High Fatigue Strength with Better Machinability Material for Powder Forged Connecting Rod

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Abstract

The powder forging (PF) process is used to produce fully dense powder metallurgy (PM) parts for high performance automotive applications. PF connecting rods have been widely accepted in the US, Japan, and other countries due to higher performance and lower manufacturing costs when compared to conventionally forged steel connecting rods [1]. In order to meet and exceed requirements for higher fatigue strength and better machinability of PF connecting rods, a newly developed machinability enhancer, named KSX, was introduced [2]. A comparison study between powder forged materials prepared with 0.3% MnS and with 0.1% KSX additions showed excellent properties in the case of the mix with KSX.

Keywords: **Powder forging, Fatigue strength, Machinability**

1. Introduction

Although various machinability enhancers have been investigated and proposed to improve the machinability of sintered parts, MnS is still the most widely used in the PM industry. Even in the case of PF connecting rods, approximately 0.32% MnS powder is added in the PF-11C50 material (2.0% copper and 0.40% to 0.60% as-forged carbon) to improve the machinability. In general, it is well known that MnS has negative effects in powder flow characteristics and mechanical properties, in particular in dynamic properties. KSX is very fine complex calcium oxide developed as an alternate machinability enhancer to overcome the disadvantages of MnS.

2. Experimental procedure

High purity iron powder (300ME) was mixed with 2.0% Cu, 0.6% graphite and lubricant. Three separate mixes were prepared, 0.3% MnS added, 0.1% KSX added, and no machinability enhancer added. Pucks with an OD of 90 mm and 45 mm in height were compacted at a green density of 6.80 g/cm^3 and sintered at 1120^{o}C for 30 minutes in an atmosphere consisting of 90% N_2 and 10% H_2. The sintered compacts were then heated at 1050^{o}C for 30 minutes and forged at a forging pressure of 1078 MPa to achieve full density. Boring was selected to evaluate the machinability. Cemented carbide inserts were used and both flank and crater wear of the tool were measured periodically every 200 passes. Furthermore, surface roughness (R_{max}) was measured on the machined surfaces after 400 and 600 passes. Typical boring conditions, boring depth of 0.1 mm and cutting speed of 150 m/min, were used during the test.

3. Results and Discussion

Figures 1 show flank and crater wear of the cutting insert measured during boring trials. As expected, the additions of machinability enhancers significantly reduce tool wear during boring. However, KSX additions seem to be more effective than MnS additions in protecting the tool from wear, even if the added amount is only 0.1%. The reason KSX improves the machinability, stands in the fact that a thin coating layer is created on the surface of the cutting tool during machining, thus protecting the tool from wear.

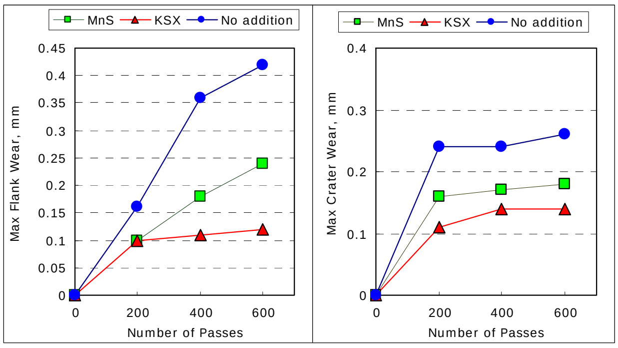

Fig. 1. Max flank and crater wears of boring insert

Figure 2 illustrates the results of surface roughness measurements after boring. As shown, surfaces obtained after boring the material with KSX are much smoother than the surfaces obtained after boring the material with MnS.

