Effect of Heat Treatment Conditions and Densities on Residual Stresses at Hybrid (FLN2-4405) P/M Steels

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Abstract

The characteristics of residual stresses occurring in PM steel based nickel (FLN2-4405) was investigated. The measurements of residual stresses were carried out by electrochemical layer removal technique. The values and distributions of residual stresses occurring in PM steel processed under various densities and heat treatment conditions were determined. In most of the experiments, tensile residual stresses were recorded in surface of samples. The residual stress distribution on the surface of the PM steels is affected by the heat treatment conditions and density. Maximum values of residual stresses on the surface were observed sinter hardened condition and 7.4 g/cm^3 density. Minimum level of recorded tensile residual stresses are150 MPa and its maximum level is 370 MPa.

Keywords: Residual stresses, PM Steels, Sintering

1. Introduction

The mechanical properties of PM steels are related directly to their microstructure and the level of porosity. In addition, the alloying mode has a significant effect on the microstructure and pore morphology of sintered steels. PM steels with high hardenability develop microstructures containing a significant fraction of martensite in the as-sintered condition. Accelerated cooling rates can be achieved in the sintering furnace (> 5 ºC/s) which permits large parts to be sinter -hardened. In sinter-hardening problems related to the oil quenching of porous PM steels, primarily oil penetration, are eliminated and there is less distortion in the parts due to the lower cooling rate [1-5].

In the present study, the residual stresses in a prealloyed and hybrid PM steels based on Ancorsteel 85 HP are reported. Two sintering temperatures and three heat treat conditions were examined. Saritas et al [6, 7] reported the mechanical properties and fatigue crack propagation rates in these steels in the same conditions.

2. Experimental And Results

PM steel processed under various densities (6.8, 7.05, 7.2 and 7.4 g/cm^3) based on Hoeganaes Ancorsteel 85 HP were examined [8].

Samples 5mm x 7mm x 40mm were removed from the shoulders of the failed fatigue crack propagation specimens by means of a wire electro-erosion machine. Layer removal by electrochemical machining (ECM) was used for measurement of the residual stresses in the PM steels [9].

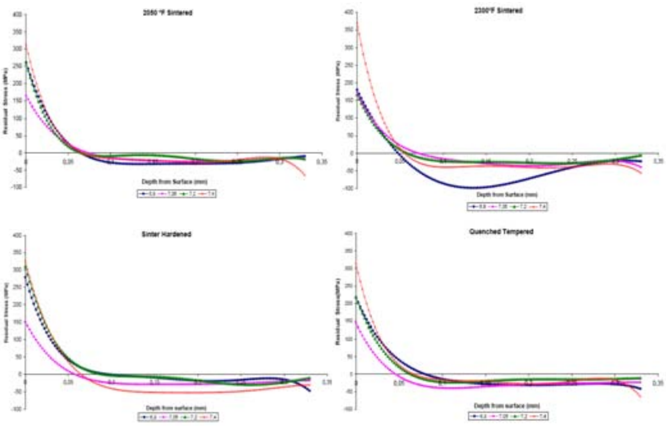

Fig. 1. Distributions of Residual stress in hybrid PM steels grouping according to densities and heat treatment conditions

The results of the residual stress measurements are given in Figures 1. These figures show the variation of residual stress from the surface of the samples to depths below the surface of about 0.35 mm. Figure 1 shows the measured residual stresses in the PM steels sintered at various densities and heat treatment conditions. As seen from these figures, there are tensile residual stresses on the surfaces of the steels at all conditions. The maximum tensile residual stress of about 370 MPa exists in 7.4 g/cm3 density and sintered at 2300 ºF. Tensile residual stresses persist in all conditions up to a depth below surface of about 0.08 mm. In 2300 ºF sintered and 6.8 g/cm3 density, the residual stress is compressive at a depth of 0.05 mm. Beyond this depth, the compressive residual stresses are about -98 MPa.

3. Summary And Conclusions

At a nominal sintered density of 7.4 g/cm^3 high temperature sintering (sintering at 2300 ºF) produced maximum tensile residual stresses. Sinter-hardening and low temperature sintering resulted in tensile residual stresses values which are higher than the as-sintered values and the quenched tempered values. These values of residual stresses, coupled with the microstructures, confirm that the cooling rate of the furnace (100% Varicool) is not sufficiently high to allow for complete transformation of austenite to martensite.

Figure 2 shows main effects and interaction plots for residual stresses on surface as the results of experiments. Maximum residual stresses on the surfaces of the PM steels change with density and heat treatment conditions. Residual stresses on surface should be of concern in the fatigue crack propagation behavior of the PM steels. The residual stress distribution on the surface of the PM steels is affected by the heat treatment conditions and density; the sinter hardened and 7.4 g/cm^3 density PM steels exhibit the greatest residual stresses on the surface.

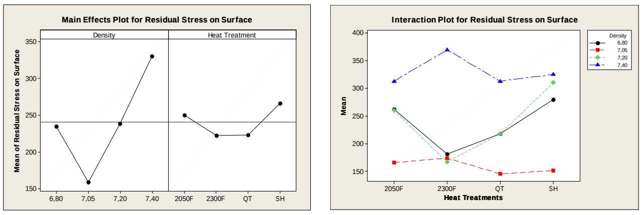

Fig. 2. Main effects and interaction plots for Residual stresses on surface as the results of experiments

We could be decided upon following conclusions when the results of experiments were analyzed as figure 1 and 2;

1. Tensile residual stresses were measured on the surfaces of hybrid P/M steels. The residual stresses were a function of processing history and ranged between 150 MPa and 370 MPa.
2. The depth of the tensile residual stresses was between 0.05 mm to 0.08 mm and was a function of processing history and density.
3. The PM steels exhibited the highest residual stresses in the sinter hardened conditions.
4. Sintered at 2300 ºF and quenched tempered PM steels exhibited the lowest level of residual stresses on the surface and in the interior of the PM steels

4. References

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