High Performance Tube and Pipe Contributing to Preservation of the Global Environment*



Hiroaki Kawasaki
General Manager,
Zinc Plate Dept.,
Kawatetsu Tubic Corp.
(Former General Manager, Tubular Products Business Planning Dept.)

Takaaki Toyooka
Dr. Eng.,
General Manager,
Tubular Products & Casting Lab,
Technical Res. Labs.

Mitsuo Kimura
Senior Reseacher,
Tubular Products & Casting Lab,
Technical Res. Labs.

Synopsis:

High strength and corrosion resistance steel pipe and tubes contribute to the production and the transportation of natural gas which is recognized as clean energy. High strength and high formability steel pipe and tubes can reduce the weight of automobile parts to save energy consumption. High Cr bearing steel pipe is used under wet CO_2 environment without using any inhibitor that causes environmental pollution. HP13Cr steel pipe can be used under wet CO_2 and slight H_2S environment. For line pipe usage, 12Cr steel that can be welded without preheat and post heat treatment was developed. HISTORY tube with ultra fine microstructure which has the high strength, high formability and uniformity of seam hardness has been developed by the thermo-mechanical controlled processing (TMCP) in the newly developed warm reducing. HISTORY tube can contribute to save energy by reducing the weight of automobile parts and eliminating heat treatment before tube fabrications.

1 Introduction

Steel tube and pipe are used in diverse applications which take advantage of the essential functions of the pipe as such, including applications in which fluids flow inside the pipe, applications in which energy is transferred between the inside and outside of the tube, and applications in which the pipe is used as a strengthening member to reduce weight by adopting a hollow design. Steel tube and pipe are also used in various industrial fields where their functions as a steel material meet the need for high strength and high formability.

As main applications, oil country tubular goods (OCTG), line pipe, boiler tubes, automotive structural tubes, and structural pipes for civil engineering and construction applications may be mentioned. Among these, energy related fields are a main demand sector, and there is a strong need for the development of products which make a large contribution to preservation of the global environment. For these reasons, Kawasaki Steel has promoted development in this area since an early date.

For the energy industry, the company has developed OCTG, premium connections for OCTG, and line pipe which support the development of clean natural gas, and has also developed high corrosion resistant pipe and high sealability premium connections to eliminate the need for inhibitors, which carry a risk of environmental pollution. Moreover, it is considered that increasing development of natural gas as a form of clean energy in the future will further increase the need for high corrosion resistant pipe and high sealability premium connections.

In the field of automotive structural tubes, there is a high need for energy saving, weight reduction, and improved recyclability for environmental improvement, and for increased crashworthiness for safety. Consequently, high strength materials, hollow parts, and stainless steel have progressively been adopted, requiring the development of steel tubes which combine high strength and formability. In order to satisfy these mutually contradictory requirements, Kawasaki Steel developed manufacturing processes which create new material properties, and developed steel tube and pipe which can be produced by those processes.

This report presents an overview of tube and pipe products which contribute to preservation of the global environment, and in particular, introduces high corrosion resistant pipes and the HISTORY tube, which were

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* Originally published in *Kawasaki Steel Giho*, **32**(2000)3, 222–229

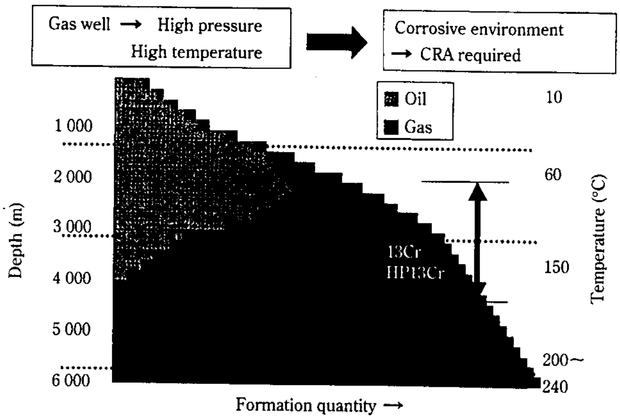

Fig. 1 Well depth, temperature vs. oil and gas formation

recently developed by Kawasaki Steel.

2 Research and Development of Steel Tube and Pipe

2.1 OCTG

By 1990, Kawasaki Steel had developed high strength OCTG, corrosion resistant OCTG, and other products which were offered in a line of special standard OCTG as the KO series. The company had also developed the FOX threaded joint as a premium connection for use in gas fields.

Figure 1 shows the relationship between the amount of petroleum and gas formation and the depth and temperature of wells. In the last 10 years, the development of clean natural gas fields has become active, and the newly developed fields have been characterized by increasingly greater depths, higher pressures, and severer corrosion conditions. Because natural gas is more plentiful in marine areas than on land, there has also been increasing development offshore, where strict standards are required for environmental protection.

On the other hand, in pursuit of economy, horizontal drilling and enhanced recovery are increasing with the aim of reducing extraction costs and increasing the recovery ratio. Due to these trends, the performance required in OCTG has become even higher. **Figure 2** shows the relationship between performance requirements and the products developed by Kawasaki Steel.

