Influence of Binders on the Structure and Properties of High Speed-steel HS6-5-2 Type Fabricated Using Pressureless Forming and PIM Methods

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Abstract

Based on the comparison of structures and properties of the HS6-5-2 high speed steels made with the powder injection moulding method, pressureless forming, compacting and sintering, and commercial steels made with the ASEA-STORA method, fine carbides spread evenly in the steel matrix were found in the structure of all tested high-speed steels in the sintered state. The steels made with the pressureless forming method are characteristic of the lowest sintering temperature and the highest density, resulting from the high carbon concentration coming from the binding agent degradation.

Keywords : HS6-5-2 high speed steel, powder injection moulding, ASEA-STORA method, pressureless forming

1. Introduction

The continuous development of powder metallurgy and especially the employment of newer forming methods, as well as the modernization of those existing so far, have led to the significant lowering of the manufacturing costs of the sintered materials. These changes are quite clearly evident in the high-speed steels case for which the price of tools made with the conventional casting is comparable with the cost of the sintered tools [1-3]. The validity of employing powder metallurgy in the case of the high-speed steels is dictated mostly by avoiding the nonhomogeneous structure resulting from conventional steel casting, calling next for carrying out the costly plastic forming of slabs. Even multiple reforging of the ingot, fails to completely remove the carbide network, as a result of which conventional steels often feature primary carbide segregation, mainly of the band type [1]. Hence in the 70s of the 20th century, the problem was solved by using the ASEA-STORA method and its variations consisting in the production of sintered high-speed steel blocks of homogeneous structure [1-3]. A block of high speed steel made by hot isostatic compacting requires plastic forming and machining, which makes it impossible to significantly lower production costs in comparison with the conventional method. On the other hand, although cheaper, the classic compacting in a die (Powder Metallurgy - PM) may be used for simple shape tools, such as multi-blade plates for lathe tools. However, these types of plates are usually made of sintered carbides, cermetals and tool ceramics characterized by significantly higher abrasion resistance from high-speed steels. To secure the development of high speed steels, other methods of powder forming must be used, in line with the tendency for making finished components or near-net-shaped components [4]. The goal of this project is comparing the structure and properties of the HS6-5-2 type high-speed steels manufactured by powder injection moulding and pressureless forming [5], with the commercial steel brand of ASP 23 type that is manufactured from hot isostatic pressing.

2. Experimental and Results

The investigations were carried out on specimens fabricated using the powder injection and the pressureless forming methods, as well as on the traditionally compacted and sintered ones. In the case of injection moulding or pressureless forming the HS6-5-2 type high-speed steel powder was used sputtered with argon, spherically shaped and with good wettability. The powder density measured with the AccuPyc 1330 type pycnometer was 8.17 g/cm^3. The powder grain size did not exceed 16μm in 80%. For test pieces formed with the pressureless method a binding agent was used in the form of a thermosetting acryl resin, which was fluid at ambient temperature and had a density of 1.0 g/m^3. The metal powder was mixed with the binding agent in the ratio 40:60%. The slurry was poured into forms and subjected to binding agent degradation in an electric chamber furnace at the temperature of 90^{o}C. After removal from the forms, the cast profiles were subjected to thermal debinding in a pipe furnace, in a flowing argon atmosphere and sintered immediately in a N_2-10%H_2 atmosphere. The heating rate was experimentally selected based on the initial debinding and sintering test results. The injection moulded test pieces were mixed with the binding agent composed of 50% high density polyethylene (PE-HD) and 50% paraffin (PW). Thermal debinding was carried out in a pipe furnace in an argon atmosphere or a N_2-10%H_2 gas mixture. The compacted and sintered specimens were made from the water sputtered powder with grain sizes below 120 µm. Compacting was carried out in a uniaxial unilateral die, under a pressure of 750 MPa. Regardless of the manufacturing method, sintering was carried out in a pipe furnace at temperatures between 1210 and 1290°C in steps of 10°C, in an atmosphere of flowing N_2-10%H_2 mixture of gases within 30 min.

The specimens sintered in the optimum conditions and specimens from the ASP 23 type steels were heat treated next. All specimens in the sintered state were subjected to density tests with the Archimedes method (fig.1). Hardness tests were made with the Rockwell method in scale C on sintered and heat-treated specimens (Fig.2).

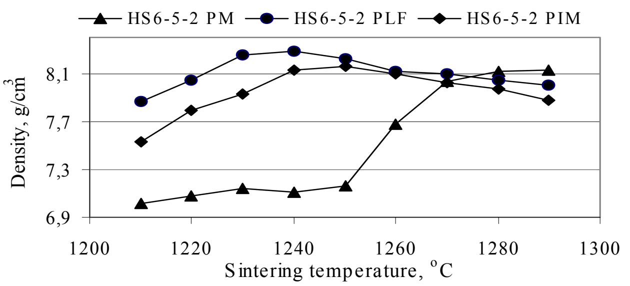

Fig. 1. Sintering curve of high speed-steel formed by powder injection moulding (PIM), pressureless forming (PLF) and compacted and sintered (PM).

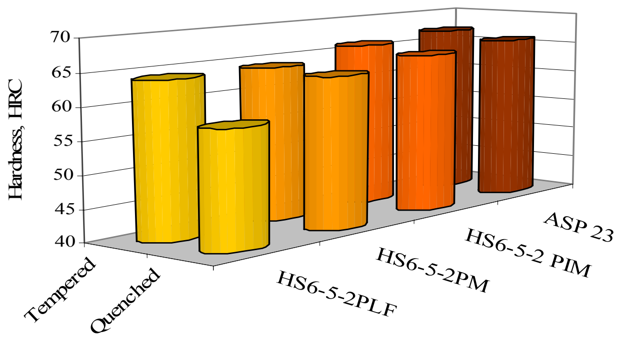

Fig. 2. Maximum hardness of investigated steels after quenching and tempering

Structure examination and an X-ray qualitative micro-analysis were made on the Philips XL30 and Opton DSM-940 scanning microscopes with a 20 kV accelerating voltage.

3. Summary

Based on the investigations carried out on the HS6-5-2 type high-speed steels produced with the powder injection and pressureless forming methods, it may be concluded that the PIM method, despite the necessity to use expensive perpetual screw injection moulding machines, is a more economical method. The main advantage of this method is the obtainability of a profile of a more elaborate shape, higher density and homogenous distribution of the powder in the binding agent matrix. In addition, the time of the degradation process is approximately 10hrs shorter than in the case of pressureless forming, which is caused by the use of a two-component binding agent. The pressureless forming method (PLF), apart from the furnace for binding agent degradation and sintering, does not require any other equipment, which is an obvious advantage. A common advantage of the injection moulded steels (PIM) and the pressurelessly formed ones (PLF), is a wider sintering temperature range in comparison to the conventional compacted and sintered where it is only 5°C. The high hardness of the injection moulded steel (PIM) in the heat treated state, which is comparable to the commercial ASP 23 type steel hardness, indicates the viability of the powder injection moulding method for making high-speed steels. An unquestionable advantage of this method is the fact that it offers a possibility of making finished tools, i.e. there is no need for plastic forming and machining necessary as in the case of the ASP 23 type steel. Moreover, hot isostatic pressure of the ASP 23 type steel is more expensive than voluntary sintering, occurring in the powder injection moulding process. The tools made with this method may be characterized by complex shapes and surface. Furthermore, sintering in an atmosphere rich in nitrogen causes the formation of fine spherical carbonitrides, stable in high sintering and austenitizing temperatures.

4. References

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