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Recent Activities in Research of Tubular Products

Takaaki Toyooka

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The new manufacturing processes for seamless steel pipe and REW steel pipe have been developed. The manufacturing concept of the developed steel pipe and its characteristics are summarized as follows. (1)Hight efficient manufacturing technologies for high alloy steel seamless tube and pipe have been established by Mannesmann rolling process. (2)New martensitic stainless steel seamless pipes with superior corrosion resistance have been developed. (3)New ERW forming mill for stainless steel pipes with excellent formability habe been developed. (4)High quality ERW pipe products have been produced by manufacturing technology for medium diameter ERW linepipe and square steel pipe.

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1 Introduction

Steel pipes are used for various products in industries such as automobile frame members, materials for civil engineering and construction, linepipe, oil country tubular goods (OCTG) and chemical plants, therefore, the development of the technologies required for steady and low cost production of various high quality steel pipe products suitable to respective applications have been greatly anticipated.

Among the various research that have been carried out by the steel pipe division of Kawakaki Steel over these ten years with the above described background in mind, this paper describes the development of high productivity manufacturing technologies for stainless steel seamless pipes by the Mannesmann rolling process, commercialization of various kinds of martensite stainless steel seamless pipes, development of forming mills for production of ERW (electric resistance welded) stainless steel pipes for automobile exhaust gas systems and development of manufacturing technologies for medium diameter ERW linepipes and square columns.

2 Summary of the Trends in Seamless Pipe Technology

The large trends in seamless steel pipe technology in the last ten years may be roughly classified into (1) improvement of high alloy steel rolling technology and (2) upgrade and enhancement of value-added products.

With respect to the development of high alloy steel rolling technology, the important subjects in technological development were the establishment of optimization technology rolling conditions and the development of lubrication technology for rolling high alloy steel. By solving these problems, we have established a mass production system for high quality high alloy steel which had been difficult to produce by the conventional Mannesmann process.

In relation to upgrading and enhancing value-added products, we developed a new 13Cr steel pipe applicable to high-temperature high-carbon dioxide environments to which high alloy steels or duplex stainless steel had conventionally been used. Furthermore, we developed weldable 12Cr seamless steel pipe for linepipes and have started actually using these pipes in some areas.

2.1 Seamless Steel Pipe Production Processes

In the field of seamless steel pipe rolling, over these last ten years we have been concentrating on research establishing high alloy steel seamless pipe manufacturing technologies. In the Mannesmann process, a round billet, after being heated, is pierced using a Mannesmann type piercing mill and then rolled to a predetermined size using rolling mills for drawing and for reducing the diameter.

Our newly developed technology related to the rolling of high alloy steel seamless pipes is explained hereun-

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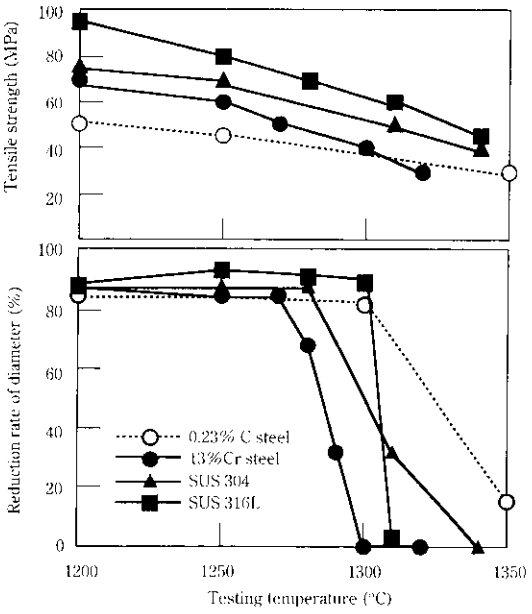
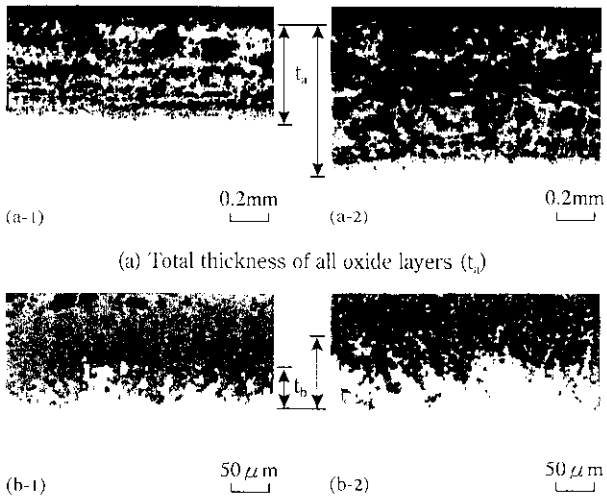