In the last 10 years, Kawasaki Steel has developed high strength OCTG for sour service and high corrosion resistant 13Cr steel pipe, and high strength OCTG for sour service, has also developed products which provide sour resistance 110 ksi (758 MPa) yield strength. As a 13Cr steel, the HP (high par) 13Cr series with added Mo and Ni was developed as 13Cr pipes for CO_2 gas environments which contain a slight amount of H_2S. The company also developed materials suitable for insulated tubes for use in special applications, and screen pipe,

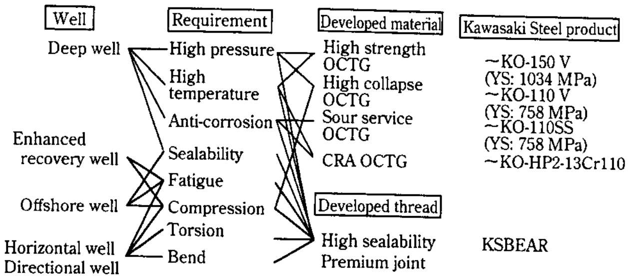

Fig. 2 Well conditions and developed products

which is used in the oil extraction part of oil wells.

OCTG are connected with threaded joints and then lowered several thousand meters to the oil bearing stratum. In horizontal drilling, the pipe may be driven to a distance of 10 km in some cases. Therefore, the requirements placed on the threaded joint which connects the pipes have become even higher, heightening the need for a special joint with performance equal to that of the mother pipe. Kawasaki Steel therefore developed a special threaded joint, the KSBEAR connection, which is capable of satisfying these requirements. In addition to having performance equal to that of the mother pipe, this joint also offers excellent performance in make-and-break test using an environment friendly dope that does not contain heavy metals, showing no galling even when the joint is made up and broken down more than 10 times. This joint enables higher productivity in make-up work than the conventional type, including work in the field.

2.2 Tube and Pipe

2.2.1 Line pipe

The first use of large diameter welded pipes for natural gas transportation was around 1945 in the United States. Thereafter, pipe lines for gas transportation were constructed in Europe in the 1960s, and subsequently, pipe line construction also became active in the former Soviet Union. In the future, construction is planned in areas which do not yet have pipe line networks, including China and other parts of Asia.

Figure 3 shows the trend in the requirements for line pipe.[1] Among the performance features which are required in line pipe, the requirements of high strength and corrosion resistance are becoming increasingly high.

Although X65 and X70 are the main grades of line pipe, a trend toward the general adoption of X70 for sour service and X80 for non-sour service is expected in the future. Performance requirements are moving in the direction of greater strictness due to new standards such as the DNV rule, ISO, and others. In particular, the clarification of the required values for the fracture toughness of materials, which will become an index of crack initiation and propagation characteristics, has become an important task for promoting high pressure and high

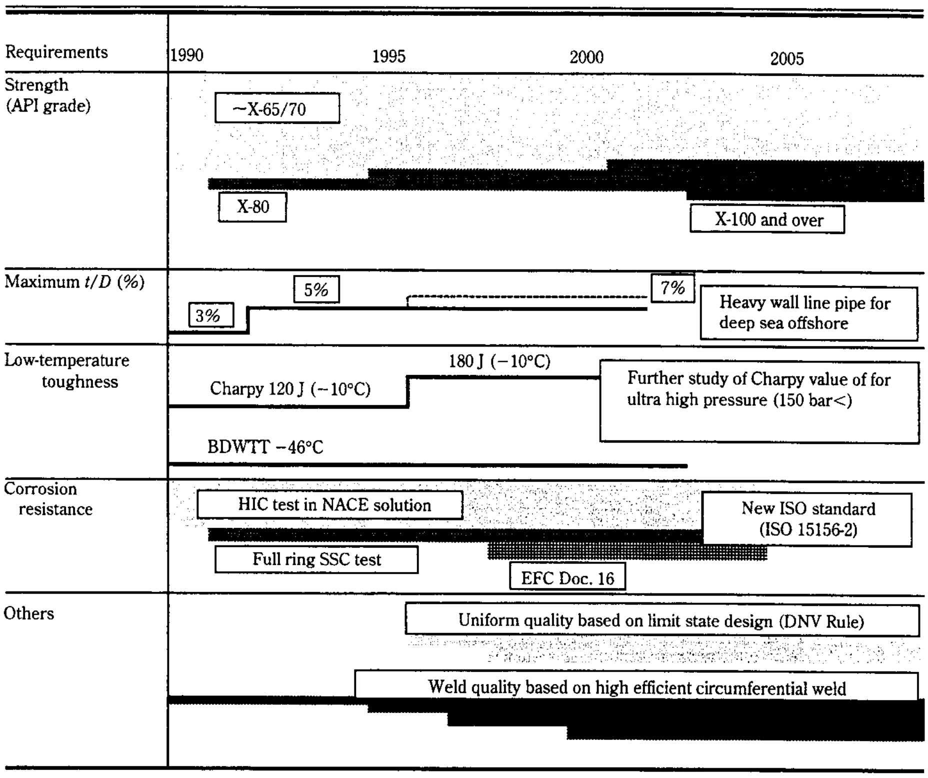

Fig. 3 Trends of requirements for line pipe

strength in pipe line design in the future. The HLP Committee of the Pipe Department of the Iron and Steel Institute of Japan has taken up this task and is promoting activities aimed at standardization.

