Microalloyed Steels
The Future of Steel Industry

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Though small yet significant for steel making, micro alloyed steel is a type of alloy steel that contains small amounts of alloying elements (0.05 to 0.15%), including niobium, vanadium, titanium, molybdenum, zirconium, boron, and rare-earth metals. They are used to refine the grain microstructure or facilitate precipitation hardening. These steels lie, in terms of performance and cost, between carbon steel and low alloy steel. Yield strength is between 500 and 750 MPa (73,000 and 109,000 psi) without heat treatment. Weldability is good, and can even be improved by reducing carbon content while maintaining strength. Fatigue life and wear resistance are superior to similar heat-treated steels. The disadvantages are that ductility and toughness are not as good as quenched and tempered (Q&T) steels. They must also be heated hot enough for all of the alloys to be in solution; after forming, the material must be quickly cooled to 540 to 600 °C (1,004 to 1,112 °F). In fact, cold-worked microalloyed steels do not require as much cold working to achieve the same strength as other carbon steel; this also leads to greater ductility. Hot-worked microalloyed steels can be used from the air-cooled state. If controlled cooling is used, the material can produce mechanical properties similar to Q&T steels. The microalloying elements are used along with other strengtheners and their use is accompanied by strict control of impurities such as sulphur, oxygen, nitrogen and phosphorus. Strengthening by microalloying dramatically reduces the carbon content which greatly improves weldability and notch toughness. The single most important microstructural feature of hot-rolled microalloyed steels is ferrite grain size, which lead to both improved strength and notch toughness. A grain size of ASTM 10 (10µ) or finer is the basic building block of these steels which allows the use of other strengthening mechanisms such as solid solution and precipitation hardening all of which lead to a reduction in notch toughness. Micro-alloyed steels, have small additions (< 0.1%) of alloying elements to low carbon steels (0.03%-0.15%C and up to 1.5%Mn) to achieve high yield and tensile strengths.

Microalloyed Steels in India

The demand for Indian steel is likely to grow at a rate of 7 percent on an average in the near future. This growth is also reflected in the large demand of HSLA steel mainly due to rise in automotive output, boom in the domestic construction industry and increase in offshore facilities. However, the automotive sector is the major consumer of HSLA steel in India and it would continue to do so in the years to come. Keeping this in view, Indian steel manufacturers are making considerable growth in this field. Various grades of EDD & IF grades of steel have been developed and successfully produced commercially. Owing to its higher strength-to-weight ratio and excellent formability, opportunities to increase the amount of steel required in vehicles has been explored taking the safety and mileage criteria in view. HSLA steels are being manufactured commercially in public and private sector companies in India including Steel Authority of India Ltd. (SAIL), Tata Steel, Essar Steel, Jindal Steel, Ispat Industries Ltd. (IIL), etc.

They have launched a major programme on high strength steel research. Research and development efforts are directed towards various aspects of production of HSLA steels including steelmaking, casting, hot rolling and cold rolling. SAIL have started the development of micro-alloyed steel in its R&D centre way back in seventies. Initially R&D work started to develop high tensile plates and they ended up with the commercial production of these plates by the name MA-300HI, MA-350HI, MA-410HI, SAILMA450HI, etc. SAIL also developed and commercialised various categories of quality line-pipe steels to be used for onshore uses.

Further to this, various other grades of steel such as weather-resistant steel, high strength cold rolled sheet mainly for automobile sector, etc have also been commercially developed in the recent years. SAIL have developed BSK-46 and SAPH-45 auto grade steels for wheel rims and discs for heavy vehicles.

In one of their plant, SAIL have successfully developed E-38 & E-34 grade micro-alloyed steel, which are being used in the manufacturing of the long and cross chassis members, reinforcement flanges etc. Extensive research is being carried out for the development of various grades of HSLA steel in Tata Steel for nearly a decade in their R&D. Some of the new development in processing techniques has already been incorporated in their plant and development of new grades of HSLA steel by varying their composition and processing route to meet the market demand for cost and properties is under R&D stage.

However, some of the new grades are also being produced commercially. Tata Steel has worked jointly with Nippon Steel, Japan and Arcelor, Europe for technical developments of auto grade steel, keeping in view the needs of the Indian automotive steel market. Over years, Tata Steel has developed and commercially produced different grades of HSLA steels. Another steel producer Essar Steel has made major advancement in development and commercial production of micro-alloyed steel. Recently they have undertaken the development work to produce BSK-46 steel in thickness range from 3-7 mm in their hot strip mill.

Apart from this, the joint R&D efforts of Essar Steel and Wheels India, India's largest steel wheel manufacturer, have borne fruit with the development of HSLA steel to meet the requirement of wheels for new generation cars. Essar Steel have also associated themselves with General Motors and Delphi Automotive Systems Ltd. to supply their newly developed hot rolled dual phase steel coils for automotive applications. The development of various grades of HSLA steel is also undertaken by other steel manufacturers, keeping in view the future demand of HSLA steel in various sectors.

Microalloy and Regular Alloy Steels

Microalloy steel is manufactured like any other, but the chemical ingredients added at the initial melt of the steel to make it a microalloy include elements like vanadium, columbium, titanium, and higher amounts of manganese and perhaps molybdenum or nickel. Vanadium, columbium, niobium and titanium are also grain refiners and aggressive oxygen scavengers, so these steels tend to also have a very fine austenitic grain size. In forgings, microalloy steels are able to develop higher mechanical properties (yield strengths greater than say 60,000 psi) and higher toughness as forged by just cooling in air or with a light mist water spray.

By contrast, normal alloy steels require a full austenitize, quench and temper heat treatment to develop properties greater than as rolled or cold worked. Since microalloyed steels are able to get higher properties using forging process heat- rather than an additional heating quenching tempering cycle- they can be less expensive to process to get improved mechanical properties.