Fig. 1 Influence of testing temperature on reduction rate of diameter and tensile strength (on heating Gleeble test)



(a-1), (b-1): Conventional plug (0.3%C-0.35%Si-0.5%Mn-3.0%Cr-1.0%Ni)
(a-2), (b-2): Developed plug (0.3%C-0.35%Si-0.5%Mn-0.5%Cr-1.0%Ni-1.0%Mo-2.0%W-0.5%Nb-1.0%Co)

Photo 1 Effect of chemical composition of plug material on surface oxidation

der. First of all, we investigated the deformability of high alloy steel as shown in **Fig.1** and then carried out temperature simulation using a heat transfer analysis model. Based on the results of these studies, we developed a method to control the billet temperature by controlling the billet heating temperature and piercing strain velocity. Furthermore, we also developed a piercing mill setting optimization method for piercing high alloy steel billets.[1] With these methods being developed, it has become possible to control the generation of various defects such as scratches on inner and outer surfaces, sticking at the leading and tail ends of billets.

However, when a high alloy steel billet is pierced and rolled by a Mannesmann type piercing mill, the guide shoes, rolls and plugs of the piercing mill wear excessively and as a result, scratches are apt to be generated on the inner and outer surfaces of the pipe.[2] Therefore, we clarified the wear mechanisms of each part through laboratory experiments and developed the following countermeasures.[3]

(1) Development of driving roller type guide shoe[4]
(2) Development of a boric acid type lubricant for preventing scoring of disc type guide shoes
(3) Development of silicon carbide scattering type of slip prevention fluid for rolls of piercing mills
(4) Development of new composition plugs and optimization of the heat treatment time for improving the exfoliation character of surface oxidized film (**Photo 1**)

Furthermore, for drawing and rolling by mandrel mills, the items which we developed for high alloy steel rolling technology include the MAP system,[5] bulge width meter,[6] lubricated rolling method and the introduction of high speed tool steel rolls.

2.2 Seamless Steel Pipe Products

Development of seamless steel pipe products is linked mostly to the growth of the petroleum industry and there are many new products related to OCTG and linepipes for sour environments with hydrogen sulfide or for sweet environments with carbon dioxide.

In sour environments, SSC caused by hydrogen embrittlement is a major problem particularly for high strength materials. Therefore, by using precipitation hardening, we developed high strength sour resistant OCTG of the 110 ksi grade (KO110SS), and have started commercial production of these pipes.

In sweet environments, on the other hand, the use of 13Cr steel pipes is rapidly increasing, however, problems had existed with the corrosion resistance in high temperature and high carbon dioxide environments and SSC resistance in hydrogen sulfide environments. Therefore, we investigated various measures to solve these problems and found that increasing the effective contents of Cr and Ni decreased general corrosion and adding Mo improved the SSC resistance. Accordingly, we developed HP 13Cr steel pipe of a low C-13Cr-Ni-Mo type.[7] As shown in **Fig. 2**, this steel pipe can be used in higher temperature higher carbon dioxide environments at temperatures higher than 13Cr steel pipes can withstand.

Unlike OCTG, linepipes are required superior weldability, therefore, carbon steel or duplex stainless steel

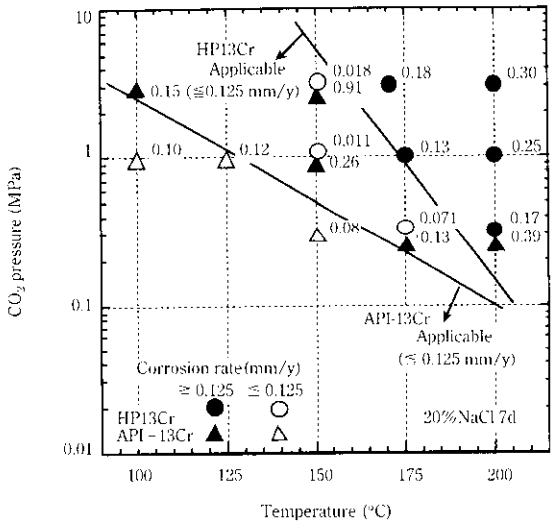


Fig. 2 CO_2 corrosion test results of HP13Cr and API-13Cr pipes

having superior weldability had been being used for linepipes.