Line pipes are broadly classified into gathering lines, flow lines, and trunk lines, corresponding to their applications. Gathering lines and flow lines are used in pipes which carry untreated crude oil or gas from the well head. Because the crude oil or gas is untreated, when corrosive gases were present, corrosion resistance was secured up to the present time by using inhibitors, which are a cause of environmental pollution. However, from the viewpoint of environmental preservation in recent years, Kawasaki Steel developed corrosion resistant martensitic stainless pipes. In these products, corrosion resistance which renders inhibitors unnecessary is imparted to the steel pipe itself, and girth welding is also possible. At president, the company has added three grades of corrosion resistant martensitic stainless pipes suitable for corrosion environments to its product line.

In offshore trunk lines, the trend has been toward large diameters and thicker walled pipes, rather than higher strength, due to the problem of stress during pipe laying, and improvement of the toughness of thick walled pipes became a task for research and development.

In contrast, in onland line pipes, large diameter steel pipes with thinner walls have progressively been adopted, which was made possible by high strength materials, and X80 is now used in practical applications. Study of research and development which will bring into view the development of high strength X100-X120 grade has also become necessary. In realizing these higher strength levels, in addition to the problems of the weldability and weld toughness of the pipe, research which includes welding methods is also becoming necessary.

2.2.2 Ordinary piping

In gas and water piping, the changeover to plastic pipe, stainless flexible pipe, and other types has proceeded in recent years. For coated steel pipes used in fire extinguishing systems and water works, a recycling system which considers the environment was established. Looking to the future, research on the use of coated steel pipes with primary treatment, without further processing, is being promoted by industry.

Stainless flexible pipe is superior in ease of work and preservation of the site environment because it is lightweight and clean. Kawasaki Steel has developed joint standards with gas companies and constructed a stainless flexible pipe plant at its Chita Works. Kawasaki Steel was the first company in the steel industry to carry out integrated production from the manufacture of the base material to the manufacture and shipment of stainless flexible pipe. This product has earned a high level of customer confidence, and production is steadily increasing.

2.2.3 Automotive structural tubes

In the automotive industry, CO_2 reduction, exhaust gas purification, and resource saving have become main tasks from the viewpoint of global environmental problems, and improved fuel economy and weight reduction are therefore advocated. For this reason, steel tubes as well as high strength, thin walled products have progressively been adopted in the steel materials used. Steel tube consumption per automobile has increased in recent years to more than 30 kg, and is continuing to rise at this level.

As performance requirements, high strength, high formability tube which can compensate for the deterioration in formability resulting from high strength have come to be emphasized. Kawasaki Steel independently developed the CBR process[2,3] as a tube-making process that further minimizes the work hardening of the material during tube-making and developed ferritic stainless steel tubes with excellent formability and corrosion resistance.

In recent years, in order to respond to the need for high strength combined with high formability, Kawasaki Steel has developed the HISTORY tube, which possesses a ultra-fine microstructure,[4] and is constructing a new manufacturing line which is scheduled to start up in fall of 2000.

2.2.4 Boiler tubes

With boiler tubes, achieving high efficiency has become a task from the viewpoint of global environmental problems, and higher temperatures and higher pressures are being adopted[5] (**Fig. 4**). Kawasaki Steel developed a 2.25Cr tube with high strength and excellent weldability, and a 9Cr tube, taking advantage of the company's strength in Cr stainless steel manufacturing technology.

Recently, because thin walled tubes are also being adopted in superheater tubes and reheater tubes, high strength materials with excellent weldability, such as ASME Case 2100 T23, have been used. In the future, it is considered that use of this type of material will expand in furnace wall tubes in cases where high pressure is adopted, and the range of applications will become wider.

Kawasaki Steel has increased dimensional accuracy by improving its manufacturing technology for seamless tubes. The resulting product, Super Hot Tube (this company's name for high dimensional accuracy hot finished seamless pipe) has begun to be adopted in applications in which cold finished seamless pipe had conventionally been used. With the recent deregulation of the Japanese power industry, IPP (independent power producers) have begun to supply wholesale electric power, heightening the demand for steel tubes with high cost performance and good dimensional accuracy even in conventional materials, and further increasing the need for Super Hot

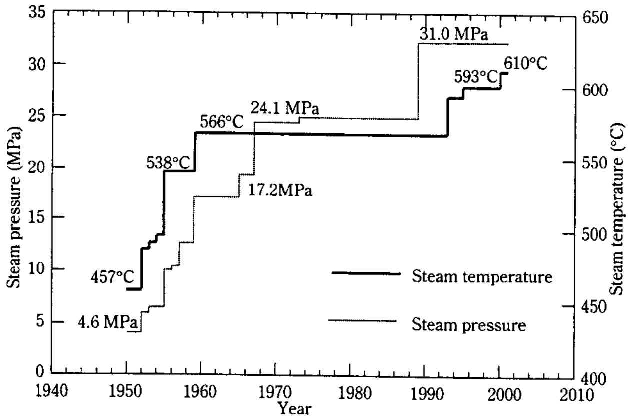

Fig. 4 Transition of steam conditions in Japanese power plant

Tube and electric resistance welded (ERW) steel tubes.

