24th COBEM - 2017

Associação Brasileira de Engenharia e Ciências Mecânicas

24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-2311
STUDY OF DOUBLE PRESSURE EFFECT ON COLD SINTERING OF FERROUS CHIPS

Lucas Ascari Salvalaggio
Sergio Renato da Silva Soares
Leonardo Carvalho Brandão
Leonardo Resende
André Luis Bierhals
Universidade Federal de Mato Grosso, Rodovia Rondonópolis-Guiratinga, km 06 (MT-270) - Sagrada Família, Rondonópolis-MT, 78735-901
lucas-salvalaggio@hotmail.com, sergeva2004@yahoo.com.br, leonardo.c.brandrao@hotmail.com, resende_leo@hotmail.com, andre_bierhals1@hotmail.com

***Abstract**. It is not economically advantageous to recycle iron and steel products via siderurgy or foundry for the manufacture of small parts. An alternative process for this is the reuse of ferrous metals through the Powder Metallurgy technique. Among the various stages of the processing of materials from particulate materials, the compaction is fundamental for a previous structural consolidation of the bulk. In the present work compact, SAE 1050 steel chips from dry turning were produced under pressure up to 3000 MPa. The high densification presented in them showed that it is possible to obtain microstructures typical of the final stage of sintering without the use of temperature and consequently the reduction of costs for the manufacture of small parts in industrial scale and interest for the automotive, electronics and aerospace industry.*

***Keywords**: Cold sintering, high pressure, iron chips.*

1. INTRODUCTION

It is not always economically advantageous to manufacture small parts from the casting of ferrous chips (Delforge, 2007). An alternative technique for producing these parts from ferrous chips is the Powder Metallurgy. In this case, ferrous powders previously obtained from the milling of chips of these materials are compacted and finally sintered. The driving force for the sintering of compacts is the temperature that can be reduced or removed if only the pressure is the primary factor responsible for the sintering process of the parts. The impossibility of sintering small parts from chips (∅ ≤ 850 μm) without prior comminution of this material via conventional routes in Powder Metallurgy opens up the opportunity to sinter them through the high-pressure without the use of temperature. The main objective of this work was to investigate the double pressure effect in cold sintering of ferrous compacts.

2. MATERIALS AND METHODS

Figure 1 presents some characteristics of SAE 1050 steel chips with a diameter (∅ ≤ 850 μm) and different length distribution (L ≥ 5000 μm) that were used in the present work. Cylindrical samples with 3 mm height and 8 mm diameter were twice compacted under uniaxial pressures up to 3000 MPa. The samples obtained under high-pressure were, after the first compaction and before the second, heat treated (temperature T≤ 700 °C). All samples were characterized by optical microscopy and density measurements using the dimensional method. The measured density (7.84 ± 0.032 g / cm^3) in the machined specimen (AM00) with the same dimensions compacted sample in high pressure was used as theoretical to determine the relative density.

