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STUDY HIG-H PRESSURE DOUBLE EFFECT IN THE DENSIFICATION OF STEEL CHIPS

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Abstract. *The compaction of powdered materials is carried out primarily to increase the density of the material. If the ultimate goal of the over-all process is the attainment of minimum porosity, compaction is responsible for most of the densification. This work aims at evaluating the high pressure double effect on the compaction and subsequent sintering of steel chips. Green and sintered densities values were 7.18 g/cm3 and 7.82 g/cm3 respectively.*
Results showed that high pressure double effect was the main responsible for increasing the densification in the samples.

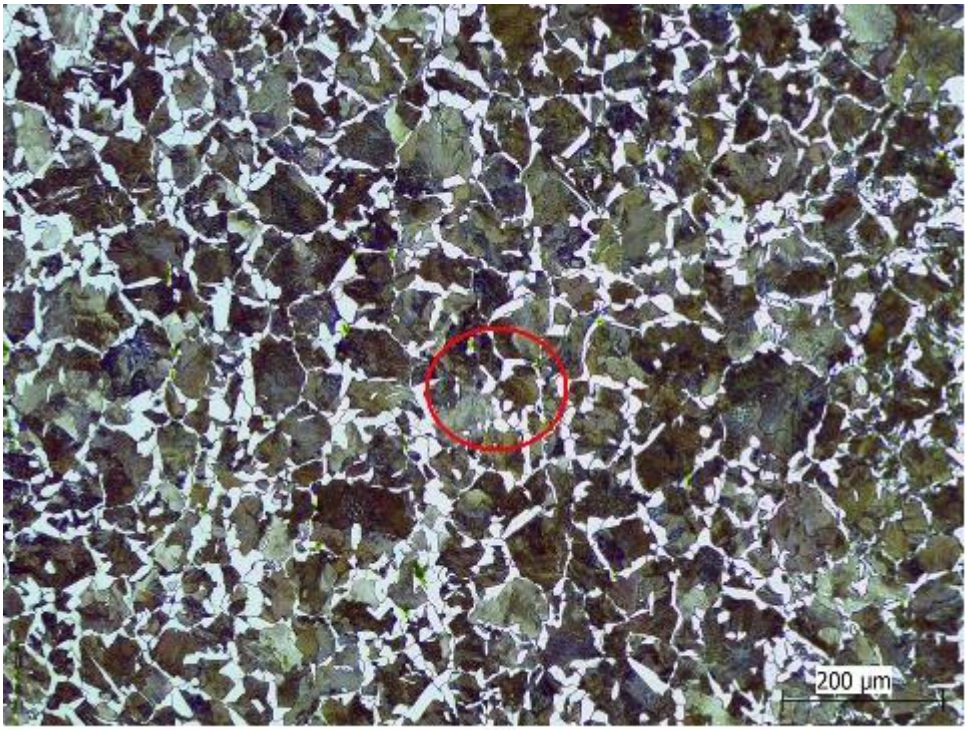
Keywords: *Chips, High Pressure Double Effect, Densification, Deformation.*

1. INTRODUCTION

The loss of up to 80% of these materials necessitates economical ways such as the powder metallurgical technique for ecycling these chips [1]. However, due to the size and morphology of the chips, which are generally large and irregular, it is unlike to obtain it with high relative density (≥95%). In recent years, a number of alternative processes have been suggested for the production of dense samples using different routes from the powder metallurgy technique such as a high pressure. In this work it was employed the high pressure technique to produce chip compacts of carbon steel. The main goal was to identify the double effect of pressure on densification of the samples.

2. MATERIALS AND METHODS

Ferrous metal ingot with typical microstructure of medium carbon steel shown in Fig. 1 was used in the present study. This ingot was then machined with an end mill to produce steel chips. Figure 2 shows the as-received chips with a heterogeneous distribution of length and morphology The as-received chips (∅≤ 0.85 μm) were compacted at room temperature up to twice in a steel cylindrical matrix under pressure up to 3000 MPa. The samples obtained under the high pressure double effect were after the first compaction and before the second, heat treated (temperature T≤ 700ºC). The compacts were sinterized in electric furnace under carbon atmosphere. The heating rate, temperature and dwell time used for sintering the samples were 20°C/min, 1100ºC and 90 min respectively. All samples were characterized by optical microscopy and density measures using the picnometric method.