In ERW tubes for use in boilers, countermeasures to prevent grooving corrosion of the weld seam are required. Therefore, it was necessary to reduce the S content of the material, and further, to apply heat treatment to the tubes. However, because the manufacturing process of the HISTORY tube developed by Kawasaki Steel does not produce enriched S, which is the cause of grooving corrosion, due to the nature of the manufacturing method itself, this new product shows excellent properties in the field of boiler tubes as a grooving corrosion free tube.

Recently, in order to make effective use of waste as an energy resource, attention has been focused on the waste incinerator power generating boiler. Progressively higher temperatures have been adopted in the waste incinerator power generating boiler from the viewpoint of improved power generating efficiency, increasing the need for high anti-corrosion tubes with excellent cost performance in superheater tubes.

3 Development of High Corrosion Resistant Cr Pipes

Recently developed oil and gas fields are frequently in locations with severe environmental conditions, and in not a few cases, large quantities of corrosive gases such as CO_2 and H_2S are present. In this kind of environment, severe corrosion occurs with the low alloy steels which have often been used in the past, and in some cases, the corrosion rate reaches a maximum of several tens of mm/y.[6,7] For this reason, inhibitors are used as an corrosion resistant countermeasure in many cases.[8] However, there were problems with the inhibitors used in the petroleum and natural gas development environment, which are a cause of red tide and give rise to pollution in oceans and lakes if leaked.

In response to these problems, there is a movement, especially in Europe, to limit the use of inhibitors. In

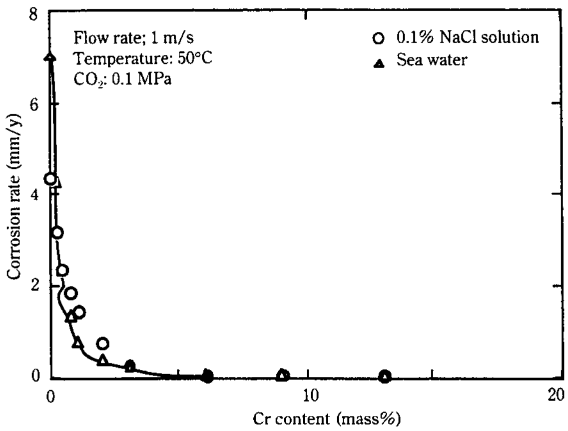

Fig. 5 Effect of Cr content on corrosion rate of steel

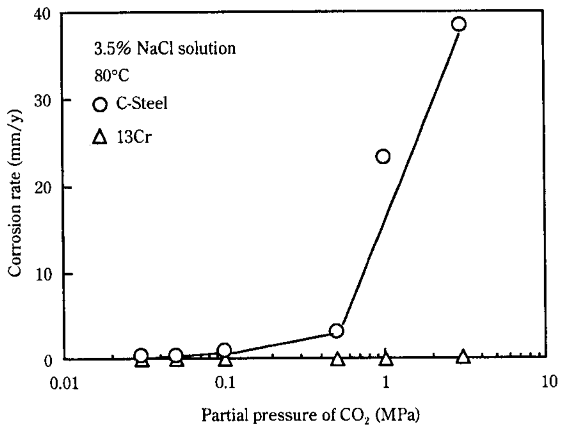

Fig. 6 CO_2 corrosion test result

particular, in order to prevent pollution in fjords in fields in the North Sea oil fields, discontinuation of the use of inhibitors by adopting steel pipes with high corrosion resistance is being studied.

To meet these requirements, Kawasaki Steel developed high Cr OCTG and line pipes with high corrosion resistance for use in the development of fields with severe corrosion environments containing CO_2 and H_2S.

3.1 Development of High Cr OCTG

It is known that steel shows an extremely high corrosion rate in wet CO_2 environments. Cr is an effective element for improving corrosion resistance in such environments. **Figure 5** shows the effect of the Cr content on the corrosion rate.[9] The corrosion rate is reduced by the addition of Cr. As a pipe which offers excellent corrosion resistance in wet CO_2 environments and is also capable of providing the strength necessary in an OCTG, 13%Cr martensitic stainless steel pipe (13Cr pipe) has been applied practically as an OCTG. The results of a corrosion test of this 13Cr pipe and an ordinary carbon steel pipe are shown in **Fig. 6**. In comparison with the carbon steel pipe, the 13Cr pipe shows a large decrease in the corrosion rate, making it possible to use this pipe even without an inhibitor. Since development, demand for 13Cr pipe has increased rapidly, particularly for environments which contain CO_2, based on the outstanding corrosion resistance of this product.