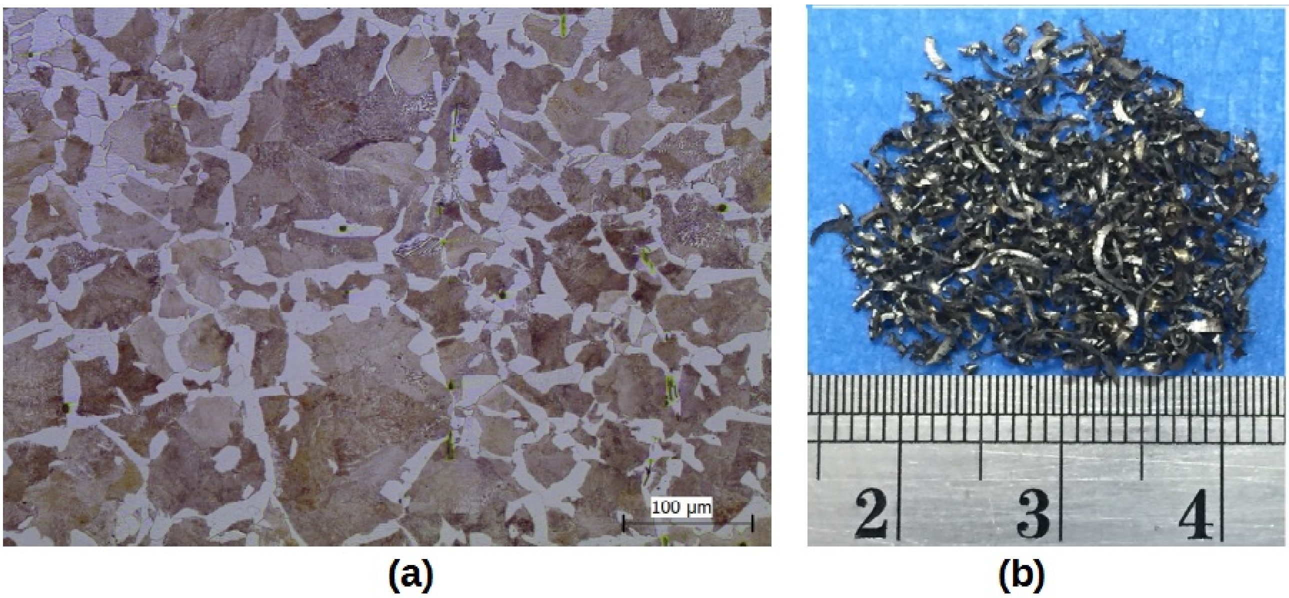

Figure 1. Characteristics of SAE 1050 steel chips: a) ferrite (light region) and perlite (dark region) phases present in the microstructure; b) Macrography showing the typical irregular morphology and size of the starting chips.

3. RESULTS AND DISCUSSION

Figure 2 shows the irregular morphology (∅ ≤ 850 µm and length ≥ 5000 µm) of chips which were compacted under pressures of up to 3000 MPa. The pressure increase influenced compacted microstructure densification behavior. The size of the chips shown in Figure 2a is smaller than that shown in its starting condition (Figure 1b). Also, the size and quantity of pores (dark areas) decreased as the pressure increased. The high pressure, similar to high-energy milling (HIRSCHHORN, 1971; SURYANARAYANA, 2001), acted dynamically, to simultaneously or not for deforming the chips (arrow 2), weld them (arrow 3) and fracture them (arrow 1). Consequently, in a reduction in the size and amount of porosity present in the sample microstructure (dark region) and consequently in a significant increase in compaction density.