Under such circumstances, we developed two types of new martensite stainless steel pipe (weldable 12Cr steel pipe) with superior weldability.[8] The first type is 11Cr steel pipe (KL-12CR) for sweet environments with carbon dioxide and the other 12Cr steel pipe (KL-HP12CR) for environments containing a small amount of hydrogen sulfide. Both types have reduced C and N contents for improved weldability and also various requirements for corrosion resistance, mechanical properties and hot workability are satisfied by adding Ni, Cu, Mo, etc. These newly developed steel pipes have already used in the North Sea and other areas.

3 Trends in Welded Steel Pipe Technology

In recent years, ERW steel pipe application areas have expanded to the fields of UOE steel pipes and seamless steel pipes as a result of upgraded and improved quality as well as reduced production costs and the fields of application have been diversified.

With such circumstances as the background, the major technology trends in the last ten years can be seen in the following three areas:

(1) Improved productivity
(2) Upgraded and improved quality
(3) Expansion of application to the fields of automobiles and construction materials

In relation to improved productivity, new technology was developed to be able to commonly use a forming roll for different sizes of ERW steel pipes. At the same time, a method has been developed to reduce the number of mother pipe sizes in the upstream process and to produce various pipes having different outer diameters using three-roll type of reducer in the down stream process.

In order to meet the requirements for improved quality of welded portion and upgraded products, laser welding with a high energy density heat source is being practically used in place of conventional high frequency welding. The environments where linepipes are used are getting severer and cost reduction has been required. In order to respond to the requirements for improved quality and enhanced strength of linepipes under such trends, effort is being made to improve the welding quality, to develop heat treatment processes and shielding technologies for welded portion of ERW steel pipes. Various materials superior in compound properties including high strength, high toughness and high corrosion resistance are also under development.

Expansion of the usage of ERW tube and pipe in recent years is noticeable particularly with steel tubes used for automobiles and construction materials. Steel tubes for automobile use are required to be of higher strength and lighter weight and steel tubes for door reinforcement and those for driving axles have been developed. Furthermore, as for steel pipes for exhaust systems, various kinds of stainless steel pipes fit for respective parts have been developed from the standpoints of rising temperature of exhaust gas and improving corrosion resistance.

As for steel pipes for construction use, application of cold formed square steel pipes has been expanded to use them as columns for medium- and low-rise buildings. In order to meet such requirements, new construction and extension of facilities were made by each manufacturer.

3.1 ERW Steel Pipe Processes

For production of ERW steel pipes, Kawasaki Steel originally developed the CBR (chance-free bulge roll) forming mill.[9] The CBR forming process is a new forming method which makes it possible to simultaneously attain high productivity and high quality for small lot production. With the CBR forming mill, waterless non-lubricated pipe forming was actualized for the first time as a high speed mill (pipe forming speed: 100 m/min) using bulge roll forming flowers of an original design as shown in **Fig. 3**. Furthermore, stabilization of electric resistance welding was achieved with this mill by using I-shape butt welding at band edges compatible with enlargement of V-shape convergence angle. By designing the mill to have the cage roll and center bend roll combined together, we have achieved extensive combined use of upstream forming rolls and at the same time, the producible range of thin pipes was extended to 0.6 mm in thickness by making the mill highly accurate.

The CBR forming mill has been used to produce ERW stainless steel pipes in the small diameter ERW pipe plant of the Chita Works and we have achieved a large improvement in the yield ratio as well as in productivity compared with conventional processes. The new mill has made it also possible to produce ERW

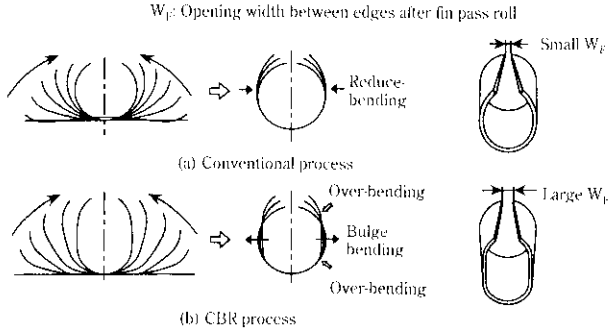


Fig. 3 Comparison of the forming flowers between conventional forming process and CBR forming process