Table 1 Chemical composition of 13Cr and HP13Cr

(mass%)

	C	Si	Mn	Cr	Ni	Mo
13Cr	0.20	0.20	0.40	13	0.1	—
HP13Cr-1	0.025	0.25	0.45	13	4.0	1.0
HP13Cr-2	0.025	0.25	0.45	13	5.0	2.0

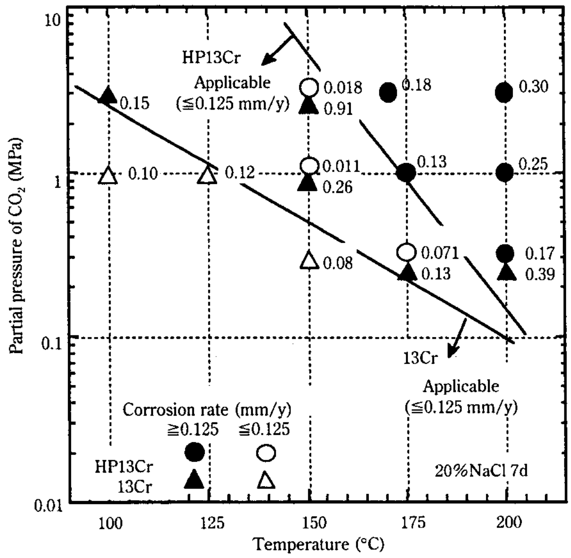

Fig. 7 CO_2 corrosion map

Although the 13Cr pipe shows excellent corrosion resistance in wet CO_2 environments at temperatures of up to 100°C, its corrosion resistance deteriorates and the corrosion rate tends to become excessive in high CO_2 environments. Furthermore, in environments where H_2S is present, susceptibility to sulfide stress cracking (SSC) is a problem. Recently, therefore, the HP13Cr pipe was developed as an oil field tube which can be used in severer environments.[10, 11] The chemical composition of the newly developed steel is shown in **Table 1**, together with that of the 13Cr pipe. In the HP13Cr-1 pipe, corrosion resistance has been improved by adopting a low C composition with added Ni and Mo. Further, in the HP13Cr-2 pipe, SSC resistance was also improved by increasing the Mo content, thus expanding the applicable range in sour environments. **Figure 7** shows the effect of the temperature and partial pressure of CO_2 on the corrosion rates of 13Cr pipe and HP13Cr-1 in high temperature, high CO_2 environments. The 13Cr pipe can be used at a partial pressure of CO_2 of 2.5 MPa or less under a condition of 100°C, and 0.5 MPa or less under a condition

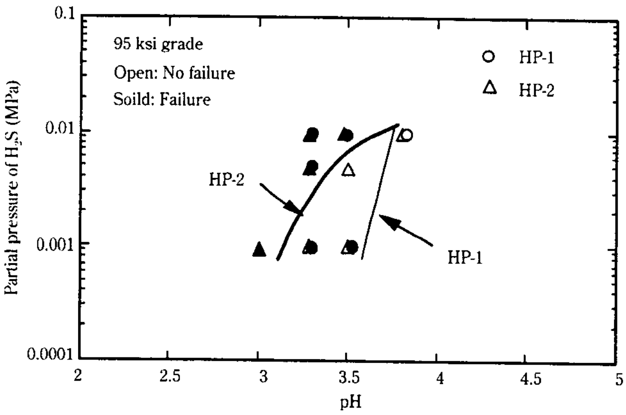

Fig. 8 SSC test results for HP13Cr pipe

of 150°C. In contrast, the HP13Cr pipe can be used even under the severer conditions of a partial pressure of CO_2 of 5 MPa at 150°C.

An example of the results of an SSC test of HP13Cr-1 and 2 is shown in **Fig. 8**. The HP-2 pipe can be used at a higher partial pressure of H_2S and lower pH than HP-1 due to the increased content of Mo in the former pipe.

As described above, 13Cr pipe and HP13Cr pipe can be used without an inhibitor even in severe environments which contain CO_2 or H_2S.

3.2 Development of Weldable 12Cr Line Pipe

Because steel pipes for use as line pipes are joined by welding, unlike OCTG, which are joined by a threaded connection, weldability in the field is important in line pipes. The 13Cr pipe, which is used as an OCTG, has poor weldability and therefore has not been used. Conventionally, either a low alloy steel or a duplex stainless steel had been adopted as the material for line pipe. However, because low alloy steel is inferior in corrosion resistance, it was necessary either to use an inhibitor or to perform dehydration and degassing treatment when a strongly corrosive gas was passed through the pipe. On the other hand, duplex stainless steels are excellent in weldability and corrosion resistance, but due to their high cost, their use is restricted to limited fields based on economic considerations. Therefore, two types of martensitic stainless steel line pipe were developed by improving the weldability of 13Cr OCTG.[12)]

The features of these pipes are as follows:

(1) Weldability: Weldable without preheating or post welding heat treatment (PWHT)
(2) CO_2 Corrosion Resistance: Equal to or better than 13Cr for OCTG
(3) Low Temperature Toughness: Charpy energy of 100 J or higher (at −40°C) in both the base metal and welded joint
(4) Strength: Yield stress of 482 MPa (70 ksi) or higher

Further, the material must also possess the hot workability necessary for seamless rolling. To meet these requirements, a weldable 12Cr pipe was developed. Weldability was secured by reducing the contents of C and N, and the contents of Ni, Mo, Cu, and other elements were controlled from the viewpoint of low temperature toughness, corrosion resistance, and hot workability. The chemical composition of the developed steel is shown in **Table 2**. 11Cr pipe is a product which was developed for use in sweet environments containing only CO_2, and is mainly suitable for gas transportation from fields developed using 13Cr OCTG. In contrast, 12Cr pipe was developed for use in higher temperature, higher CO_2 environments or environments which contain a slight amount of H_2S, and is suitable for the transportation of gas from fields developed using the HP13Cr OCTG.