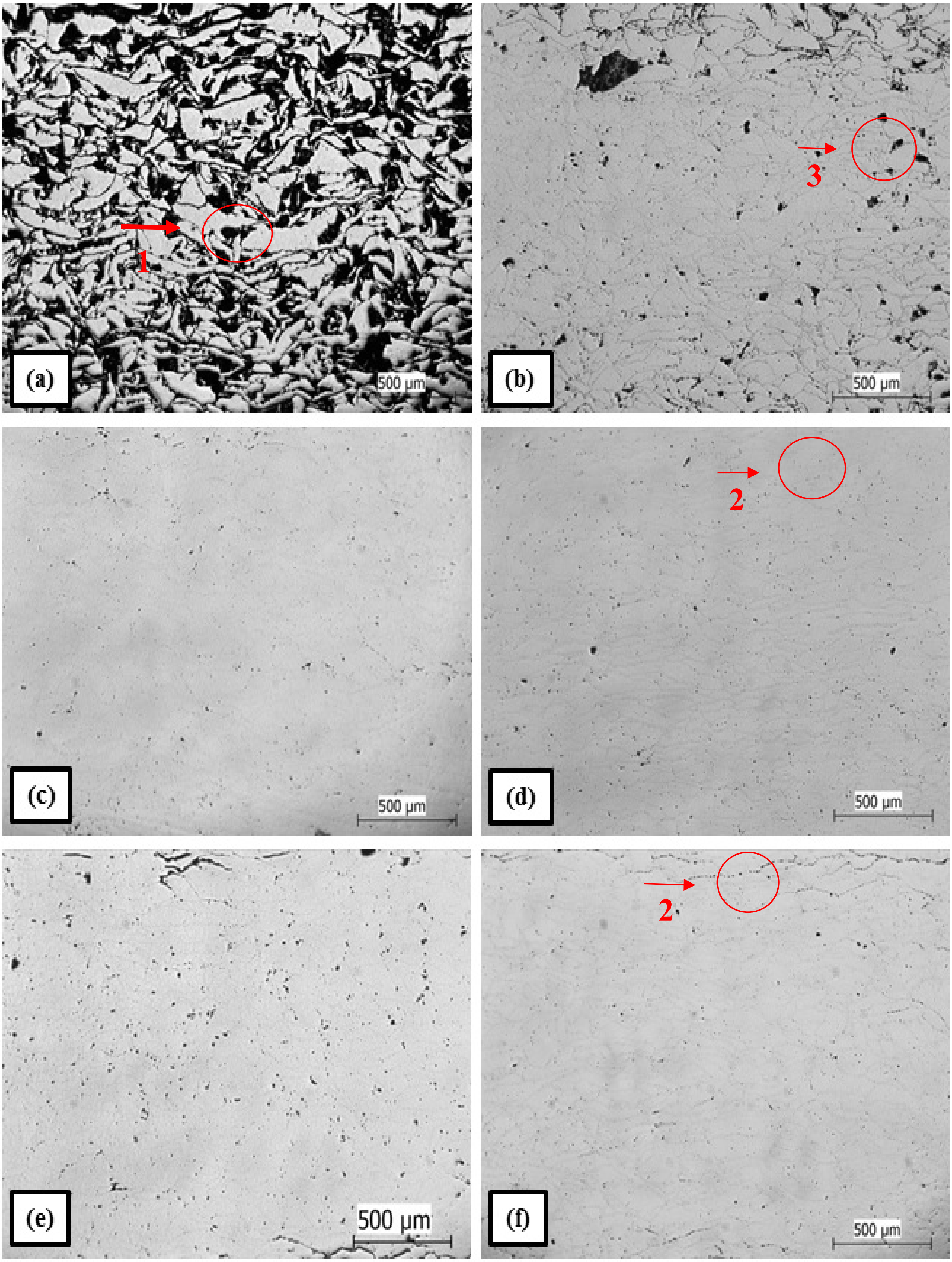

Figure 2. Microstructure of samples compacted under high pressure: a) AM05 (500 MPa); B) AM10 (1000 MPa); C) AM15 (1500 MPa); D) AM20 (2000 MPa); E) AM25 (2500 MPa) and f) AM30 (3000 MPa).

Figure 3 shows the behavior of the compacted microstructure that was submitted to different compaction pressures. It is noted that the evolution of the compacted microstructure is consistent with the gradual increase in the relative density values of the compacts as the compaction pressure increases. All compacted samples in pressures greater than or equal to 1500 MPa are in final sintering stage (relative density ≥ 95%) and this is due to the cold solid sintering of the compacted microstructure. The main driving force for the sintering of the compacts was not the temperature, but contrary the conventional sintering processes, it was the high pressure. Although similar results were obtained in the literature, the pressure range required to get the high values of relative density shown in figure 3 was lower. Differently from the literature (Djuricic, 2006), in the present study the compacts were produced under the double high-pressure effect and between the first compaction and the second, heat treated. Furthermore, In the present study, the great dimensions of the chips and their irregular starting morphology significantly affected the densification dynamics of the compacts. This result agrees to previous works (Djuricic, 2006; Al-Qureshi at all, 2005; Gutmanas and Lawley, 1983; Gutmanas and Rabinkin, 1979). According to these researchers the different characteristics of the starting particulates as such as chemical composition, mechanical properties, morphology and chips size, influence in the dynamics of rearrangement of these materials under high pressure.

