of powder residue. Fig. 4 shows the shape of particles in the residue and its distribution.

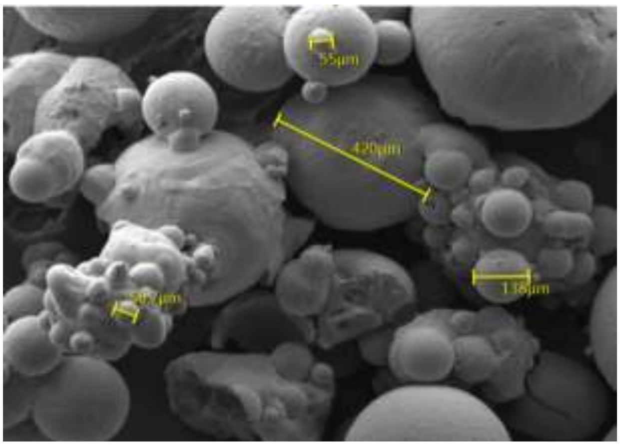

Figure 4. Scanning Electron Microscopy of metal waste of laser cutting. (500X)

In the analysis of Fig. 4, which shows the SEM image of the metallic residue in powdery state, particles of different sizes are observed. This phenomenon may be related to rapid cooling of the metal particles in liquid, when they are still merged in the cutting process. This phenomenon resembles the atomization process to generate metal powders which are applied in powder metallurgy. In the metal powder atomization process particle size are also generated randomly, with subsequent sieving them solid. Another characteristic observed in the microscope was the spherical shape of the particles for the most part. The peel oxide, effect "egg shell" formed in the periphery of the iron particle is observed in SEM due to high heating temperature at which the laser cutting process subjects the work piece. This phenomenon has been observed by most researchers and is of great importance in engineering materials science [13]. The rapid cooling which succeeds the cutting operation also favors this formation. This effect can be seen in Fig. 5.

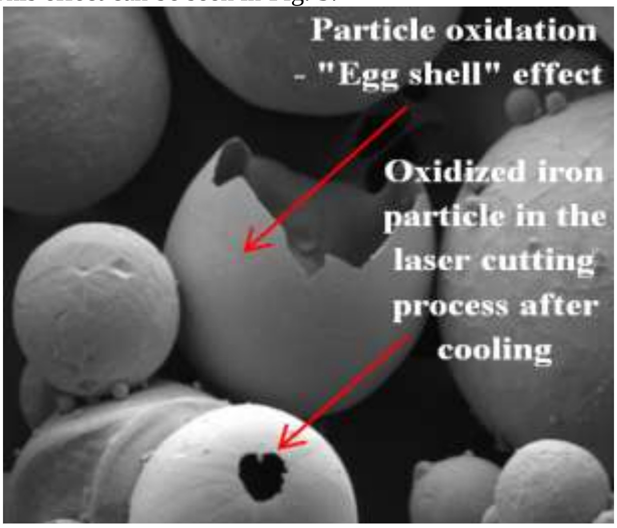

Figure 5. "Egg shell" effect.

Immediately after the realization of SEM, EDS test was performed. This test was complementary to microscopy and revealed qualitatively the present constituents in the waste and its distribution. Fig. 6 shows how the elements of the residue are distributed qualitatively in powdery state.

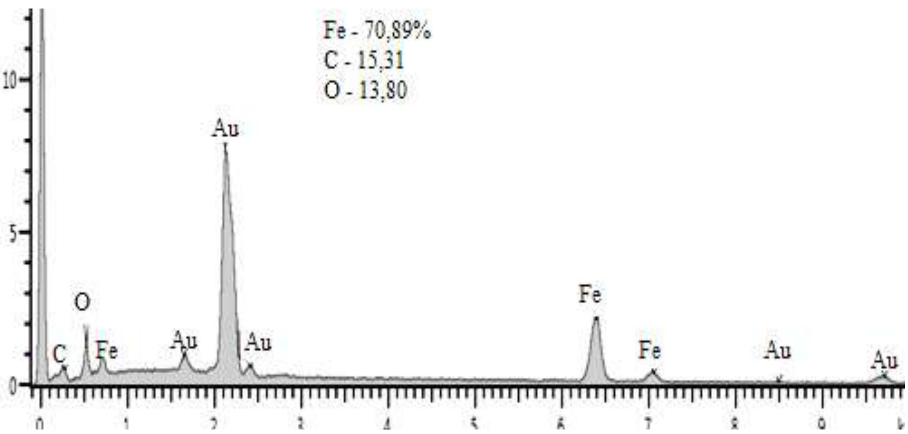

Figure 6. EDS of laser cutting residue in powdery state.

In the EDS analysis can be seen that are contained in the metallic waste coming from the laser cutting elements such as iron (Fe), carbon (C), oxygen (O), gold (Au), as the chemical analysis have shown in Table 1. The gold was used to prepare the sample for a better analyze In addition, as can be seen in the EDS, there is a greater presence of iron than carbon in the residue structure. Such condition is considered satisfactory, since the presence of too much carbon in the structure could be an inconvenience in sintered parts from this residue. The presence of oxygen can be related to exothermic reactions of the cutting surface in contact with atmospheric air. The exothermic reaction is intrinsic laser cutting and other cutting processes process. In MIG / MAG and TIG welding, for example, external effects are minimized using protective gas in the process.

III. CONCLUSIONS

With the results presented in this paper, it is clear that there is great potential to use this waste in the manufacture of parts by conventional powder metallurgy. However, as can be seen, there are variables to be better checked and treated, for example, segregation of the other elements realized in chemical analysis and EDS. The influence of "egg shell effect" in the sintering process and the study of its reduction are also factors to be better seen. On the other hand, the work suggests the possibility of recycling a residue, which is still poorly tapped by reprocessing industry, and can present a great potential for competitive industry in general.

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