New Products & Technologies

# High Formability Stainless Steel Pipe for Automotive Exhaust Systems*

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## 1 Introduction

In recent years, the environmental pollution problem has led to new demands being made on automobile exhaust systems. These include higher exhaust gas temperatures, alkalinization of cold condensates, increased use of snow-melting salt, extended antirusting guarantees and this has resulted in a greater use of stainless steel rather than conventional carbon steel and aluminized steel. These factors have resulted in the use of stainless steel pipe in exhaust systems, and the search for low-cost stainless steel suitable for high temperature conditions had led to the development of ferritic stainless steel pipe.

This report introduces R409L[1] ferritic stainless steel pipe, designed for an application temperature of 800°C or below and which has excellent creep characteristics, corrosion resistance and formability.

## 2 Manufacturing Process in Electric Resistant Welding

The manufacturing process for stainless steel for exhaust systems is shown in **Fig. 1**. Various manufacturing processes after the coil receiving inspection are carried out at Kawasaki Steel's Chita Works, a factory exclusively producing steel pipe.

The seam welding (ERW) of stainless steel has the following differences from the electric resistant welding of carbon steel:

(1) Stainless steel contains a large amount of Cr which is liable to combine with oxygen in the atmosphere and generates Cr based oxides with high melting points, thereby causing defective welds.
(2) Since stainless steel has a high electrical resistivity, the current necessary for melting the V-shaped edge is smaller. Consequently the electromagnetic force needed to discharge the molten steel is also smaller, thereby increasing the risk of a welding defect.

In view of these differences, Kawasaki Steel pays careful attention to the following points when manufacturing pipe by the ERW process:

(1) Application of Inert Gas Shield Welding
To suppress the formation of Cr oxides during melting, the gas-shield welding method is adopted in which welding is carried out while the weld-joint

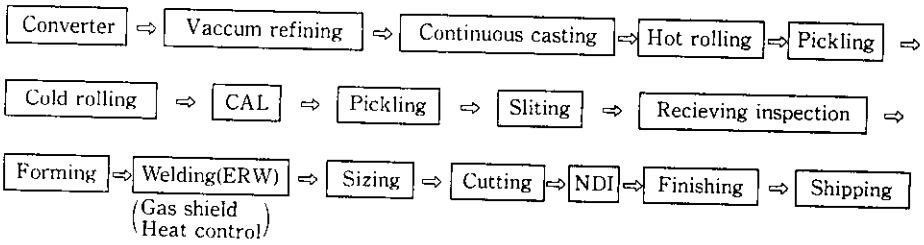


Fig. 1 Manufacturing process of stainless steel exhaust pipe

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portion is in an inert gas atmosphere, thereby ensuring the soundness of the seam weld.

(2) Automatic Heat Control

Since welding of stainless steel is characterized by the narrowness of the proper welding temperature range, continuous measurements are made for plate thickness ($T$) during welding, welding speed ($V$), and temperature ($\theta$) of the weld, and proper welding heat input ($E$) is maintained on the basis of Eq. (1) below.

$$E = K \cdot T^a \cdot V^b \cdot \theta^c \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

where $K$, a, b, and $c$ are constants.

## 3 Product Specifications

### 3.1 Chemical Composition

Kawasaki Steel's standard values and sample values of the ladle analysis of R409L steel is shown in **Table 1**. This stainless steel is an extra-low carbon ferritic steel with a Ti content controlled to improve its weldability and elongation.

Table 1 Ladle analysis

| | | C | Si | Mn | P | S | Ni | Cr | Ti |
|---|---|---|---|---|---|---|---|---|---|
| R409L | Standard | ≦ 0.03 | ≦ 1.00 | ≦ 1.00 | ≦ 0.040 | ≦ 0.030 | ≦ 0.60 | 10.50 to 11.50 | 6×C to 0.75 |
| | Ladle | 0.010 | 0.50 | 0.50 | 0.022 | 0.006 | 0.10 | 11.26 | 0.135 |

### 3.2 Mechanical Properties

The standard values of mechanical properties of R409L electric resistant welded steel pipe are shown in **Table 2**. Tensile test values and the hardness distribution of the electric resistant welds are shown in **Figs. 2** and **3** respectively. There are no great variations in yield

Table 2 Mechanical properties

| | | |
|---|---|---|
| Tensile test | YS | ≧21 kgf/mm² |
| | TS | ≧37 kgf/mm² |
| | El | ≧22% |
| 90° bend test | | 2 D |
| 90° flattening test | | ≦1/3 D |
| Flaring test | | ≧1.25 D |
| Hardness test | Pipe body | ≦HV200 |
| | Weld | ≦HV250 |
| Ferrite grain size | | 5-9 |

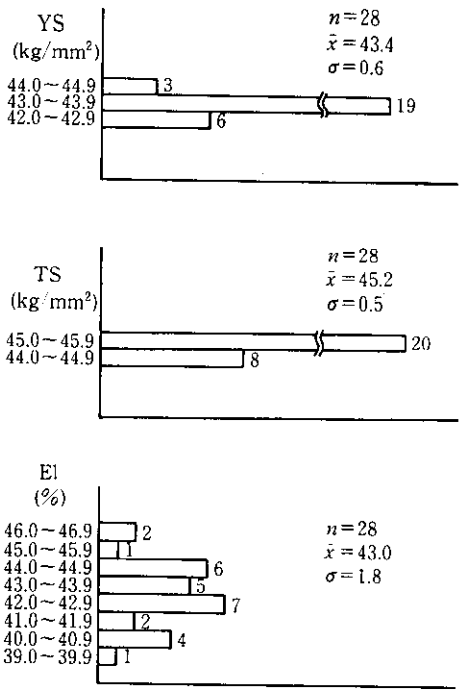


Fig. 2 Mechanical properties of R 409L ERW pipe (38.1 mm$\phi$ × 1.5 mm$t$)

