KAWASAKI STEEL TECHNICAL REPORT
No.14 (March 1986)
Special Issue on Stainless Steels

13Cr-3.5Ni Martensitic Stainless Steel Castings for Hydraulic Turbine Runners

Hiromasa Niinaka, Akira Hirose, Satoru Sogabe, Hiroshi Noguchi

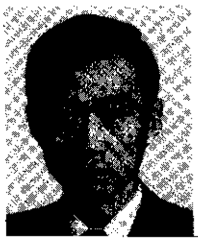
Synopsis :

A 13Cr-3.5Ni martensite stainless steel is used for the hydraulic turbine runner, because it is suitable for high strength, high corrosion resistant and high abrasion resistant materials. These material properties are affected sensitively by heat treatment of normarizing and tempering. In manufacturing the hydraulic turbine runner, Kawasaki Steel established quality control in the manufacturing process, using the following technical improvements: (1) design of casting plans with solidification simulation using CAD, (2) control of the volume of gases that are generated from the core, (3) control of core drying, (4) control of the pouring process by sealing with the argon gas, (5) control of the knockout temperature, (6) control of heat treatment, (7) control of repair welding. It has now become possible to manufacture satisfactory products of the three types of runners: Francis, Kaplan, and Pelton runners.

The body can be viewed from the next page.

KAWASAKI STEEL TECHNICAL REPORT No. 14 March 1986

13Cr-3.5Ni Martensitic Stainless Steel Castings for Hydraulic Turbine Runners*



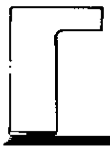
Synopsis:

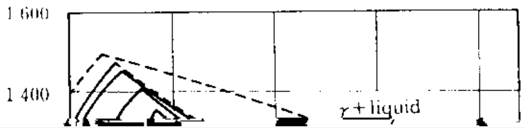
A 13Cr-3.5Ni martensite stainless steel is used for the hydraulic turbine runner, because it is suitable for high strength, high corrosion resistant and high abrasion resistant materials. These material properties are affected sensitively by heat treatment of normarizing and tempering. In manufacturing the hydraulic turbine runner, Kawasaki

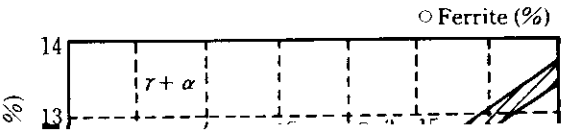
tion. This is the mainstream of hydraulic turbine runners.

(2) Kaplan type

Kaplan turbine runners are used in low-head, large-water-volume power plants, which account for 10%




1 600
1 400
γ+liquid


○ Ferrite (%)
14
13
%)
γ+α

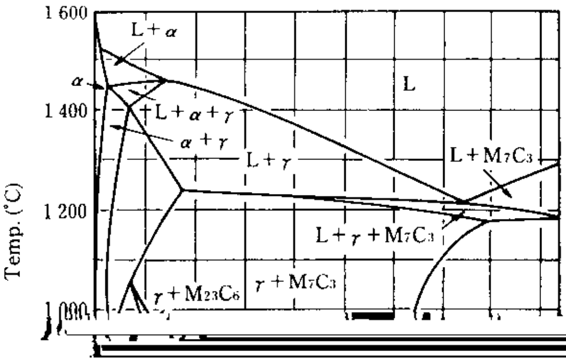
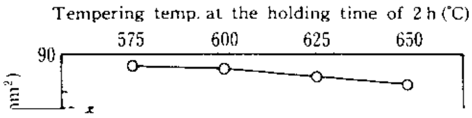


Table 2 Mechanical properties of 13Cr-3.5Ni cast steel

YP (kgf/mm²)	*TS* (kgf/mm²)	*El* (%)	*RA* (%)	HB	Charpy impact value (kgf·m/cm²)
≧55	≧75	≧15	≧40	217～302	≧6 (0°C)

and hardness are high. **Table 2** shows the mechanical properties specified for this runner material. The tensile



malizing and tempering (NTT) are conducted. Heating was conducted at two temperatures, 590°C and 610°C; the tempering temperature during NTT was the same as

