SUMNotes

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CASE HARDENED STEELS - *INDUCTION HARDENED* *by Dr. E. MOGIRE*

Background

Induction hardening of steel components involves raising the temperature of the surface layer to where it's transformed to austenite and rapidly cooling to produce a hard martensitic microstructure. This is mainly done on hardenable steels although some carburized steels are often reheated in selected areas by induction heating.

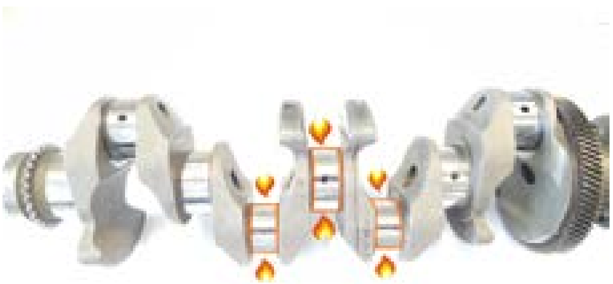

Figure 1.1 Shows a crankshaft with illustration of induction heating of the surface layer of the crank journals

Typical steels are;

- Medium-carbon steels for automotive drive shafts, gears
- High carbon steels used for drills bits, hand tools
- Alloy steels used for bearings, automotive valves and machine tool components

Microstructural analysis is carried out on the induction hardened part to check that correct microstructures are obtained and validated through case hardness depth measurement. For both microstructural and hardness checks, samples are prepared using standard metallographic techniques. Traditional preparation methods are now considered arduous and take longer times. To cut down on preparation times, Buehler developed a stone planar grinder, dubbed PlanarMet 300, to reduce the grinding times whilst producing excellent surface finish, flatness and minimal deformation to the material. The machine also has good reproducibility when compared to traditional grinding using SiC papers.

Preparation Procedure

Sectioning: various sectioning machines are used depending on the geometry of the induction hardened part. This may necessitate using a large cut-off machine with 18inch abrasive wheels such Abrasimatic 450 and progressively using smaller machines, AbrasiMatic 300 (12" wheel) or 250 (10" wheel) to get appropriately sized samples for mounting.

Mounting: Where samples require mounting, shrinkage free EpoMet epoxy-mounting compound is recommended for induction hardened samples. EpoMet is used in a compressive mounting machine such as the SimpliMet 4000. The choice of mounting compound depends on its abrasion rate and edge retention characteristics as these are important parameters for hardened parts.

Planar grinding - PlanarMet 300

The PlanarMet 300 is used to grind both mounted and unmounted hardened steel parts. It can control material removal in the Z axis up to 3mm in any one stage. The incremental Z-axis resolution on the machine is 100μm. The following parameters were successfully used with a Z-axis target of 500μm ground in less than 1minute 10sec for a variety of induction-hardened parts.

	Surface	Abrasive	Force (Per specimen)	Platen Speend (rpm)	Head Speed (rpm)	Rotation
1	Alumina Wheel	120 Grit	30N	Fixed	150	»

Table 2.1 Parameters for PlanarMet grinding

The surface finish after PlanarMet grinding was excellent with good flatness and lack of edge rounding. Depth of deformation was also below 3μm for hardened parts.

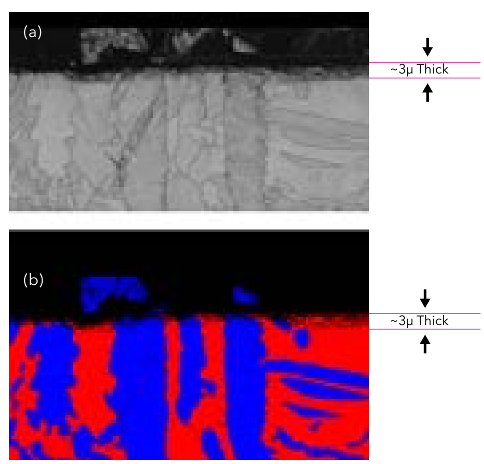

Figure 2.1 shows EBSD quality map (a) and phase map (b) of a duplex steel, illustrating the depth of deformation after planar grinder of approximately 3um thick

Polishing – EcoMet/AutoMet 250/300

With the observed minimal deformation depth after planar grinding, the samples were taken through a coarse polish on either a 10" (254mm) or 12" (305mm) platen. Polishing was also carried out in central force mode using a hard woven cloth (UltraPad) or a rigid composite disk (Hercules S/H). For a 3 step procedure, a final fine polish using a napped cloth (MicroFloc) produced excellent finish for microstructural analysis and hardness checks.