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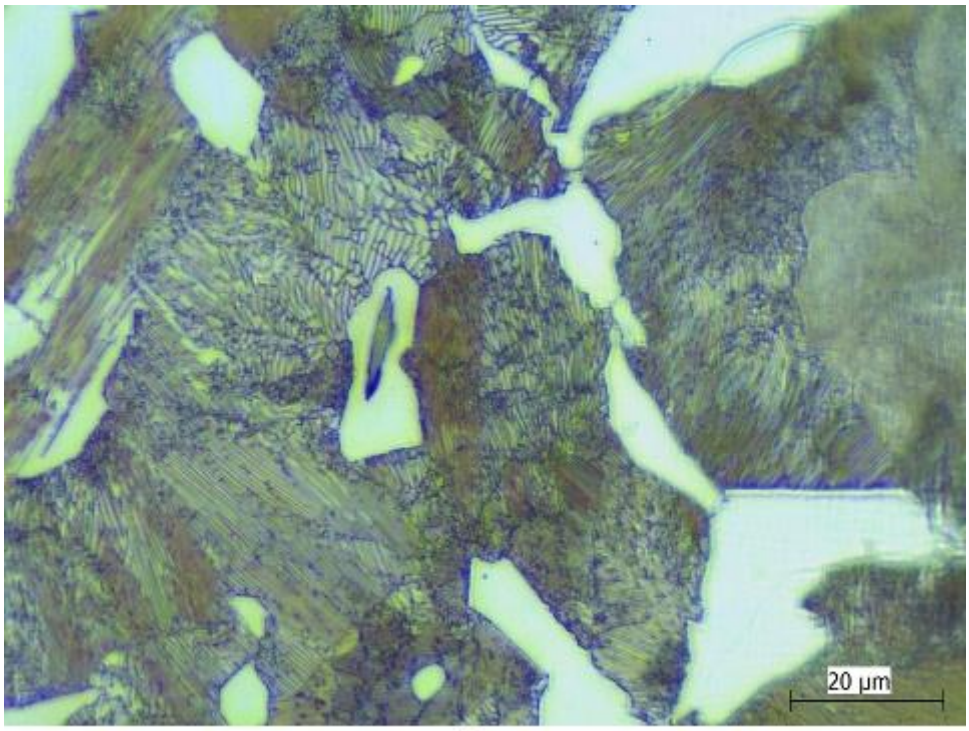


(b)

Figure 1. Microstructure attacked with Nital (3.5%) of the standard sample (AM00): a) Homogeneous distribution of typical phases; b) Identification of the ferrite (clear region) and pearlite (dark region) phases present in the circled area.

Figura. 2. Macrographs of the as-machined chips showing heterogeneous distribution of length (up to 5 mm) and morphology.

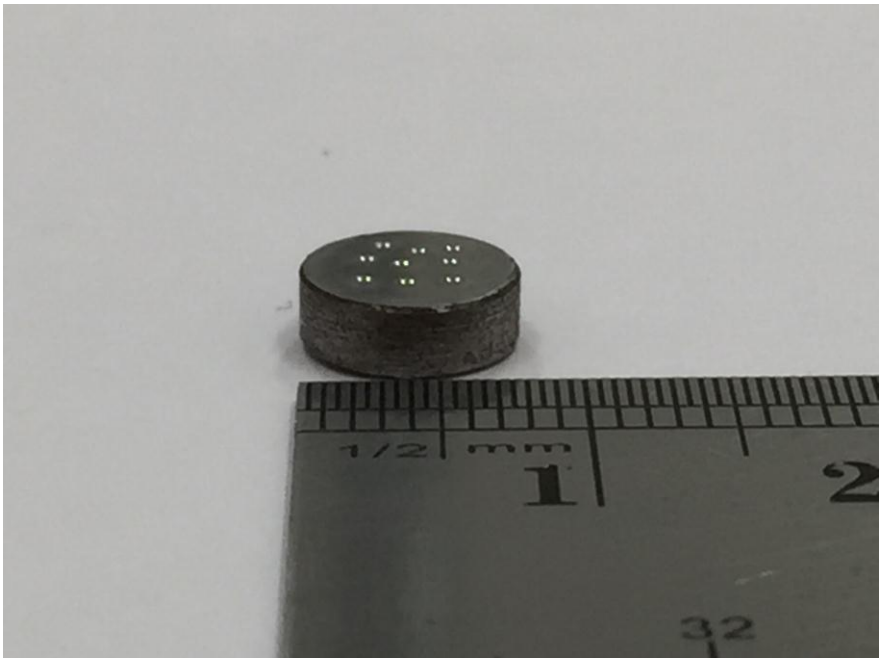
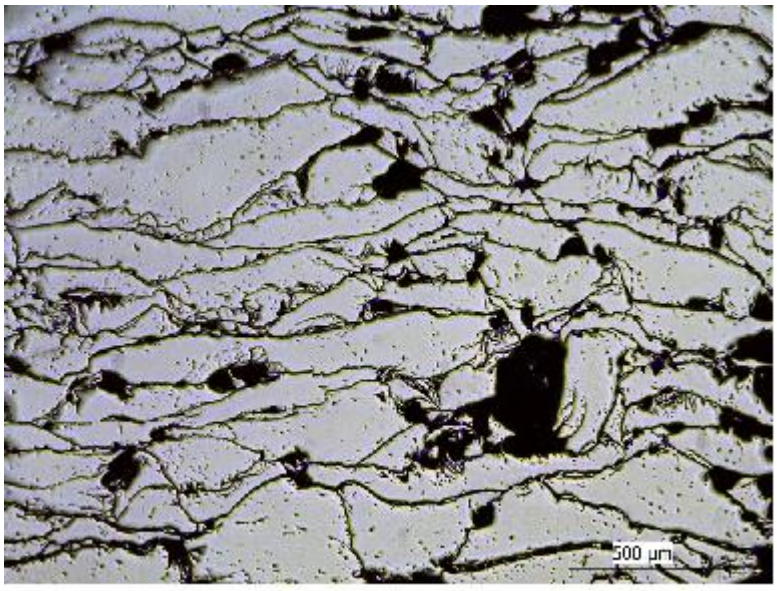