The developed microstructure ultimately makes the difference. The microstructure developed in the steel depends on the grade and type. Normal alloy steels require a transformation to martensite that is then tempered in order to achieve higher properties.

Apart from that, microalloy steel precipitates out various nitirides or carbides and may result in either a very fine ferrite-pearlite microstructure or may transform tobainite. If the steel is already at its hardest condition, the microalloyed microstructure of either ferrite pearlite or bainite is less abrasive than that of a fully quench and tempered alloy steel.

Affect of Microalloy Element

Micro alloying elements such as strontium and titanium have been used in the melt and their effects on the morphology of intermetallic compound and their growth rate have been investigated by the immersion experiments at the temperature of 680 °C for the time of 0.5–2.5 h.

Results showed that two layers of Al8Fe2Si and Al5FeSi formed at the interface and Al12Fe5Si layer was not observed. Nitride coating decreased the overall thickness of the intermetallic layer about 50% after immersion time of 0.5 h. Addition of microalloying elements such as Sr (0.05 wt%) and Ti (0.2 wt%) to the melt decreased the total thickness of the intermetallic layer about 31% after immersion of steel for 0.5 h in the melt. Both nitride coating and addition of strontium (0.05 wt%) and titanium (0.2 wt%) micro alloying elements to the melt had the most influence on decreasing the overall thickness of the intermetallic layer. The thickness of the intermetallic layer decreased about 60% after immersion of steel for 2.5 h in the aluminium melt. The experimental results clearly indicate the beneficial effect of strontium on the kinetics of the formation and growth of the intermetallic layers. In fact, microalloyed steel is, often referred to as High-Strength Low-Alloy Steels (HSLA) to which application has been expanded to almost all fields viz. ship building, line pipe, building construction, bridges, storage tanks, pressure vessels, high strength fasteners, suspension springs to name a few, after its initial application in the automobile industry.

Owing to its high strength to weight ratio, excellent toughness and formability, demand for HSLA steel is increasing globally. In India, the boom in automobile sector, construction industry and various offshore facilities promises a huge potential for HSLA steel applications. This paper discusses processing routes and applications along with the present scenario and future prospects of HSLA steel in India.

To meet the growing demand for steels with structural integrity and high quality levels in terms of strength and toughness, intense research have been carried out for development of HSLA steels in recent years. The development of HSLA steels - their alloy design, processing and application covers the last four decades.

During this period, micro-alloyed or HSLA steels became an indispensable class for structural applications. Their ability to achieve final engineering properties in hot-rolled conditions eliminated the need for heat treatment.

Development of HSLA steels was based on the idea of increasing strength by microalloying with Group VI elements, which readily form carbides. Dual advantages were drawn by way of grain refinement and precipitation strengthening. The crux of the technique has been the balancing of microalloying elements viz. Nb, V and Ti and imparting suitable thermo-mechanical controlled processing.

However, the influence of Nb, V and Ti in each strengthening mechanism as well as their overall effect is not the same. Further addition of elements such as Cr, Ni and Mo increases hardenability of hot austenite during slab soaking prior to rolling. These elements being rather expensive, Boron doping to ppm level has been found quite effective to achieve identical effect.

Processing of HSLA steels

Steel making and continuous casting Hot metal, after pretreatment is refined in an oxygen blowing converter. Then the molten steel is treated using a vacuum degasser to achieve lower carbon content. The decarburizing step is followed by an addition of microalloying elements, with the aim of formation of carbides of microalloying elements for precipitation hardening. The steel produced by mini mills for thin slab casting is made mainly in EAF, using scrap as charge material.

In several instances, a thin slab caster associated with an integrated steel plant will be relying on steel from BOF shop. Of the various residual elements, inherited from scrap, several can be tolerated and used as alloy addition. The high residual nitrogen content of EAF steel is being used to advantage in HSLA slabs by promoting the formation of micro-alloyed nitrides, rather than carbides for precipitation. Molten steel that has had its chemical composition thus adjusted is continuously cast into slabs, which in turn, passes through subsequent processes such as hot rolling, cold rolling and turned into final product.

The vertical mould continuous caster, in which the mould and support rolls are arranged vertically, is used for better quality because it promotes the separation (by flotation) of non-metallic inclusions poured into the mould. The

mini/midi thick slab solidifies at a faster rate than the conventional thick slab. For example, a 50 mm thick slab solidifies within 1.5 minutes compared to 15 minutes for conventional slab of 190-230 mm thickness

[2]. This has a positive effect on formation of inclusions, they are small and globular. Bending and impact properties are both in the rolling direction and transverse to it. The occurrence of transverse cracks caused by loss in ductility on cooling is avoided by bending of the slab at a temperature above the ductility trough. The main purpose of HSLA steel processing is to produce fine and homogenous ferrite grains as well as high volume fraction of carbide/nitride precipitate during or after austenite-ferrite transformation. This process results in superior mechanical properties such as high strength, toughness, good ductility and weldability.

Prospects of HSLA Steel

It is said that the twenty-first century will be a century concerned with the global environment. In recent years, many discussions have been made on a worldwide scale about global warming, protection of the global environment, and life cycle assessment (LCA) as urgent and important subjects. From the standpoint of the global environment, social needs for energy saving, higher safety, and longer life will become increasingly stronger in future. It is, therefore, expected that the properties, which can meet these needs, will be required for steel.

The future market demands for HSLA steel will be higher strength to contribute to weight reduction; higher toughness to ensure safety from earthquakes, fires, and other incidents; higher reliability to prolong life against fatigue behaviour and corrosion; higher weldability to realise high heat input weldability, higher workability to realise economical fabrication.