Table 2 Chemical composition of weldable 12Cr (mass%)

	C	Si	Mn	Cr	Ni	Cu	Mo
11Cr	0.01	0.2	1.2	11	2.5	0.5	—
12Cr	0.01	0.2	0.4	12	5.0	—	2.0

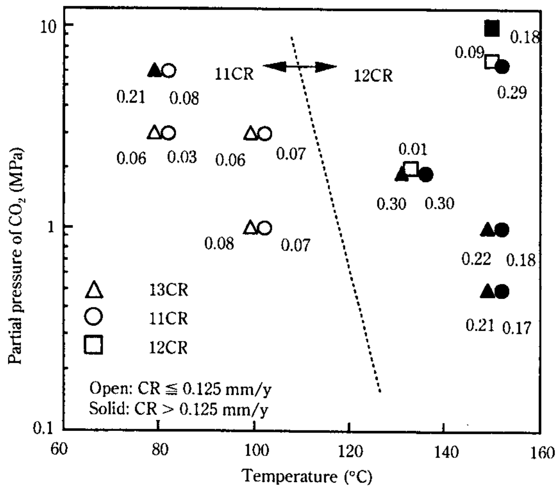

Fig. 9 CO_2 corrosion map for weldable 12Cr pipe

Figure 9 shows the results of a CO_2 corrosion test of the weldable 12Cr pipe. When the applicable corrosion rate is 0.127 mm/y (5 mils/y), the applicable range of the 11Cr pipe is 120°C or under, whereas the 12Cr pipe can be applied even at 150°C. Further, because the 12Cr pipe contains Mo, it also possesses SSC resistance and, as shown in **Fig. 10**, can be used in sour environments with a partial pressure of H_2S of 0.004 MPa or under in environments with pH: 4.0 or higher. Application of weldable 12Cr to pipe lines has already begun, mainly in the North Sea.

3.3 Summary

13Cr pipe was developed as an OCTG for wet CO_2 environments. HP13Cr pipe was developed as an OCTG

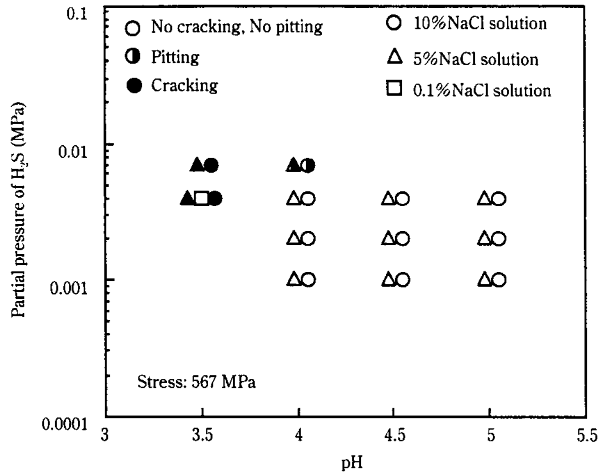

Fig. 10 SSC test result for welded joint of 12Cr steel pipe

for high temperature, high CO_2 environments and light sour environments. Weldable 12Cr pipe, which can be welded and has excellent corrosion resistance, was developed for use in transporting oil and gas extracted using these OCTG. The development of high Cr OCTG and line pipe made it possible to develop energy resources in offshore oil fields, severe corrosion environments, and other difficult environments. Because it is not necessary to use inhibitors, these products are also effective in preventing marine pollution.

4 Development of the HISTORY Tube

4.1 Features of the HISTORY Tube

Figure 11 shows the manufacturing process of the HISTORY (high speed tube welding and optimum reducing technology) tube. After the steel strip is formed into an open pipe in the cold or warm condition using the CBR (chance free bulge roll) forming mill developed by Kawasaki Steel,[2,3] the edges are joined by electric resistance welding. With the CBR mill, forming and welding of thin walled tubes can be performed stably. Next, the ERW tube is heated and reduced by a stretch reducer. On-line termomechanical control process in a newly developed stretch reducer makes it possible to manufacture the HISTORY tube, which has excellent

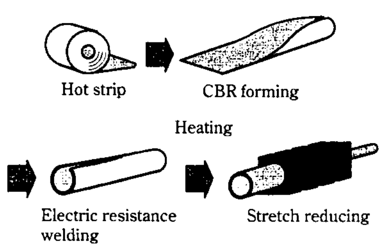

Fig. 11 Manufacturing process of HISTORY tubes

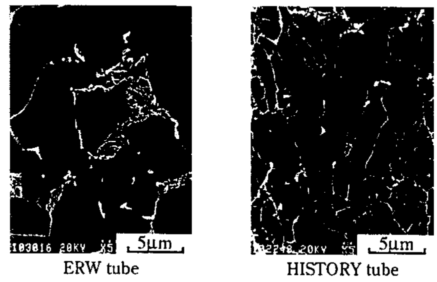

Photo 1 SEM images of HISTORY and ERW tubes

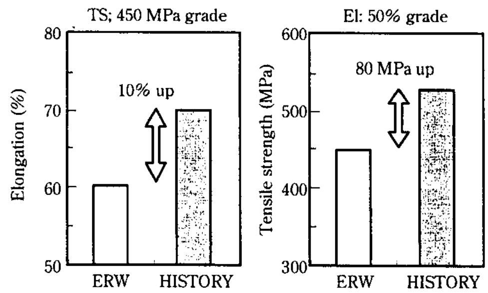

Fig. 12 Mechanical properties of HISTORY and ERW tubes (Steel: 0.1%C-0.8%Mn, Test piece: JIS11, 42.7 mmϕ × 2.3 mmt)