Figura 3. Macrographs of sample size used as a standard to measure the relative density of the compacted and sintered samples.

3. RESULTS AND DISCUSSION

Figure 4 presents the samples' microstructure under high pressure. Figure 4.a presents the microstructure of the compact under 2000 MPa (simple effect – AM01), and Figures 4.b and 4.c show the microstructure produced under 2000 MPa and 3000 MPa, respectively (double effect – AM02 and AM03). It is possible to notice a basic difference when comparing the microstructure of the sample AM01 with those presented by samples AM02 and AM03, which may be associated to the level of deformation contained in the samples' structure, and influenced in the decreasing of the porosity level [2]. The samples obtained under the double effect presented the lowest level of porosity in the structures. The thermic treatment applied to these samples, before their second compaction, was effective to remove the deformation level contained in their microstructure [3]. The samples, at the second compaction free from the deformation level acquired in the first compaction, gained a new level of deformation, evident through the increase to the adjacent contact between the chip contours. Which resulted on the decrease of size and quantity of pores (see dark areas in Figure 4) in the compact's microstructure and, therefore, in the increasing of its green density. Samples AM02 and AM03's microstructures, sintered in the cold or simply under the pressure's double effect, were shown as typical from final stages of sintering. These results show that with no alteration in the pressure of compaction (in the current paper at 2000 MPa and 3000 MPa), it is possible to increase the densification of the compacts with no use of temperature, as from the back forth of the sample's microstructure compacted to its free deformation state (original state), [3, 4, 5].



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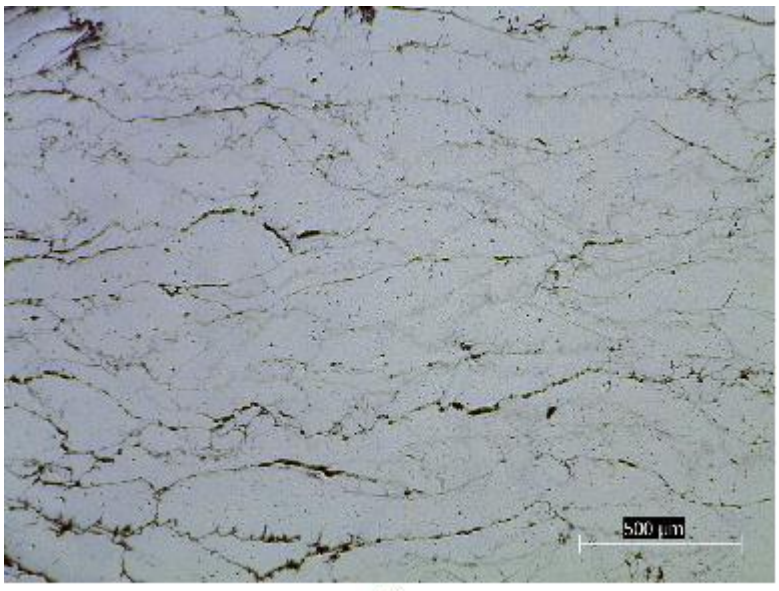

