High strength and toughness low carbon nanostructured bainitic steel and preparation method thereof

Strength of bainitic steels mainly arises from fine bainitic plates and adequate ductility is gained due to the presence of ductile phase austenite. A lower isothermal transformation temperature consumes more amount of austenite in addition to forming finer bainitic plates. However, the lowering of kinetics at lower temperatures as well as the possibility of formation of martensite creates a lower limit for the austempering temperatures at which bainite can be formed. The problem of martensite formation can be solved by choosing a steel with a higher carbon concentration since that will lower the martensitic start temperature (MS). However, the problem with these steels is the high transformation time (in days) and poor weldability (formation of cracks in conventionally welded joints) along with considerable loss in mechanical properties like ductility, impact and fracture toughness. Transformation time can be reduced with the addition of alloying elements like Al and Co. However, this significantly adds to the cost of the steel. Moreover, welding of these high carbon steels needs pre-heating and post welding heat treatment to regenerate the original microstructure circumventing the possibility of formation of cracks. Hence, despite having very high strength, high-carbon nanostructured bainitic steels do not meet many commercial/anticipated applications. There is a need for developing a low-carbon nanostructured bainite that can be produced in relatively small transformation times with strength similar to what has been achieved for high carbon nanostructured steel as well as possessing improved ductility and toughness.

Features of our invention:

• Our invention provides the composition and processing steps to make a low carbon carbide-free nanostructured bainitic steel having exceptional combination of strength, ductility, impact toughness and fracture toughness and a microstructure showing absence of detrimental blocky type retained austenite.
• The nanostructured steel is comparatively cost-effective for large production.
• The present invention produces a low carbon carbide-free nanostructured bainitic steel having strength above 1.2 GPa through multistep transformation.

• The transformation time is within 8 hours.

• Offers solutions for the problem of coalescence of bainitic plates that degrades the strength in low carbon steels transformed at low temperatures without compromising the strength of steel.

• The yield strength above 1.2 GPa and ultimate tensile strength above 1.5 GPa was achieved through multi-step bainitic transformation that formed 0.87 volume fraction of bainitic ferrite with almost 50% of bainitic laths below 100 nm, along with a ductility above 18 percent. The plane-strain fracture toughness is 82 MPam0.5 and impact energy is 31 J.