QUALITY ASPECTS OF SPECIAL FORGIN3S OF LOW ALLOY STEELS

S.Pandit
Deputy General Manager
Foundry Forge Plant
Heavy Engineering Corporation Ltd
Ranchi

1. IN'IRODUCI'ION

Within the span of last twenty years, the quality requirements of steel forgings has changed drastically. In early Seventies, 80-85% steel forgings belonged to mainly plain carbon steel grades and only about 10-15% forgings are of low alloy steel grades containing Ni, Cr, Mb and V. In the past, the customer asked for chemical composition, hardness, tensile and impact properties only. The ultrasonic test was not stipulated for the general engineering purpose forgings such as sugar mill shafts, roller etc. At present, 70% of steel forgings belong to low alloy steel grades like 40Ni2Cr1Mo28, 40NiCr1Mo15, En 24, 40 x HM, 38 x 2H2MA, En 30B etc. The quality requirements of these forgings specify rigid ultrasonic quality acceptance norm, Dye penetrant test, less gaseous content, low inclusion count and high impact property. The ultrasonic acceptance norm of critical forgings is 2-4 mm E.F.S (Max. allowable defect size) in D.G.S Scale.

Growing demand for quality forgings has warranted Foundry Forge Plant, HEC to update technology of steel melting, forging, heat-treatment etc and constantly strive for quality improvement through QC, QAP and R&D efforts. At present HEC **is** able to manufacture critical forgings for mining, shipping, cleience, railway, power, steel plants etc.

2. SlhEL-MAKING

Constantly playing an important role in the manufacture of special forgings, steel-making has made impressive strides. For meeting quality requirements, **FEC Ilas** adopted modern techniques of steel melting in EAF and preferably through EAF-Degassing or EAF-VAD routes. Yet sophisticated and heavy forgings requiring very low sulphur, oxygen, hydrogen and improved cleanliness made from steels through EAF-VAD-SD route.

The quality of steel is one of the most important factors which involves improved deoxidation, reduction of gases and non-metallic inclusions and sounder ingot making. Detrimental effect of inclusions to forging need not be emphasised. Steel-makers have to make cleaner steels to reduce inclusions so as to 'get no defect' in USQ test and superior mechanical properties.

Experience has shown that conventional deoxidation is not capable to meet such high standard of quality requirements. Author's industrial research has brought out optimum deoxidation with special techniques, using complex deoxidisers, sequence of removal of oxides. VCD reaction in vacuum-arc-deoxidation was resulted ultra cleanliness in rotor forgings. Besides composition, temperature and slag condition, the degree of deoxidation is controlled effectively by Fe0 content of slag and total oxygen content of steel. Composition of steel is rigidly controlled through Quantovac Analyser.

Various methods in the ingot making practice are being adopted such as usage of bottom pouring, exhothermic/insulating hot tops, floating ingot moulds etc. Throughout steel-making, a rigid temperature control is exercised by Immersion Thermocouples (ITC). Rate of teeming and hot transfer of ingots are monitored rigidly.

Though steel-making starts from scrap segregation and ends on hot transfer, deoxidation is the most impressive phase as removal of oxygen is directly connected to steel quality. Therefore process design or quality assurance plan has to take utmost care in deoxidation and reoxidation to get quality forgings.

The facilities available in SMS are as follow:

(a) Electric Arc Furnaces (EAF) -- 5 T, 10 T, 20 T, 30 T and 60 T capacity

(b) VAD Ladle Furnaces -- 10 T, 30 T, 40 T and 60 T

(c) Vacuum Degassing Unit -- 90 T, 30 T (Tank capacity)

(d) Ca-Si treatment

The steel ingots for special forgings are made through EAF-VAD route and mostly ingots are bottom poured. The floating type ingot moulds with lower H/D ratio are in use. Teeming and tapping temperature is taken during the ingot making in order to avoid ingotism etc. Gas analysis for H, 0 and N is carried out before hot transfer of ingots. Vacuumity less than 1.0 Torr at our VAD unit helps in achieving gas content of H = 2.0 ppm max and 0 = 30.0 ppm max normally.

Ca-Si treatment is done after slag off and normally during deoxidation. Ca-Si wire injection machine has been installed recently in our steel-making shop and it has been commissioned. Some trials have been also carried out. It is expected that Ca-Si wire injection will be helpful in controlling the morphology of inclusions and will be able to make ultraclean steel with improved transverse properties.

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One of the significant achievements of Melting Shop was in making of 100 tonnes ingot of 35Ni3Cr2Mo35V12 steel grade for 210 MW T.G rotor. By proper synchronising, HEC was axle 'to manufacture this 100 tonnes through EAF -VAD -SD route with S & P content less than 0.010% each. The 210 MW T.G rotor shaft forging had met all the physical, magnetic property, non-destructive testing, residual stress test, thermal stability and metallographic requirements (free from ferrite and lesser non-metallic inclusions).