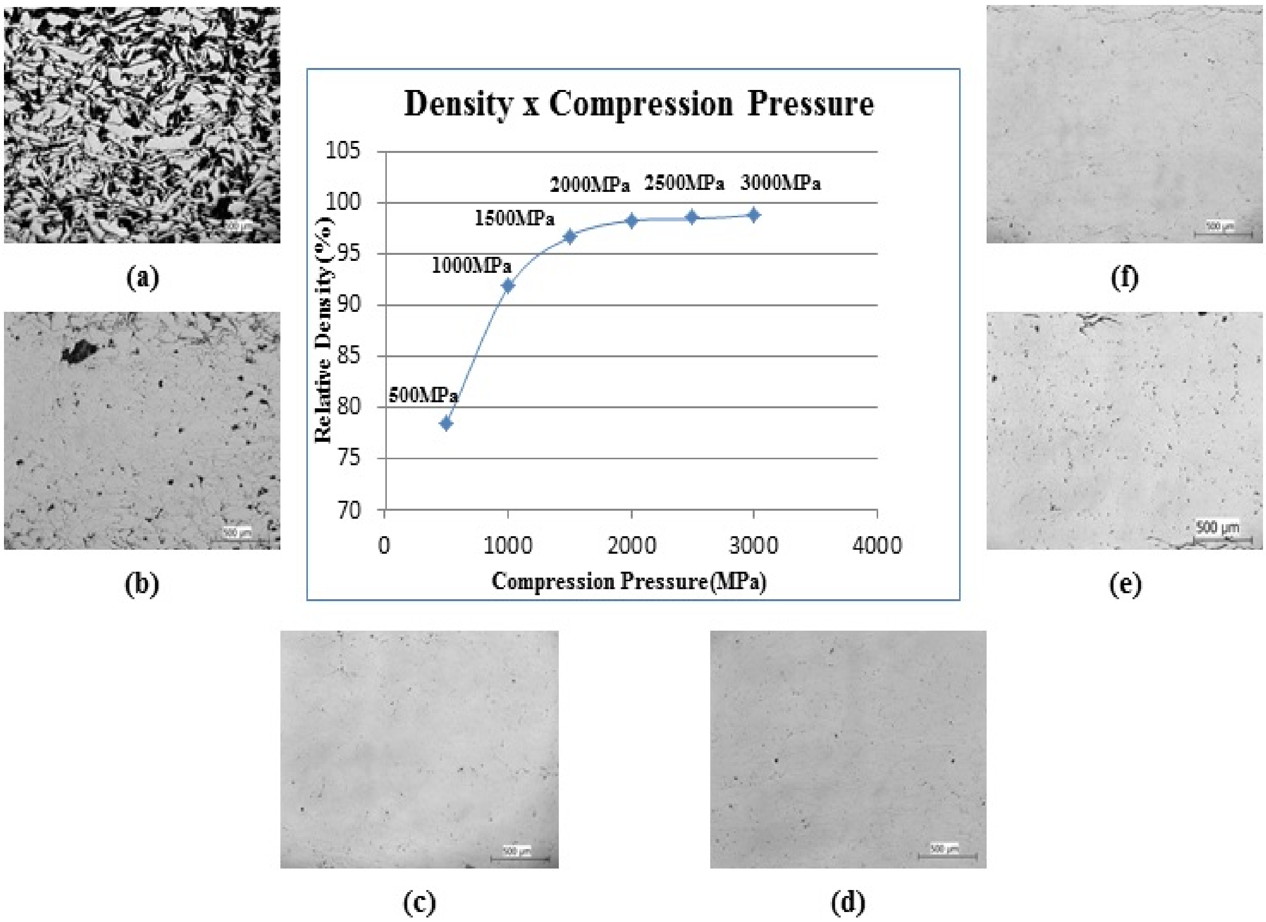

Figure 3. Double effect of the pressure in cold solid sintering of the compacted samples: 1) AM05; 2) AM10; 3) AM15 MPa; 4) AM20 MPa; 5) AM25 MPa and 6) AM30 MPa.

