EFFECT OF MICROSTRUCTURE ON PROPERTIES AND PERFORMANCE OF SPRAY FORMED AISI M2 HIGH-SPEED STEEL

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ABSTRACT

The microstructure of the spray formed AISI M2 high-speed steel was evaluated and correlated to their mechanical properties and machining performance. The spray formed material was hot rolled at 50% and 72% thickness reduction and the result materials were heat-treated (quenched and tempered). Samples were taken for microstructural analysis, hardness and flexural testing, and machining. The results of the analysis highlight the potential of the spray forming technique for the obtention of materials with good characteristics and properties, proper for application in machining operations.

Keywords: spray forming, high-speed steel, machining, microstructure.

INTRODUCTION

It is well known that the obtainment process has a strong influence on properties and performance of materials. Engineers and researchers had worked constantly aiming the development of new techniques for obtainment of materials, improving its characteristics at low cost. In the field of materials for tools applications, there are three processes that allow the obtainment of tool steel: conventional casting, powder metallurgy and spray forming. This last (spray forming process), has showed to be technically and economically feasible for obtainment of a large range of materials, including tool steels.

MATERIALS AND METHODS

In this study, it was considered four materials variation for AISI M2 high-speed steel, regarding the obtainment methods and subsequent applied thermo mechanical process, see Tab. 1.

Table 1 - AISI M2 high-speed steels specification regarding the obtainment methods and subsequent applied thermo mechanical process.

Material	Obtainment method	Post processes
MCSR50	Spray formed	Annealed and hot rolled at 50% thickness reduction ratio, heat treated
MCSR72	Spray formed	Annealed and hot rolled at 72% thickness reduction ratio, heat treated
MConv	Conventionally cast	Heat treated
MP	Powder metallurgy	Heat treated

The spray formed material (see Fig. 1) was obtained in a pilot plant installed at IPEN/SP. After obtainment, the material was soft annealed to improve its workability (machinability). For annealing, the parameters found in literature (1-9), were efficient to provide enough hardness reduction in order to allow the machining of the material. Slabs were removed from the annealed material, which were hot rolled at 50% (MCSR50) and 72% (MCSR72) thickness reduction ratio that corresponds an area reduction of 20% and 67%, respectively.

Figure 1. Spray formed AISI M2 obtained in a plant installed at IPEN/SP.

The conventional cast material (MConv) is commercially available. Details of manufacturing methods were not supplied by vendor; however, for attaining a suitable microstructure, the literature (10, 11) quotes that a reduction ratio of 94% and over is needed. Long and onerous esferoidization heat treatments are also necessary for the obtainment of these materials.

The material made by powder metallurgy (MP), was supplied into square shape, with dimensions close to that necessary for the manufacture of machining test inserts. The sintered inserts were prepared from water atomized powder, which was unixially pressed at 800 MPa followed by vacuum sintering at 1249 ± 3 °C (12, 13).

Samples from all materials mentioned above were heat treated (quenched and tempered) together in equal conditions for guarantee of similar properties. Heat treatment was carried according to indicated in Fig. 2.