	Surface	Abrasivie	Force (/Sample)	Time Min:Sec	Platen Speed	Head Speed	Rotation
1	Ultrapad	9μ Metadi Supreme	30N	05:00	150	60	><
2	Microfloc	3μ Metadi Supreme	30N	4:00	150	60	»

Table 2.2 Parameters for Ecoment / Automet polishing

Analysis

Microstructure

Microstructural analysis of medium-carbon, high carbon and alloy steel is normally carried out before and after etching in Nital (2-3%). Etching is carried out by swabbing or immersion in Nital for a few seconds to minutes, rinsed with water and a solvent before examination. The etched surface and non-etched samples are optically examined using brightfield microscopy as shown in figures below.

Figure 3.1 As-polished surface with MnS inclusions in the alloy matrix

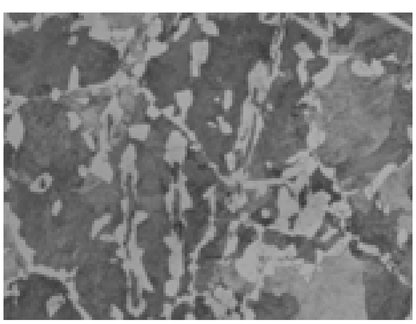

Figure 3.2 Same material as Figure 3.1, showing the etched microstructure with ferrite phase decoration on prior austentite grain boundaries and pearlitic microstructure in the grains

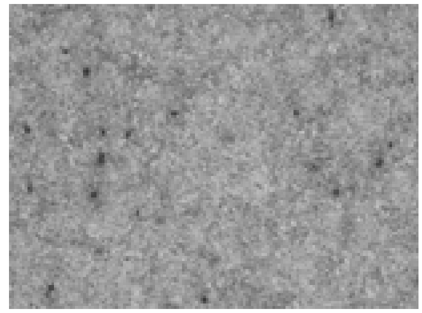

Figure 3.3 Induction hardened microstructure devoid of ferrite with a martensitic microstructure. The dark spots are inclusions observed in the alloy microstructure grinding

Hardness

Case hardening depth measurements were carried out to validate the induction hardening process on a fully automatic micro Vickers machine, VH3100 with Buehler DiaMet software, using 500gf (HV0.5) as shown below. Case depth at 500HV was noted at 3.34mm from the surface.

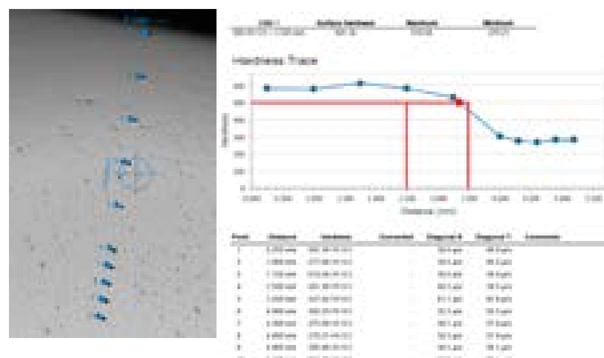

Figure 3.4 shows case hardening profile using DiaMet software with corresponding chart illustrating hardness values. The two red lines are the upper (3.5mm) and lower (2.5mm) tolerance limits where case depth at 500HV should lie

Summary

- Minimal depth of deformation observed after planar grinding was easily removed by coarse polishing
- Faster 3-step preparations (9μm/3μm) are achievable.
- For advanced microstructural analysis, a final finish using oxide polishing with either 0.05μm MasterPrep alumina, or 0.02-0.06μm MasterMet colloidal silica can be adopted.

References

1. Buehler® SumMet™ - The Sum Of Our Experience – A Guide to Materials Preparation & Analysis, © 2007. Buehler, a division of Illinois Tool Works Inc.

2. ASM International. Handbook Committee., ASM handbook. 10th editon. ed. 1990, Materials Park, Ohio: ASM International. Volumes

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