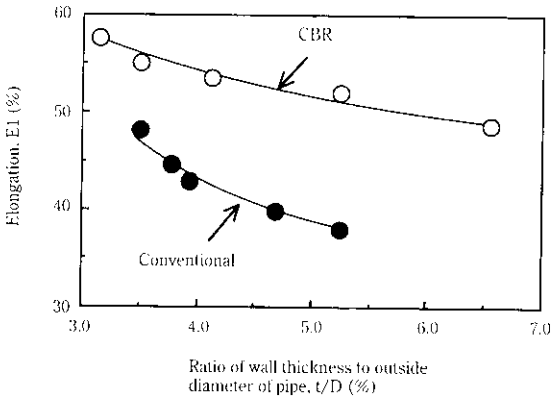


Fig. 4 Comparison of elongation of ERW stainless steel exhaust pipe by tensile test between CBR and conventional forming (SUH409L)

stainless steel pipes for automobile exhaust gas systems having excellent welding quality. These pipes are also superior in fabrication performance with high elongation properties as shown in **Fig. 4**.[9-11] Furthermore, the CBR forming process is gradually being introduced into steel mills in Japan and abroad as a licensed technology and has been gaining a high evaluation.

In relation to steel pipes for construction use, we have converted the No. 2 medium diameter ERW steel pipe mill of the Chita Works to the production of square steel pipes and we are now capable of producing pipes having 550 mm of outside diameter and 22 mm in thickness, which are the largest sized cold roll formed square steel pipes. With respect to these square steel pipes, we have carried out basic research on various matters including clarification of deformation behavior when forming square steel pipes by four rolls[12] and the mechanism of generating deformation at cut ends.[13] The results of the research are making a contribution to production of dimensionally very accurate square steel pipes.

3.2 ERW Steel Pipe Products

Conventionally, ERW steel pipes had never been used

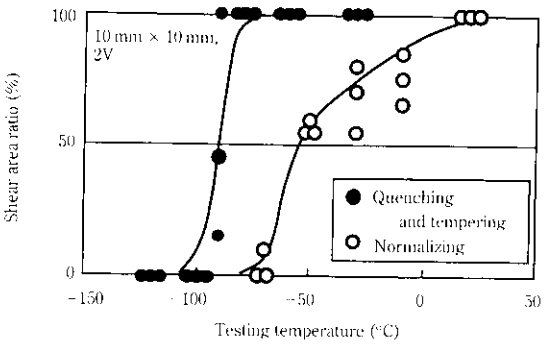


Fig. 5 Charpy impact property of weld seam

for offshore pipelines and only used for pipelines on land. Recent pipelines are required to have high strength of API X65 grade, high toughness and high sour resistance. As a measure to meet such requirements, we aimed at establishing heat treatment technology. As shown in **Fig. 5**, low temperature toughness can be remarkably improved by applying QT treatment at welded portion. Taking the opportunity of the welding quality having been extensively improved by establishing QT technology for electric resistance welded parts, we tackled development of ERW steel pipes for offshore pipelines.

In order to fully satisfy the required strength, toughness and corrosion resistance, we studies the matter from the chemical composition and of raw material rolling conditions and succeeded in developing mother materials which satisfy the required characteristics by finding a new composition with reduced carbon content and by optimizing the hot rolling condition.[14,15] Furthermore, by developing a new pipe production method which reduces defects in seam welded portion, we were able to successfully develop ERW linepipe having high strength, high toughness and high corrosion resistance. This newly developed steel pipe has already been produced commercially. These pipe were used in the North Sea as the world's first offshore pipelines and received high evaluation also from the oil majors.

4 Conclusion

Among the various types of steel pipes, with seamless steel pipes, in particular, Kawasaki Steel aimed at maintaining profitability of production by establishing its policy toward selection of kinds and grades with high alloy steel pipes as the main and by developing technologies for mass production of these products as a countermeasure against the relatively decreasing demand due to the worldwide surplus. In the domestic market, on the other hand, competition among manufacturers was intensified in the field of general use steel and we have been working to reduce cost and to upgrade steel products.

We expect that the demand for cost reduction will get stronger than ever before coupled with an intensification

of competition in the future. As a research laboratory in the field of steel pipe and tube, we aim at developing differentiation technologies and products and foster stronger competition by advancing technological development together with our colleagues in the business and production divisions.

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