3. FCRGIIC All) HEAT TREATMENT

In Forge & Heat-treatment Shop, MEC has got following facilities:

- Hydraulic Press: Capacity - 6000 T, 2650 T, 1650 T and 1000 T
- Pneumatic Hammer - 3 T Hammer
- Die Forging Hammer - 25 T Beche Hammer
- Electric Pit Furnace
- Bogie Furnace
- Horizontal Mist Quenching equipment
- Vertical Mist Quenching equipment
- Gas Cutting equipment
- Hot scarfing machine
- Tool Manipulator
- Spring-heded Swage Block
- Low Frequency Induction Hardening machine
- Medium Frequency Induction machine

Quality measures taken into the forging starts shop with the hot transfer of ingot (temperature 650°C min) to Forge Shop and charging into the reheating furnace to avoid cracking of ingot and thermal shock. The Ni -Cr -Mo bearing steel grade ingots are slowly heated to forging temperature (around 1200°C) in comparison to plain carbon steel to avoid thermal shock. Soaking at forgin6 temperature is given more for homogenisation. The reduction ratio is generally kept more than 3. Some time higher size ingots are being double upset to get good ultrasonic quality. Proper top and bottom discards are given to

eliminate harmful defects such as shrinkage, segregation and inclusions.

The black forging is subjected to precautionary heat-treatment just after forging. This includes normalising and tempering cycle to have better microstructure for quality heat-treatment. This also helps in getting better machiqability.

The ultrasonic in black condition is done to evaluate the quality of forging after grinding on two strips. The ultrasonic in black condition also eliminates the unnecessary machining of ultrasonically defective forgings.

The preheat-treatment of Ni-Cr-Mb steel is carried out to remove the technological allowance before heat-treatment, to remove the surface cracks so as to avoid development of cracks during heat-treatment and to achieve better mechanical properties by reducing the section to a min. level in view of the mass effect during heat-treatment and by removing black surface with scale which would lower the cooling rate during normalising or hardening.

The quality heat-treatment of Ni-Cr-Mo steel grade includes normalising, hardening and tempering, oil or water quenching is done. Rate of cooling after tempering is adjusted so as to avoid temper embrittlement and to have min. residual (oil/water quenching after tempering is done in order to have min. FATT value (Fracture Appearance Transition Temperature).

HEC **has** adopted some of new techniques in the production of forged rolls and forgings. Swage blocks have been used during the finishing stage of forged rolls. Use of swage blocks has almost eliminated the uneven surface forging and forging with close tolerance can be made with swage block.

Rejection of ingots on account of cracks has minimised with hot scarfing of ingot.

Ship-building shafts having length over 18.0 metre are quality heat-treated in electrically heated pit furnace for uniform micro-structure, mechanical properties and to have minimum warpage. These shafts were found ultrasonically sound and statically balanced. These shafts were trepanned throughout the length. These ship-building shafts have been made for the first time in the country and despatched after due inspection. Now HEC is in a position to undertake manufacture of propeller shafts for ship-building industries.

Walk shaft, rotate shaft, swing shaft etc of En 24 steel grade requiring high UTS of 850 N/mm^2 and high impact of 30 ft.lb. have been made successfully at FFP. These shaft forgings are critical forgings for walking dragline. Their performance at mines are comparable to that of imported ones.

Hot strip mill work rolls weighing 27.5 tonne piece weight are developed successfully at FFP. These rolls are made through EAF-VAD-VD route and double upsetting tech. of ingot is carried out to achieve the desired ultrasonic quality. These rolls are mist quenched and tempered to achieve the desired barrel hardness of 55' sh 'D' min. This is also a import substitute item.

Quality of CRS rolls and HRM rolls supplied to BSP, Bokaro are comparable Co imported ones. Some of the rolls have even exceeded the performance of imported ones.

Spindle, Coupling and Feed Rolls of Ni-Cr-Mo steel grade for steel plants have been developed successfully; Quality control measures right from reheating of ingots to quality heat-treatment is exercised to meet the service conditions.

4. **QUALITY** CONTROL, QAP **and R&D**

HEC has well equipped testing facilities and testing equipments to monitor the desired quality. Some of the testing equipments are listed below:

(a) Vacuum Spectrograph for quick determination of chemical composition.
(b) Atomic Absorption Spectrometer - For determination of trace elements like Sh, Sn and Non-ferrous analysis.
(c) Gas Analyser - H2, 02 and N2
(d) Ultrasonic Flaw Detector
(e) Magnetic particle testing machine
(f) Magnaglow testing equipment
(g) Radiographic Camera
(h) Boroscopic examination equipment
(i) Metallography

Needless to add that Quality Control measures at any stage of production is utmost essential and so rigidly exercised.

Simply testing and forwarding results are not enough. Technical services are rendered to manufacturing departments how to improve upon products at, hand. As for example, microstructure examination is carried out to suggest modified heat-treatment parameters. By ultrasonic test results are corelated with heat-treatment, anti-flaking cycle and inclusion content.

For special products, quality assurance plan is prepared so as not to miss any vital check points.

For process and product development, in-house R & D efforts are continuously directed towards excellence. This has resulted in developing import substitute products of casting and forgings.

5. CONICIIISION

Quality is fitness for use and not only meeting technical requirements -- such as chemical composition, physical property, ultrasonic acceptance norm.

Forging performance is not only what is available at purchase but it is expected to have similar performance throughout design life.

Therefore every organisation needs to have systematic quality control and continuous research and development suiting to their requirements. Then only can . the technological challenges posed by Igloblisation' **be met.**

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