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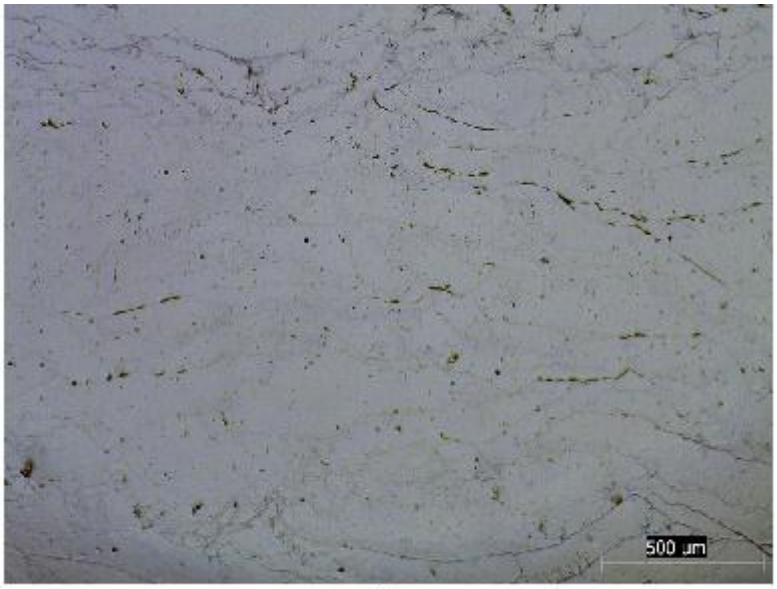
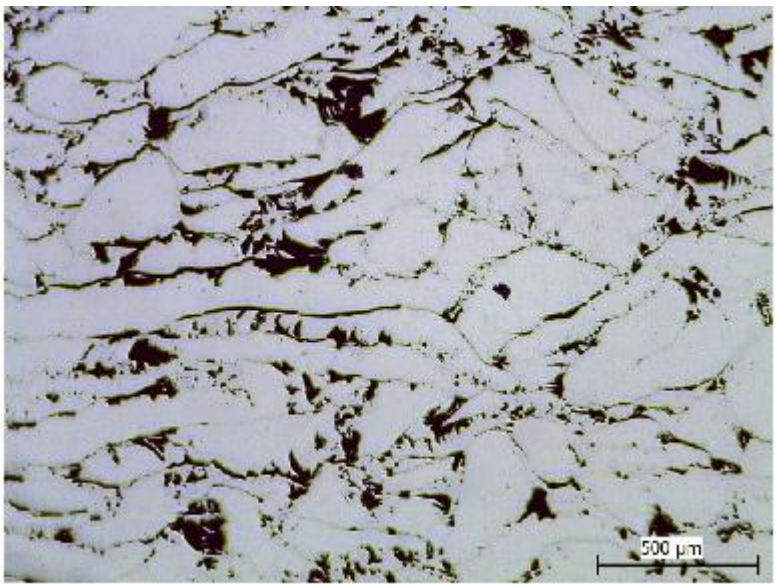


(c)

Figure 4. Microstructure of the samples compacted under high pressure: a) AM01; b) AM02; c) AM03.

Figure 5 presents the microstructure of the samples compacted under high pressure and synthetizes at 1100ºC. When comparing the sintered microstructure with those compacted shown in Figure 5, it is possible to perceive that among all the sintered, there has been a major reduction of the quantity of pores present in its structures. Moreover, the former structures are typical from final stages of sintering (≤ 95%). According to Figure 5.a, sample AM01 presents the biggest size and the greatest quantity of pores. Figure 5.a, differently from the samples of the Figures 5.b and 5.c, was merely compacted and afterwards sintered. These results show the different effects of pressure and temperature on the densification of the samples. Although the temperature has contributed to the reduction or quantity and size of the pores, it was not as effective as the pressure. The main responsible, as motor force, to the increase of densification in the samples was the high pressure, used in the current paper. Furthermore, the route adopted to raise the density of the compacts (double effect of the high pressure), is more efficient than those used only samples compacted and afterwards sintered at 1100ºC during 90 minutes.