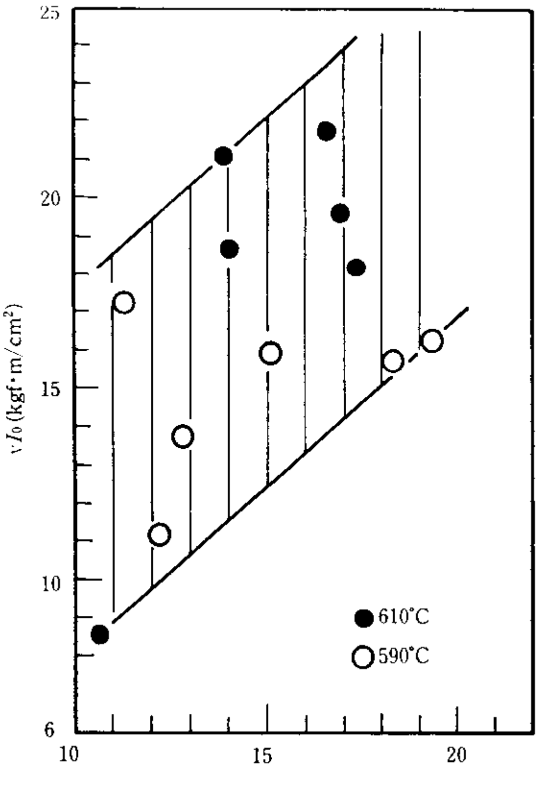


Fig. 11 Relation between the amount of retained austenite and Charpy impact value

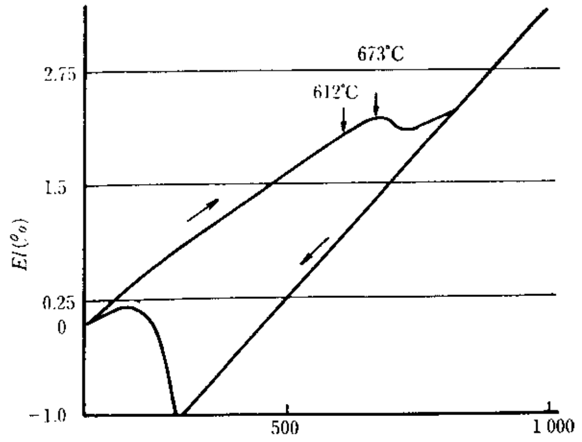
the precipitaion of carbides at austenite grain boundaries. If the precipitated austenite is stable, it should be measured as retained austenite. Therefore, the data in Fig. 10 has been rearranged in terms of retained austenite and is shown in **Fig. 11**. Toughness tends to increase with increasing amounts of retained austenite. However, differences in toughness exist even with equal amounts of retained austenite, showing that evaluation is impossible based on the amount of retained austenite alone. This seems to be because the carbides precipitated at grain boundaries, in addition to the retained austenite, are a cause of this deterioration, as pointed out by Y. Iwabuchi, *et al.*

As mentioned above, tempering conditions and the frequency of stress relief annealing have a great effect on the mechanical properties, especially toughness, of this runner material. Especially, repeated stress relief annealing after normalizing and tempering poses a problem and, therefore, it is desirable to conduct repair welding before normalizing and tempering. If repair welding must be conducted after normalizing and tempering, it

4.2 Changes in Transformation Point with Tempering Conditions

The preceding section described the marked effect of tempering conditions on the mechanical properties of this 13Cr-3.5Ni steel, with the conclusion that one cause is the stability of the austenite which precipitates during the temper heating process.

Figure 12 shows an example of a thermal expansion curve of this steel. The specimen expands with an increase in temperature, with the degree of expansion changing at about 612°C. This seems to be the temperature at which austenite begins to precipitate at martensite grain boundaries.[13] The relationship between this temperature Ac_{1S} and the frequency of tempering and stress relief annealing is shown in **Fig. 13**. It is apparent that Ac_{1S} shifts toward the low-temperature side as this frequency increases. The extent of this temperature drop is great on the first and second instances of tempering and stress relief annealing, but decreases gradually as annealing is repeated three or four times. However, it seems that the difference in temperature between 590°C and 610°C has little effect on Ac_{1S}. In this steel, Ac_{1S}, the temperature at which austenite is beginning to precipitate, decreases to 510~520°C when the frequency of tempering during NTT is increased. It subsequently decreases somewhat with each two repetitions of stress relief annealing. This suggests that austenite precipitates at lower temperatures when the frequency of tempering and stress relief annealing is increased. It seems that the higher the heating temperature reached, the larger the amount of precipitated austenite. If this austenite is stable, it contributes to the improvement of toughness, in which case the larger amounts of austenite are considered desirable. On the other hand, however, it seems