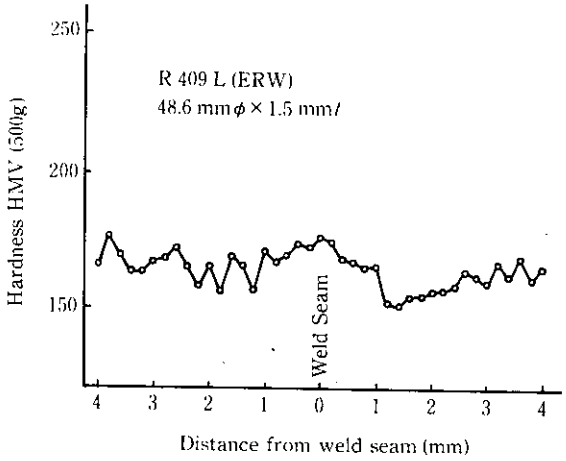


Fig. 3 Hardness distribution

strength (YS) and tensile strength (TS), and elongation (El) is very high. The hardness of the pipe is the same as that of the base coil with a uniform hardness distribution. Since the pipe will be used in exhaust systems, its strength at high-temperatures is very important. As an example, the creep strength is shown in **Fig. 4**. Its creep rupture stress is higher than non Ti-added R410L steel.

Performance tests of R409L electric resistant welded steel pipe are shown in **Photo 1**. Despite flattening it developed no cracking. In the flaring test, cracking was

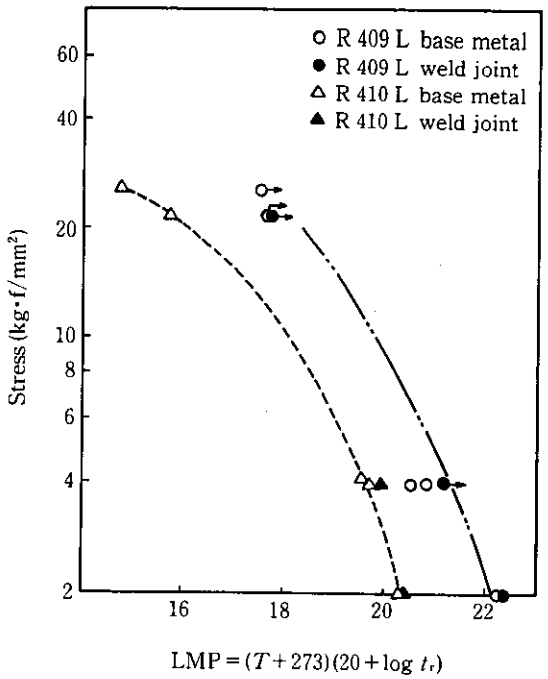


Fig. 4 Master rupture curves of the steels to determine the results of creep testing

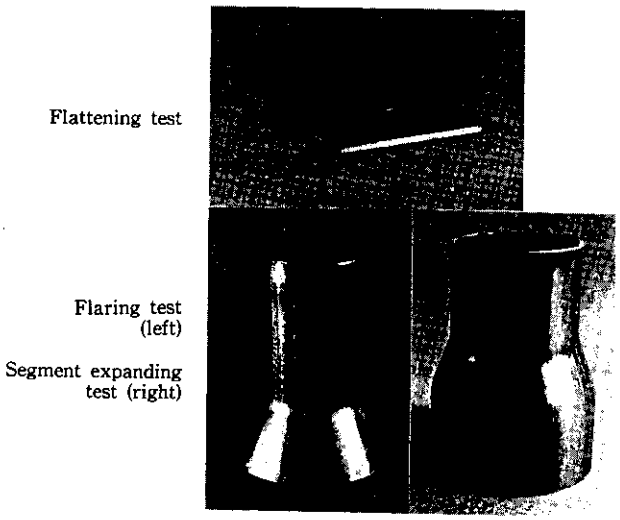


Photo 1 Appearance of tested pipe

not generated until the sample buckled at 1.5 to 1.6 D, and it withstood segment expansion up to 1.2 D.

## 4 Available Sizes

Available sizes of the stainless steel pipe for exhaust systems made by electric resistant welding are shown in **Fig. 5**.

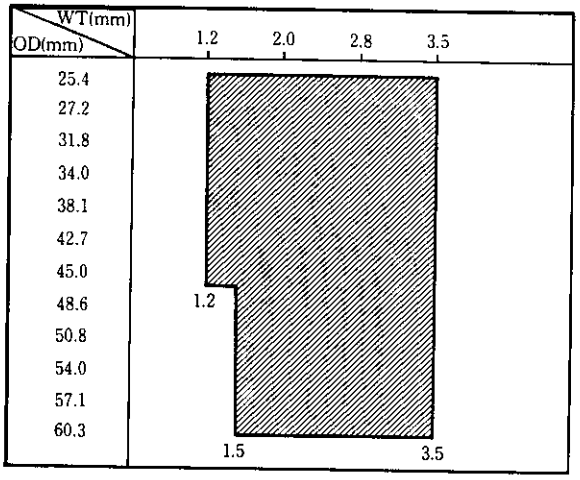


Fig. 5 Available size of ERW stainless pipe (OD, outside diameter; WT, wall thickness)

It comes in 12 sizes with outside diameters ranging from 25.4 mm to 60.3 mm.

### References

1) M. Kobayashi, T. Kawasaki, Y. Mihara, H. Sato, M. Takada, F. Yanagishima: *Kawasaki Steel Giho*, **20**(1988)1, pp. 20–26