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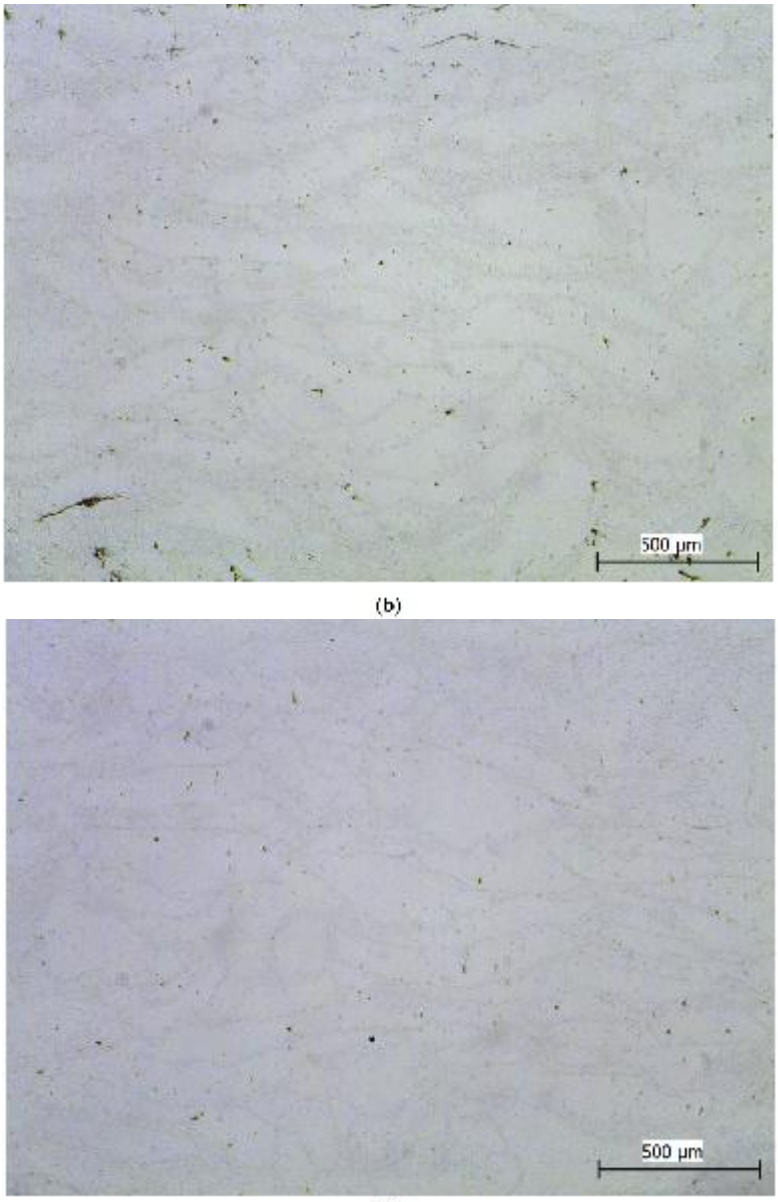

Figure 5. Microstructure of the samples compacted under high pressure and sintered at 1100ºC: a) AM01; b) AM02; c) AM03.

Table 1 demonstrates the values of green and sintered density of the samples employed in the current paper. When comparing the values of the densities compacted, with those observed to the sintered, it is possible to perceive that the temperature contributes to the reduction on the size and the quantity of porosity of the sample's microstructure, therefore increasing its densification. However, it was more representative to sample AM01, which is coherent with the discussion of the previous paragraph, to Figure 5. Moreover, noticing the values of relative density of the samples sintered, presented on Table 1, it is possible to notice that their values increase, and they are found between 94,90 and 99,75%, that is, close to the theoretical density of the sample machined and assumed as standard (AM00) in the current paper.

Table 1 Values of density on compacted and sintered samples at 1100ºC.

Samples	Density			
	Green (g/cm^3)	Relative (%)	Sintered (g/cm^3)	Relative (%)
AM01	7.18± 0.020	91.53	7.44 ± 0.027	94.90
AM02	7.55± 0.023	96.30	7.71 ± 0.020	98.34
AM03	7.78 ± 0.013	99.23	7.82 ± 0.022	99.75
Note: The density of the standard sample, AM00, utilized in this paper as theoretical and measured through the picnometric method was 7,84 ±0.032 g/cm^3.				

4. CONCLUSIONS

The route adopted to raise the density of the compacts (double effect of high pressure) is more efficient than the applied only for samples compacted and afterwards sintered at 1100ºC during 90 minutes;

Although the temperature has contributed for the reduction of quantity and size of pores in the samples, it was not as efficient as the pressure. The main responsible, as motor force, to the increase of densification in the samples was the high pressure, applied in the current paper. From economic and environmental point view, the route of sintering (double effect of high pressure), developed in the current paper, it may be an alternative to manufacture small parts, such as cutting tools for automobile, electronical and aero spatial industries.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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