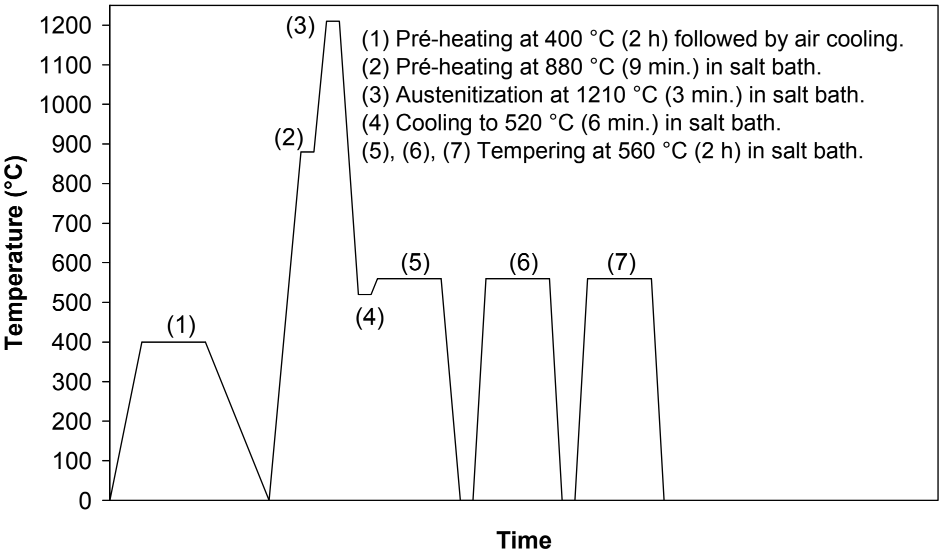


Figure 2. Parameters utilized for samples heat treatment (quenching and tempering).

Heat-treated samples from MCSR50, MCSR72, MConv and MP materials were prepared for the transverse rupture strength (TRS) testing (14). After the flexion test, the broken parts were hardness tested.

For carbides distribution and size observation, samples were mounted, ground and polished until diamond paste of 1 µm, followed by final finishing in colloidal silica 0.25 µm. The samples were analysed using a scanning electronic microscope (SEM) for microstructure observation, in the as polished and etched conditions. The used etching was a solution of HCl (10 mL), HNO_3 (5 mL) and ethanol / methanol 95% (85 mL) (1, 8, 9), aiming to reveal the austenitic grain boundary.

RESULTS AND DISCUSSION

The hardness measurements results showed a small value for MP material and similar values for MCSR50 and MCSR72 materials. The higher hardness value was encountered in MConv material, however, it is important to comment that higher hardness value is not connected to a better machining performance, as verified by Jesus (1) and Santos (15) in works with conventional, sintered and spray formed high-speed steels (see Fig 3).

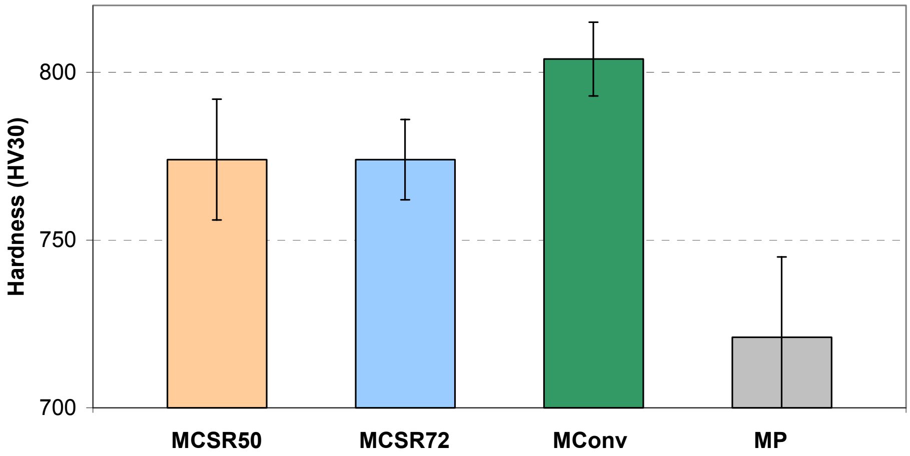
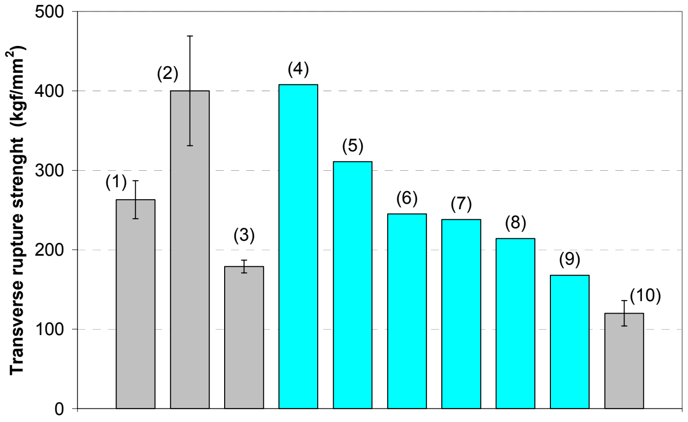


Figure 3. Hardness testing results for the four materials under study.