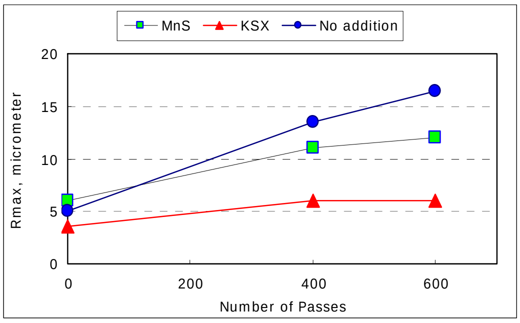

Fig. 2. Surface roughness after boring

4. Application – PF Connecting Rods

Connecting rods containing 0.1% of KSX were submitted to side by side testing with PF connecting rods manufactured with the same material, with 0.32% MnS instead. Figure 3 illustrates the microstructure of both materials in the unetched condition. As shown, a much lower inclusion content is present in microstructure in the case of the material with KSX, due to the lower amount needed to achieve similar or slightly better machinability enhancements than in the case of the material with MnS. Furthermore, the size of the KSX particles is much smaller and the shape is more rounded than the size and the shape of particles of MnS. These factors bode well for an improvement in strength, in particular during dynamic loading conditions, which is the case of connecting rods.

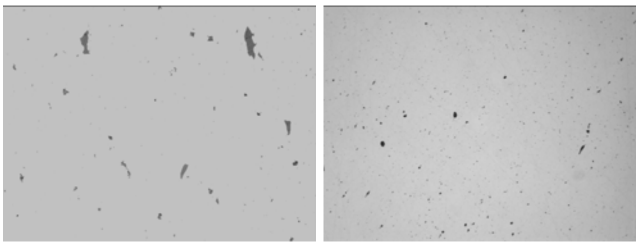

Fig. 3. Unetched microstructure of the material with MnS (left) and KSX (right) ↔ 100 micro meter

Axial, constant amplitude, fully reversed (stress ratio r = -1) fatigue tests were run on both groups of connecting rods at room temperature using a MTS servohydraulic closed loop controlled testing machine. Runout was considered the result of the test for connecting rods surviving 10^7 cycles. The staircase method was used to evaluate the fatigue strength. The results are summarized in the chart shown in Figure 4. As shown, the connecting rods manufactured out of the mix with KSX sustained higher loads during fatigue testing. A summary of the fatigue limit calculations at 50% and at 90% probability of survival for the stress ratio r = -1, is presented in Table 3.

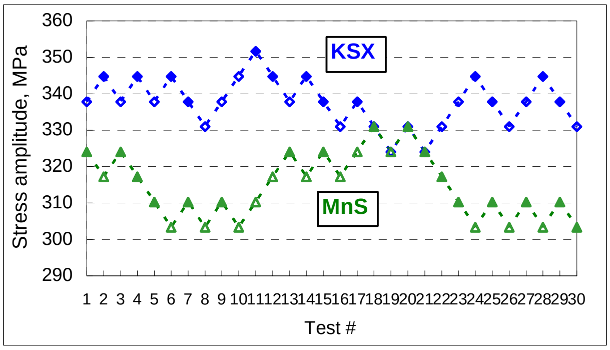

Fig. 4. Results of fatigue tests, r = -1

Table 3. Fatigue test results (r = -1)

	KSX	MnS	Difference
FL at 50% PS	337.40	314.53	7.27%
FL at 90% PS	327.69	294.69	11.20%
Scatter	7.58	15.50	-51.11%

As shown, the fatigue limit at 50% probability of survival is 7.27% higher and the fatigue limit at 90% probability of survival is 11.20% higher in the case of PF connecting rods manufactured with the material containing KSX, due to a lower scatter in the data obtained from fatigue testing. These preliminary results obtained from fatigue testing on connecting rods clearly confirm the advantage of using KSX to replace MnS as a machinability enhancer in the case of PF connecting rods.

5. Summary

(1) A new machinability enhancer, KSX (complex oxide in the form of a very fine powder), in the amount of 0.1% was applied to PF connecting rods to replace 0.30% MnS.
(2) The machinability evaluated by boring clearly showed that PF material with KSX machines better than PF material with MnS, even though less KSX than MnS is needed.
(3) Fatigue test results on actual PF connecting rods, manufactured with KSX, showed an improvement of 11.20% in the fatigue strength at 90% probability of survival when compared to the mix with MnS.

6. References

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