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Hot-Rolled Steel Coil for High Strength Heavy Wall Spiral Linepipe

1. Introduction

As the distance between gas production site and consuming regions has increased in recent years, there is an orientation toward high pressure transportation in pipelines for transportation of natural gas, crude oil, etc. with the aim of reducing transportation costs. Heavy wall and high strength linepipes are essential for achieving high pressure transportation, and high toughness is also necessary to prevent large-scale disasters[1).

In order to improve the toughness of steel as evaluated by Drop Weight Tear Test (DWTT) and Charpy impact test, austenite grain refinement was attempted during hot rolling[2)] by using controlled rolling (CR), in which rolling is performed in the austenite non-recrystallization temperature region. JFE Steel developed high toughness hot-rolled steel coils of X70 grade for spiral linepipes with thicknesses up to 20 mm by applying the optimum controlled rolling based on the relationship between the controlled rolling reduction ratio (CR ratio) in the non-recrystallized austenite region and the ductile brittle transition temperature (vTrs). To meet the demand for heavier wall products, the company introduced a coiler for heavy gauge hot-rolled coils in the Hot Strip Mill at East Japan Works (Keihin District) in 2013[3)] and developed heavy gauge hot-rolled steel coils with thicknesses exceeding 20 mm.

This report introduces the concept and features of these high strength heavy gauge hot-rolled steel coils.

2. Concept of High Strength Heavy Gauge Material

2.1 Target Properties

In order to satisfy the property requirements for steel pipes, it is necessary to improve the performance of the hot-rolled steel coils used as the material for pipe-making. The development targets for this hot-rolled steel coil were set at thickness > 20 mm, X70 grade (TS ≧ 570 MPa) and satisfying the specification of −20˚C or less as the toughness of the base metal and welds, that is, 85% SATT (Shear area transition temperature) of the base metal in DWTT ≦ −20˚C and ductile brittle transition temperature (vTrs) of the weld HAZ (Heat affected zone) in Charpy impact test ≦ −20˚C.

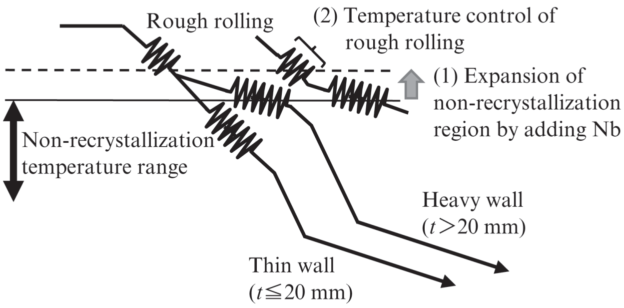

Fig. 1 Approach for achieving higher CR ratio

2.2 Concept

As shown in **Fig. 1**, the CR ratio of heavy gauge hot-rolled steel strip in the finish rolling process decreases due to the slowed cooling rate of the center of strip thickness, and as a result, the toughness of the product decreases. Therefore, the following approach was adopted from both the directions of chemical composition and the manufacturing process in order to improve the toughness of heavy gauge hot-rolled steel coils.

(1) Because Nb has a higher austenite recrystallization suppression effect than Al, Ti and V[4)], a higher CR ratio was achieved by expanding the austenite non-recrystallization region by adding Nb.
(2) In addition to adding Nb, a high CR ratio was achieved in the total hot-rolling process by appropriately controlling the temperature and reduction ratio not only in the finish rolling process but also in the rough rolling process.
(3) To avoid a decrease in weld HAZ toughness due to Nb addition, chemical composition design to hold the weld crack sensitivity composition P_{CM} (parameter crack measurement) at low level was introduced by using Cu, Ni, Cr, Mo, etc., thereby improving the HAZ toughness of this high Nb steel.

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Table 1 Chemical compositions of developed steel

Chemical compositions (mass%)						P_{CM}
C	Si	Mn	Nb	Ti	Others	
0.05	0.35	1.53	0.08	0.02	Cu, Ni Cr, Mo	0.18

P_{CM}=C+Si/30+Mn/20+Cu/20+Ni/60+Cr/20+Mo/15+V/10+5B

Table 2 Mechanical properties of developed steel

Thickness (mm)	YS (MPa)	TS (MPa)	YR (%)	DWTT 85%SATT (˚C)
22.7	603	668	90.3	−30

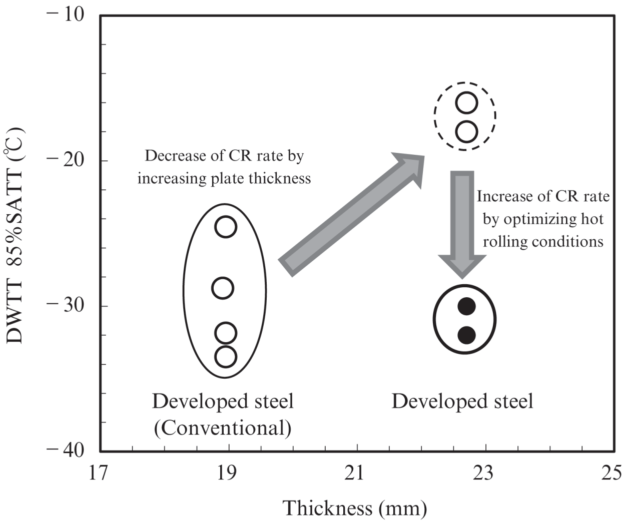

Fig. 2 Relationship between thickness and DWTT toughness

3. Properties of Developed Steel

3.1 Base Metal Performance of Developed Steel

The chemical composition and mechanical properties of the developed steel are shown in **Table 1** and **2**, respectively. The thickness-toughness property balance is shown in **Fig. 2**. The target strength and base metal toughness were obtained, even in heavy gauge material with a thickness of 22.7 mm, by achieving a high CR ratio by Nb addition and precise control of the hot-rolling pass schedule, including rough and finish rolling.

Table 3 Toughness of welded joint of developed steel

Position	Heat input (kJ/cm)	Cooling rate (˚C/s)	HAZ toughness, vTrs (˚C)
Inner side	45	5.2	−35
Outer side	49	4.4	−30

3.2 Welded Joint Performance of Developed Steel

The welded joint performance of the developed steel is shown in **Table 3**. With the developed steel, satisfactory HAZ toughness (vTrs) of −20˚C or less was obtained at both the inner and outer surfaces, showing that the developed steel provides sufficient welding performance, even as a high Nb steel.

4. Conclusion

JFE Steel has established a system which is capable of responding to a wide range of customer requirements by building bases for the production of steel pipes and steel materials for pipes at its East Japan Works, West Japan Works and Chita Works. Utilizing this system, in 2016, the company received orders and supplied a total of 78 000 tons of hot-rolled steel coils, steel plates and UOE pipes as materials for a pipeline with a length of approximately 878 km, which will transport natural gas produced in the Caspian Sea from the border between Turkey and Greece to Italy[5]. In the future as well, JFE Steel will produce and market linepipes suited to the needs of its customers, making full use of its ability to respond to a wide range of products.

References

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3) Primetals Technologies. Product Catalog “Hot Strip Mill”. p. 22.
4) Tsukada K. 104th and 105th Nishiyama Memorial Seminar. ISIJ, Tokyo. 1985, p. 59.
5) JFE News Release, July 8, 2016. JFE to Supply 78,000 Metric Tons of Steel Products to Unincorporated Consortium of MISI and CPW for TAP Project.

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