The results of the transverse rupture strength tests showed that when the spray formed material is submitted to a hot rolling reduction about 50%, the strength value is higher than the conventional materials. When the reduction ratio is increased to 72%, the results are comparable to materials obtained by powder metallurgy. Fig. 4 shows the present work results of transverse rupture strength tests, in comparison to published data obtained by others researches for AISI M2 high-speed steel.



(1) MCSR50 (present work)
(2) MCSR72 (present work)
(3) MConv (transversal) - (present work)
(4) Powder metallurgy (MP) (16)
(5) Conventional (16)
(6) Spray forming + forging (transversal) (17)
(7) Conventional (17)
(8) Conventional (18)
(9) Conventional (transversal) (18)
(10) Powder metallurgy (MP) (present work).

Figure 4. Results of transverse rupture strength testing (TRS) of evaluated materials, in comparison to data obtained by others researchers (after quenching and tempering).

Microstructurally, if the micrographs showed in Fig. 5 were evaluated aiming the identification of the best material in terms of microstructure refinement (better distribution and small carbides), characteristics that usually promote better mechanical properties; the MCSR72 material would be chosen. However, when dealing with materials for machining tools an application (which is the case); there are other significant characteristics that need be considered: the abrasive wear resistance. According to Schruff et al. (19, 20) and the results of machining tests made by Jesus (1), the better microstructural condition that promotes a good material performance regarding wear resistance, is that where the carbides are homogeneously distributed and with coarse sizes. In this condition, in any region and direction there are anchors points which has enough resistance to obstruct the passage of an abrasive element; this resistance will be higher, the higher the carbide size is (Fig. 6).

Carrying on a comparative analysis among micrographs showed in Fig. 5 and establishing a parallel with the results of the machining tests made by Jesus (1) with these materials, it follows:

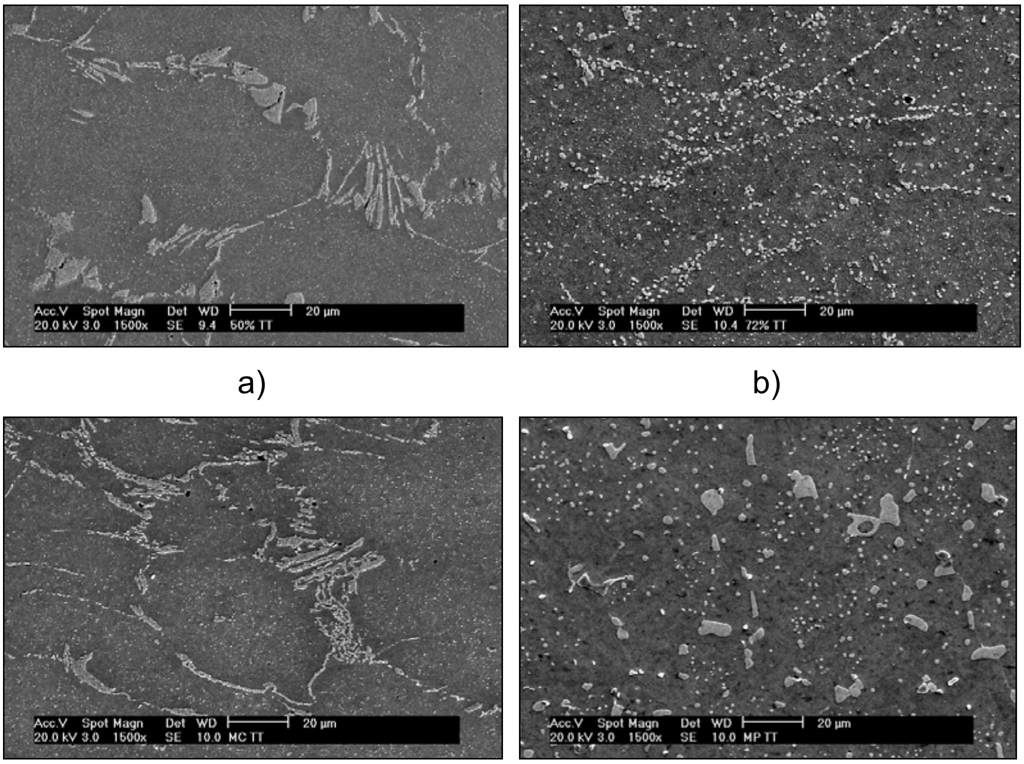
a) The MCSR50 microstructure is very similar to the MConv. However, the MCSR50 material presented inferior results in terms of wear resistance during machining tests when compared to the MConv material.

