Microstructure, Mechanical and Corrosion Behaviour of Indigenously Developed Carbide-free Nanostructured Bainitic Steel

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By

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CHAPTER 8

SUMMARY AND SUGGESTIONS FOR FUTURE WORK

8.1 SUMMARY

Austempering of specially designed steels at 250°C results in carbide-free nanostructured bainite along with filmy and blocky retained austenite. The patenting treatment of the steels at 550°C provides 100% fine pearlitic microstructure of varying inter-lamellar spacing.

Yield strength of nanostructured bainite increases with increasing bainite content but ultimate tensile strength is mainly controlled by SIM. In the case of austempered steel, the YS typically falls within the range of 878-1428 MPa, On the other hand, the UTS is in the range of 1554-1889 MPa. Chemically stable but mechanically unstable retained austenite undergoes strain-induced martensitic transformation that leads to high ductility because of high work hardening rate and delay in onset of necking. The investigated austempered steels demonstrate a total elongation ranging from 13.3% to 29.2%, indicating their capacity for significant deformation before fracture or failure. The product of strength and elongation for the investigated austempered steels falls within the range of 20.67 GPa% to 55.16 GPa%, highlighting their ability to combine strength and deformation resistance, indicating good toughness. Work hardening behaviour of the selected nanostructured bainitic steel matches usually with the Swift model of three stages of deformation mechanism with increasing strain. Bainitic-austenitic steel of selected composition fails by mixed mode of fracture but the ductile fracture predominates.

Fatigue life decreases with increasing strain amplitude. B15VA-2 steel demonstrated best fatigue life (11322 cycles) amongst the studied steel and cyclic hardening was observed at all the strain amplitudes for all the steels. XRD studies of fatigue tested samples revealed the formation of new phase, martensite. During cyclic loading, blocky retained austenite which is chemically stable but mechanically unstable, is transformed to martensite and contributed to cyclic hardening. The crack initiation takes place at the surface in all the fatigue tested samples. The fracture surface reveals striations, which are very fine and are visible on transgranular facets.

B15VA-1 and B15VA-2 samples reveal better Charpy impact energy of 15-18 J/cm^2. Charpy impact samples reveal typical quasicleavage fractographs, indicating a specific pattern of fracture morphology. The crack propagation predominantly occurred through interlath cracking, suggesting a specific mechanism of crack growth within the material.

The specific wear rate of the materials decreases with increase in applied normal load due to the formation of strain-induced martensite in bainitic pins, however, strain hardening effect was responsible for pearlitic steel. Worn surface morphologies at lower load (10 N) confirm the abrasive wear mechanism in all bainitic and pearlitic pins. As load increases from 10 N to 50 N the wear mechanism shifted from abrasive to adhesive along with abrasive in bainitic steels. In pearlitic steel (P15VA), the wear mechanism was similar to that of bainitic steels along with oxidative wear.

Electrochemical (EIS and potentiodynamic test) corrosion and immersion tests (30 days) confirm that a reduction in blocky austenite content with increasing austempering time, reduces Galvanic cell formation, resulting in a lessening of rate of corrosion due to formation of uniform, compact and non-porous passive layers. The uniform distribution of ferrite and cementite in pearlite of patented steels form micro-level galvanic couples and promote severe localized corrosion attacks due to the presence of stress in the corrosion layer. Therefore, corrosion resistance of bainitic steels B12VA-2, B14VA-2 and B15VA-2 is higher than that of respective pearlitic steels P12VA, P14VA and P15VA.

8.2 SUGGESTIONS FOR FUTURE WORK

- Strain level at which strain-induced martensitic transformation occurs, morphology and orientation relationship of SIM to retained austenite.
- Interrupted tensile test and characterization of SIM to resolve deformation mechanism of high carbon carbide-free nanostructured bainitic steel.
- High temperature fatigue test of carbide-free nanostructured bainitic steel.
- Dynamic fracture toughness of high carbon carbide-free nanostructured bainitic steel.
- Welding behaviour of high carbon carbide-free nanostructured bainitic steel.