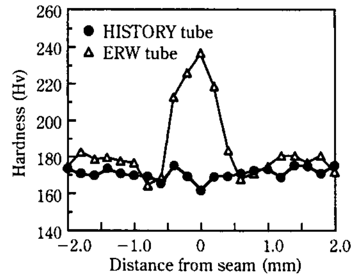

Fig. 13 Hardness distribution of welded portion (Steel: 0.1%C-0.8%Mn)

forming performance and high strength in comparison with conventional ERW tubes.

Photo 1 shows the microstructure of the HISTORY tube and an ERW tube.[4,13] Because high diameter reduction rolling in the warm region is used in manufacturing the HISTORY tube, the ferrite grains are refined and cementite is finely spheroidized. As a result, it is possible to obtain high strength and high elongation in comparison with ERW tubes, as shown in **Fig. 12.**[14] The HISTORY tube is the first steel tube in the world to realize an ultra-fine microstructure in industrial scale tube production.

Figure 13 shows the hardness of the area around the seam in the HISTORY tube and a conventional ERW tube. The seam of the ERW tube has a quenched structure as a result of electric resistance welding, and there-

Table 3 Mechanical properties of tested tubes (JIS11, 15 mmϕ × 1.8 mmt)

	YS (MPa)	TS (MPa)	El (%)
HISTORY tube	530	575	32
ERW tube	480	509	18

Table 4 Mechanical properties of tested tubes (JIS11, 38.1 mmϕ × 2.0 mmt)

	YS (MPa)	TS (MPa)	El (%)
HISTORY tube	519	556	47
ERW tube	360	404	41

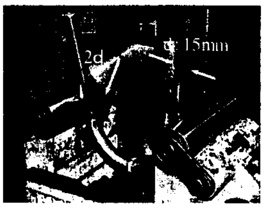

Photo 2 Appearance of three-point bending test

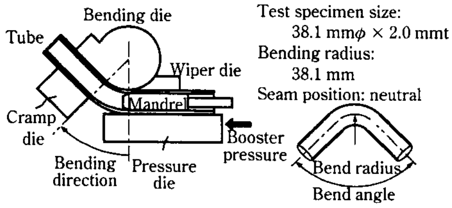

Fig. 14 Procedure of stretch bending test

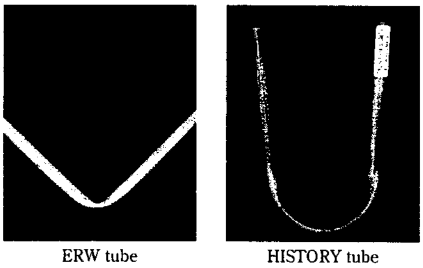

Photo 3 Appearance of bent tubes compared with HISTORY tube and ERW tube

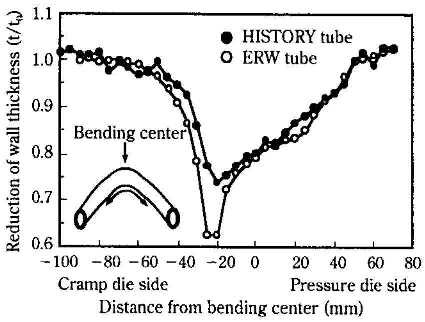

Fig. 15 Variation of wall-thickness of HISTORY and ERW tubes

fore shows marked hardening and is inferior in workability. In contrast, at the seam of the HISTORY tube, the quenched structure is decomposed into the same ferrite and carbides as the base material by the warm reducing process, and the hardness of the seam is on the same level as the base material.

Thus, with the HISTORY tube, the seam has the same good formability as the base material without annealing and normalizing.

4.2 Properties and Examples of Applications of the HISTORY Tube

4.2.1 Automotive structural parts

In automotive structural members, high strength is required in order to reduce weight. Moreover, to reduce costs, omission of heat treatment processes such as quenching and tempering by using high strength material is being studied. On the other hand, as automobile bodies have become more compact, the shape of parts has tended to become even more complex, and the need for high formability, namely, small radius bending, has also increased.

Because on-line thermo-mechanical control process is applied to the HISTORY tube, it is capable of satisfying the mutually contradictory requirements of high strength, high formability, and low cost, and can therefore meet the above-mentioned needs. Here, the bending property and fatigue strength of the HISTORY tube will be described.