b) The MCSR72 presents a homogeneous carbides size distribution and smaller carbide size than MConv, hence, with a microstructure much more refined. However, the machining tests showed that both materials have a very close performance condition, with narrow advantage for the MConv material.

c*)* The MCSR72 material presented a microstructure as refined as the MP material, including very small carbides size. However, the MP material presented the best result during machining testing, among all evaluated tool materials.

The affirmation of Schruff et al. (19,20), perhaps not the unique explanation for all cases (items a, b and c) mentioned previously, is certainty that one that can better explain the superior performance of the material obtained by powder metallurgy, in comparison to the others materials, according to verified by Jesus (1) during machining tests with these materials.

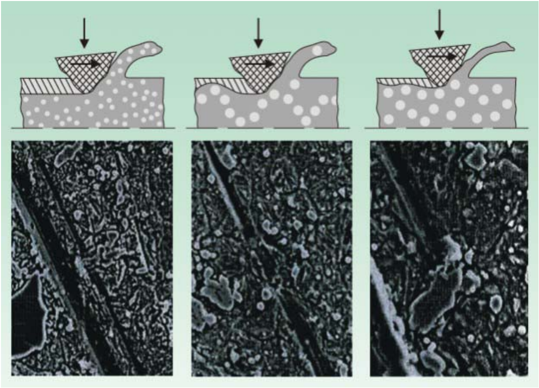
Regarding the austenitic grain size, analysis on all samples using the scanning electron microscope (SEM) after heat treatment (quenching and tempering), revealed a mean grain size (about 22 µm) for the powder metallurgy (MP) sample, in comparison to the samples of the others materials; that can explain the small hardness and transverse rupture strength (TRS) values measured in this material. In the case of MCSR50 and MCSR72, the grain size was smaller than the MP material, 15 µm and 17 µm, respectively. This fact can partially explain the higher hardness and transverse rupture strength values in relation to MP material. For the MConv material, it was measured the smallest grain size (about 13 μm), that can be associated with the higher hardness values encountered in this material.



a) b)

c) d)

Figure 5. Secondary scanning electron micrographs of AISI M2 high-speed steels, after quenching and tempering (without etching). a) Spray formed material hot rolled 50% thickness reduction. a) Spray formed material hot rolled 72% thickness reduction. c) Conventionally cast material. d) Powder metallurgy material.



a) b) c)

Figure 6. Effect of carbides size and distribution on the wear resistance of tool steels. a) Very fine carbides. b) Larger carbides in a network orientation. c) Homogeneous dispersion of larger carbides (19, 20).

CONCLUSIONS

The 50% thickness reduction ratio and post thermo mechanical process of spray formed material not was enough to turn possible a good distribution, broken and disaggregate of carbides net formed during spray forming.

The 72% thickness reduction ratio and post thermo mechanical process of spray formed material (MCSR72) has proportioned a refined microstructure and better mechanical properties such as high hardness and transverse rupture strength values, however, according to machining tests made by Jesus (1) presented evidences of reduction in wear resistance in comparison to MConv and MP materials.

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