5 Manufacturing Process and Quality Control

5.1 Manufacturing Process

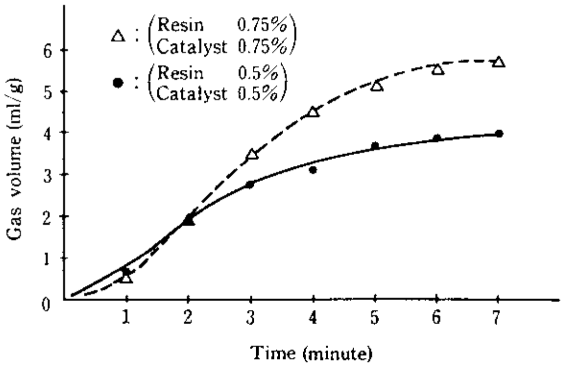


Fig. 17 Time-volume profile of gaseous effluent from phenolic urethan molds

[illegible]

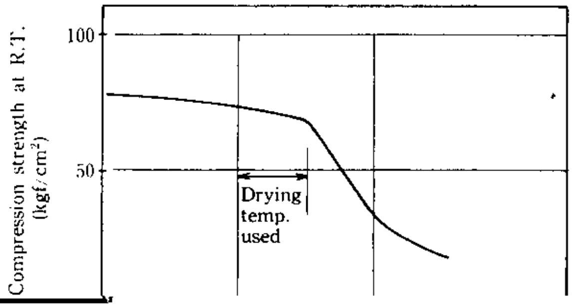
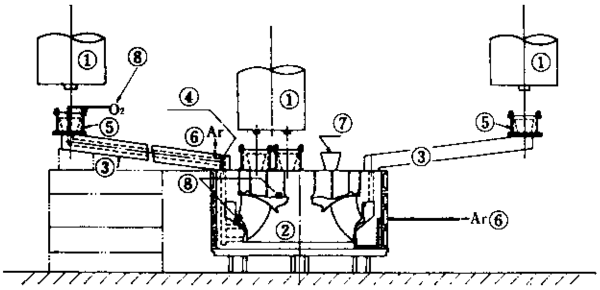
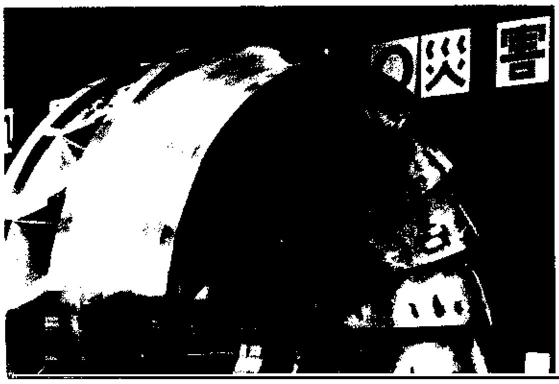


Fig. 18 Variation of retained strength with heating temperature for phenolic urethan molds



method, contact of poured molten steel with air between the ladle and the sprout is prevented by an argon gas

The steel temperature is controlled to within ±20°C of settings, with measurements at two locations on the


災
害

9) A. Tokuda, Y. Kumada, and Y. Nakagawa: "Development and Results of a Trial Production of 13% Cr Base Cast Stainless [illegible] (1970), 3142

10) The Iron and Steel Institute of Japan & The Japan Institute of Metals: "Tekko-Zairyo-Binran," 1099, [Maruzen]

11) Y. Iwabuchi: "Study on the Toughness of Low Carbon 13% Cr-Ni Martensitic Stainless Cast Steel," *IMONO* (*J. of Japan Foundrymen's Society*), 55(1983)11, 683

12) Y. Iwabuchi: "Toughness Deterioration of 13Cr-3.8Ni Cast [illegible] **70**(1984)7, 701

13) Y. Iwabuchi: "Effect of Tempering Condition on Toughness Degradation in 13Cr-3.8Ni Cast Steel," *Tetsu-to-Hagané*, **70**(1984)10, 1437