Table 1 shows the effect of pressure in the density behavior of the samples that were submitted to different compaction pressures. The compacted sample under high pressure (P> 1000 MPa) presents values of density higher than that obtained in the sample of low pressure (P <1000 MPa). From the pressure of 1500 MPa, the relative density values are between 96.62% and 98.67% and could be attributed to the high pressure used to compact chips with dimensions of ∅ ≤ 850 µm and L ≥ 5000 µm. Density values greater than 7.57 ± 0,03 g/cm^3 until how much is known, are not possible to be obtained by conventional compression techniques (Lenel, 1980). These results are consistent with the discussion presented in the previous paragraph on the effect of pressure in samples densification. This fact is of significant importance since, unlike samples compacted under low pressure and sintered by conventional sintering techniques, compacts produced under high pressure do not require the use of temperature to reach such high densities.

Table 1.Compacted density and relative density of the double effect of pressure on cold sintering of compacted samples.

Samples	Pressure (MPa)	Density (g/cm³)	Relative Density (%)
AM05	500	6,1452 ± 0,02	78,3827
AM10	1000	7,1913 ± 0,04	91,7258
AM15	1500	7,5747 ± 0,03	96,6161
AM20	2000	7,6948 ± 0,02	98,1480
AM25	2500	7,7152 ± 0,03	98,4082
AM30	3000	7,7359 ± 0,06	98,6722
Obs: Density considered as theoretical and measured in sample AM00 - 7.840 ± 0.032 g/cm³.			

4. CONCLUSION

During the dynamics of solid and cold sintering of the chips the simultaneous or not of their deformations, weldings, strain hardening and fractures contributed significantly to the increase of densification of the compacts.

In the present study the large dimensions of the chips (∅ ≤ 850 μm and L ≥ 5000 μm), their irregular starting morphology and the double pressure method, contributed to, under pressures of up to 3000 MPa (lower than the ones used in the literature), obtaining of highly densified compacts.

The primary agent for the cold sintering of the compacts with typical microstructures of final sintering stage (relative density ≥ 95%) was high pressure (P> 1000 MPa).

The manufacturing of small parts via cold solid sintering without the use of temperature, as such as cutting tools and of interest to the automotive, electronics and aerospace industry, can become an attractive alternative from the economic point of view.

5. ACKNOWLEDGEMENTS

The experimental results presented in this work were obtained mainly in the Mechanical Engineering Laboratories of the Federal University of Mato Grosso.

6. REFERENCES

Delforge, D. Y. M. Cavaco de um Aço Inoxidável Austenítico Reciclado por Metalurgia do Pó: Uma Rota Alternativa para o Reaproveitamento de Materiais Metálicos. 2007, 116p. Tese (Doutorado em Materiais e Processos de Fabricação) - Universidade Estadual de Campinas,Faculdade de Engenharia Mecânica.

Hirschhorn, J. S.; Stresses in Powder Particles a Review. Powder Technology- Elsevier Sequoia S.A. Lausanne, v.4, p. 1 – 8, 1971.

Suryanarayana, C.; Mechanical alloying and milling. Progress in Materials Science, v.46, p. 1-184, 2001.

Djuricic a, M. R.; Acimovic-Pavlovic, Z. S.; Andric, L. D.; The correlation of technological parameters and the structure of cold sintered iron as a basis for material property prognosis. Materials Letters, v.60, p. 3390-3393, 2006.

Al-Qureshi, |H. A.; Galiotto, A.; Klein, A. N.; On the mechanics of cold die compaction for powder metallurgy. Journal of Materials Processing Technology, v.166, p. 135-143, 2005.

Gutmanas, E. Y.; Lawley, A.; COLD SINTERING - A NEW POWDER CONSOLIDATION PROCESS. TECHNICAL REPORT. p. 3-21, 1983.

Gutmanas, E. Y.; Rabinkin, A.; COLD SINTERING UNDER HIGH PRESSURE. Scripta METALLURGICA, v.13, p. 11-15, 1979.

Lenel, F. Powder Metallurgy**:** Principles and Applications. Princeton, New Jersey: Metal Powder Industries Federation, 1980. 589 p.

7. RESPONSIBILITY NOTICE

The authors are only responsible for the printed material included in this paper.