(1) Three-Point Bending Property

A three-point bending test at a bending radius of 30 mm was carried out using specimens with an outer diameter of 15 mm and the mechanical properties shown in **Table 3**. The appearance of the actual test is shown in **Photo 2**.

Photo 3 shows a comparison of the bending property of the HISTORY tube and an ERW tube. In contrast to the ERW tube, which buckled before 180° bending was completed, buckling did not occur with the HISTORY tube, and bending to 180° was possible.

(2) Stretch Bending Property

A stretch bending test at a bending radius of 38.1 mm was performed with specimens with an outer diameter of 38.1 mm and the mechanical properties shown in **Table 4**. The test procedure is shown schematically in **Fig. 14**. Bending was performed while applying booster pressure with a pressure die.

Figure 15 shows a comparison of the wall thickness reduction with the HISTORY tube and an ERW tube.

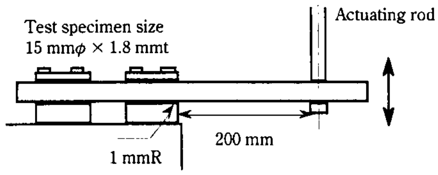

Fig. 16 Procedure of bending fatigue test

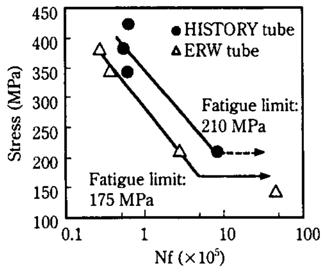

Fig. 17 S-N diagram by bending fatigue test

In spite of the fact that the tensile strength of the HISTORY tube is approximately 38% higher than that of the ERW tube, its wall thickness reduction ratio was approximately 10% smaller than that of the ERW tube. This is considered to correspond to the fact that the HISTORY tube has good elongation.

(3) Fatigue Strength

Figure 16 shows the procedure used in the bending fatigue test. The test specimen was the same as that used in the three-point bending test described above.

Figure 17 shows the S-N diagram of the fatigue test. The high strength realized in the HISTORY tube improved the fatigue limit of this tube by approximately 20% in comparison with the conventional ERW tube.

It is considered that automobile parts, for example, stabilizers, can be manufactured at a lower cost using the HISTORY tube because high formability and high fatigue strength can be obtained without heat treatment.

4.2.2 Impact absorbing parts for automobiles

In impact beams and other impact absorbing parts of automobiles, steel tubes with a tensile strength of 1 200~1 500 MPa, which were treated by quenching and tempering, had conventionally been used. In recent years, the use of ERW tubes without heat treatment has been studied in order to reduce costs.[15] However, the work hardening and residual stress of such high strength ERW tubes are large, making it extremely difficult to obtain an adequate impact absorbed energy.

The HISTORY tube, which is manufactured by online thermo-mechanical control process can solve these problems of ERW tubes.

Figure 18 shows a comparison of the absorbed energy of the HISTORY tube and ERW tube. When compared using tubes of the same strength, the absorbed energy of

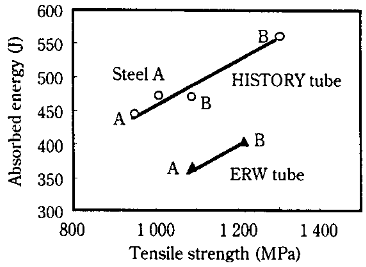

Fig. 18 Comparison of absorbed energy obtained by three point bending test between the HISTORY tube and ERW tube

the HISTORY tube is approximately 25% larger than that of the ERW tube.

It is considered possible to lighten the weight and reduce the manufacturing cost of impact beams by using the HISTORY tube, which is capable of absorbing a large amount of energy without heat treatments such as quenching and tempering.

4.3 Summary

The HISTORY tube is manufactured using a new thermo-mechanical control process technology called warm high diameter reduction rolling, giving this product a number of outstanding features, as shown below.

(1) With the HISTORY tube, the hardness of the area around the seam is uniform with that of the base material.

(2) The HISTORY tube offers both high strength and high ductility. High strength is realized by refinement of the microstructure, and high ductility is achieved by suppression of work hardening and ultra-fine dispersion of the second phase.

(3) The HISTORY tube has a 20% higher fatigue limit than comparable ERW tubes.

(4) The HISTORY tube has excellent bending properties.

(5) The ultra-high strength HISTORY tube has a 25% or higher bending absorbed energy than ERW tubes with the same tensile strength.

5 Conclusion

Recent research and development in the field of steel tube and pipe products have been described in outline, focusing on high performance products which contribute to preservation of the global environment. In recent years, advanced use of natural energy has become increasingly important for global environmental preservation. Among fields which will attract attention for the use of natural energy, there are still many which can contribute to global environmental preservation by utilizing the functions of steel tube and pipe, including use in the resource and energy fields of solar power generation, wind power generation, geothermal power generation, marine temperature-differential power generation, deep strata water extraction, and use with methane hydrate. Reducing the weight of materials by realizing higher strength and further improving high temperature strength, adopting stainless steel, etc. is also an important field. The policy of the tube and pipe making division of Kawasaki Steel is to maintain a tube and pipe manufacturing technology development capability and product development capability which lead the world, and to consistently develop and manufacture products which meet the needs of the times.

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