DIN - DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

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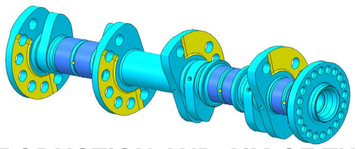
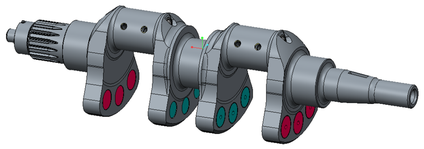


OPTIMIZATION OF MATERIALS AND PROCESSES FOR MOTORBIKE RACING COMPONENTS



1. INTRODUCTION AND AIM OF THE WORK

Weight reduction is the most effective method to reduce gas emissions and increase performance [1-3]. When high stiffness, toughness, fatigue strength and wear resistance are required, for example in the case of crank and cam shafts for motorsport applications, steels are almost the only solution. Fatigue strength of steels is usually increased by means of thermochemical treatments, such as nitriding [4], that is time consuming when high case depth is required [4,5]. In recent years new generations of tool steels have been developed offering new potential for replacing nitrided steels, thanks to their high quality related to the controlled production processes [5-7]. Based on the above, the aim of first year of the PhD research project was to assess the fatigue resistance of two tool steels, by comparing their performance with that of a conventional nitrided steel.

2. EXPERIMENTAL

Three steels processed by Electro Slag Remelting (ESR) were studied. Their chemical compositions (analysed by a glow discharge optical emission spectroscope GD-OES) are reported in table 1. Nitrided steel was also studied in the quenched and tempered condition.

Elements / Material	C	Cr	Mo	V	Ni	Si	Mn	Co	Al	Fe
A (Tool steel)	0.350	4.462	1.157	0.323	0.141	0.980	0.297	0.159	0.011	Bal.
B (Tool steel)	0.462	4.016	3.091	0.581	0.072	0.199	0.240	0.236	0.010	Bal.
C (Q&T steel) D (Nitrided steel)	0.317	2.839	0.931	0.292	0.101	0.266	0.543	0.078	0.003	Bal.

The mechanical characterization was carried out by hardness, tensile, fatigue and fracture toughness tests. Microstructural and fractographic analyses allowed to study the mechanisms of failure. The residual stresses on the surface layer and the volume fraction of retained austenite were evaluated on the fatigue specimens by a X-ray diffractometer.

3. RESULTS AND DISCUSSION

3.1 Microstructural analysis

Tempered martensite were observed in all tested steels (Fig.1); some larger carbides were detected in B steel probably due to its higher C, Mo and V content. The typical outer white layer can be clearly seen in the nitrided D steel (Fig.1-D). XRD analyses (Fig.2) do not show any evidence of retained austenite on A and C steels, while about 10% of retained austenite was detected in B steel.

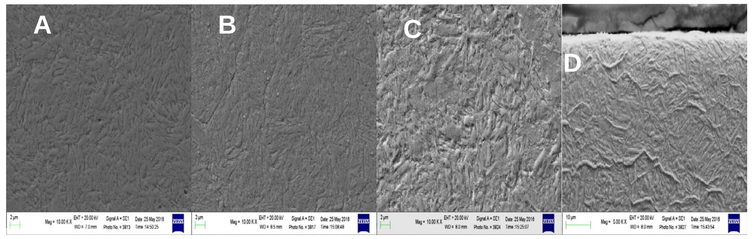


Figure 1 – SEM micrographs of etched specimens: (A-C) bulk microstructures; (D) nitrided layer on D steel.

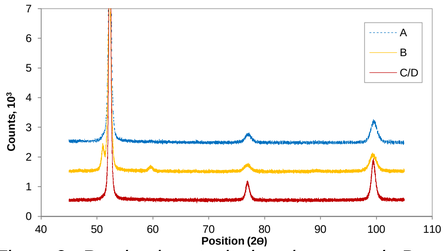


Figure 2 –Retained austenite is only present in B steel.

3.2 Mechanical Properties

The data reported in Fig. 3 highlight linear relationships between hardness and tensile properties (UTS, YS and E%) for all the studied steels (no tensile tests were carried out on D steel because negligible effects of the nitriding treatment on tensile properties were expected [4]). In particular, higher hardness lead both to higher yield and ultimate tensile strengths and lower elongation to failure. By studying the effects of inclusions on the fatigue life of steels [8], Murakami proposed the following modified equation:

$$\sigma_f = \frac{K \cdot (HV + 120)}{(\sqrt{A})^{\frac{1}{6}}}$$

where A is the area of the inclusion from which fatigue crack nucleates, K is a constant, equal to 1.43 for surface defects and 1.56 for internal defects and HV is Vickers hardness It can be clearly seen that equation underestimates the fatigue strength of the studied steels (Fig.4) and this is probably because it was developed by Murakami for steels of lower quality than the ESR steels used in this work.

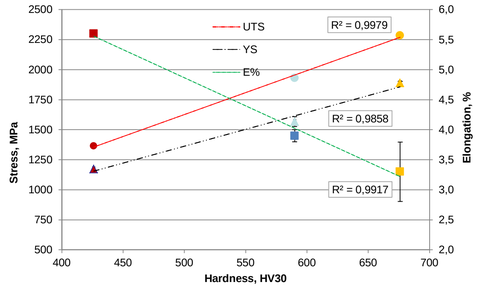


Figure 3 –Tensile and hardness data (average and standard deviations) of A, B and C steels.

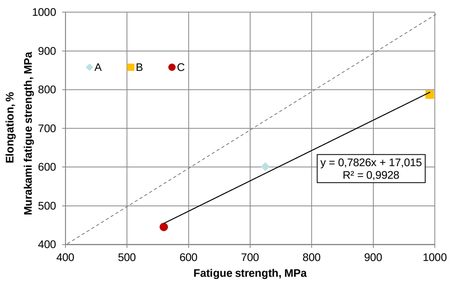


Figure 4 –Comparison between experimental and modelled (fatigue strength (50% probability of failure) of the studied steels.

4. CONCLUSIONS

The mechanical properties and microstructural features of the investigated tool steels were compared with those of a 33CrMoV12 steel both in quenched and tempered (C), and nitrided (D) conditions.

The following main conclusions can be drawn:

- ✓ Tensile properties were linearly correlated to the hardness of the steels. B steel, with higher C and Mo contents, showed the highest strength with the lowest elongation to failure.
- ✓ The rotating bending fatigue tests show fatigue strengths of about 1000 MPa for B steel and nitrided D steel.
- ✓ These results highlighted that appropriate ESR tool steels could replace nitrided steels.

A paper based on this research have been submitted to the *Journal of Material Engineering and Performance* (ASM International)

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