High Tensile Steel Wire Rods Applying Mist Cooling Process†

1. Introduction

The forced air-cooling process such as "STELMOR" cooling bed is generally used for a cooling method of the rolled wire rod. The strength and ductility of high carbon steel wire rods can be controlled by online process in the rolling line with this process. However, because forced cooling is performed with an air blast, the cooling capacity of the forced air-cooling process is inadequate. As a result, the strength and ductility of wire rods produced by the forced air-cooling process are low in comparison with wire rods produced by lead patenting, in which the material is reheated and immersed in a lead bath by a secondary processor. Mist cooling makes it possible to secure the same cooling capacity as lead patenting, and thereby enables transformation at low temperatures. Therefore, JFE Bars & Shapes commercialized the mist cooling process for wire and rods that led the world. The company also developed the new high tensile steel wire rods by utilizing this process.

A comparison of mist cooling and the conventional cooling processes is shown in **Fig. 1**. Mist cooling has the following advantages in comparison with the conventional methods.

(1) Because water droplets which have been atomized with air are blown on the material at high speed, the heat transfer coefficient is large.
(2) Because the process uses fine water droplets, uniform cooling is possible.
(3) The cooling capacity can be controlled over a wide range.
(4) The process can be installed in combination with existing forced air-cooling lines and used in combination with the existing operation.
(5) The process contributes to improvement of the global environment by making it possible to omit the lead patenting process performed by secondary manufacturers.

In order to quench wire rod material that has been coiled at a specified temperature, a mist-spraying device was installed above the conveyor in the first cooling zone of the forced air-cooling process, which is located adjacent to the coiling equipment. The mist flow rate is controlled corresponding to the diameter of the wire rod material and steel grade while measuring the material online with a thermometer.

The following high tensile steel wire rods have been developed by applying the mist cooling process. However, due to space limitations, only (1) and (2) will be introduced in this report.

(1) High strength, high ductility high carbon steel wire rods: "TMP wire rods" (prior-austenite grain refining, pearlite lamellar refining)
(2) Low carbon high tensile steel wire rods: "TNH® wire rods" (satisfaction of both strength and weldability by utilizing high cooling capacity)
(3) Non-heat-treated medium carbon steel wire rods (omission of heat treatment processes by utilizing high cooling capacity)

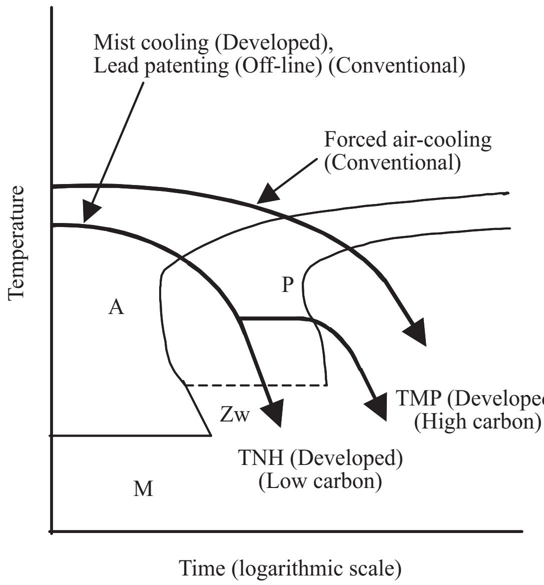

Fig. 1 Schematic cooling curve of lead patenting, mist cooling and forced air-cooling

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2. High Strength, High Ductility High Carbon Steel Wire Rods: "TMP Wire Rods"

Figure 2 shows the tensile properties of these high carbon steel wire rods (5.5 mm diameter). With the mist

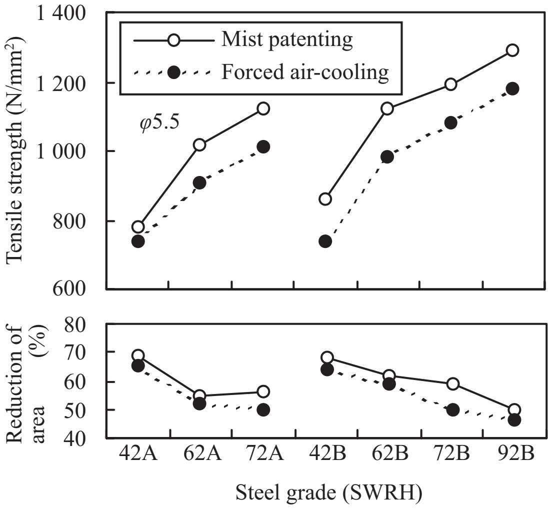

Fig. 2 Tensile properties of wire rods (φ5.5)

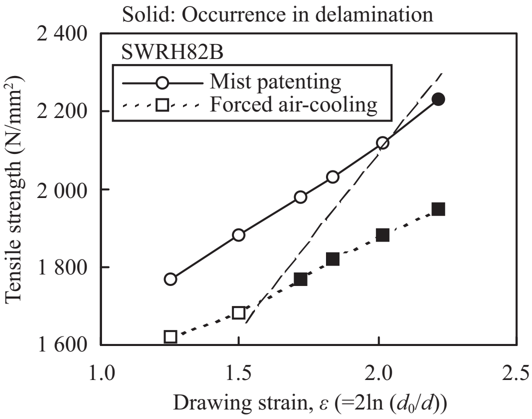

Fig. 3 Limit of occurrence in delamination

patenting material, the prior-austenite grain size is small because direct patenting is performed after hot rolling, and the pearlite lamellar spacing is also narrow in comparison with forced air-cooling wire rods because transformation occurs on the lower temperature side as a result of the increased cooling capacity of the mist patenting device. As a result, high ductility can be achieved simultaneously with high strength.

Figure 3 shows the delamination (longitudinal crack) occurrence limit in a torsional test of SWRH82B steel wire. The limit drawing strain of the forced air-cooling material is approximately 1.5. In contrast, the limit of the mist patenting material is increased to approximately 2.0. As a result, although it was only possible to obtain steel wire with a strength of approximately 1 700 N/mm^2 with forced air-cooling material, values up to approximately 2 100 N/mm^2 are possible with mist patenting material, realizing high strength in high carbon steel wire rods.

Table 1 Comparison of wire rods properties for sheet frame

Grade		Strength	Ductility	Weldability	Total
Conventional	High C type	○	△	△	△
	Low C type	△	○	○	△
Developed	(Low C-high Si-Mn-Cr type)	○	○	○	○

○ : Good
△ : Inferior

3. Low Carbon High Tensile Steel Wire Rods: "TNH®"

Automobile seat frames are manufactured using frames with a wire structure. SWRM6 class low carbon steel and the high carbon steels SWRH62A and SWRH82B are used in this application, but as shown in **Table 1**, both types have disadvantages. Specifically, with the low carbon steel, the weight of structure increases due to the low strength of the material. The strength of the high carbon steels is high, however, its productivity in joining process is inferior because of necessity for caulking caused by poor weldability.

Therefore, in order to develop a low carbon high tensile steel wire rods with strength comparable to that of high carbon steel, combined with excellent weldability and ductility, the high cooling capacity of the mist cooling process was applied as a means of achieving high strength and high ductility.

Figure 4 shows the tensile properties of the developed low carbon high tensile steel wire rods. The

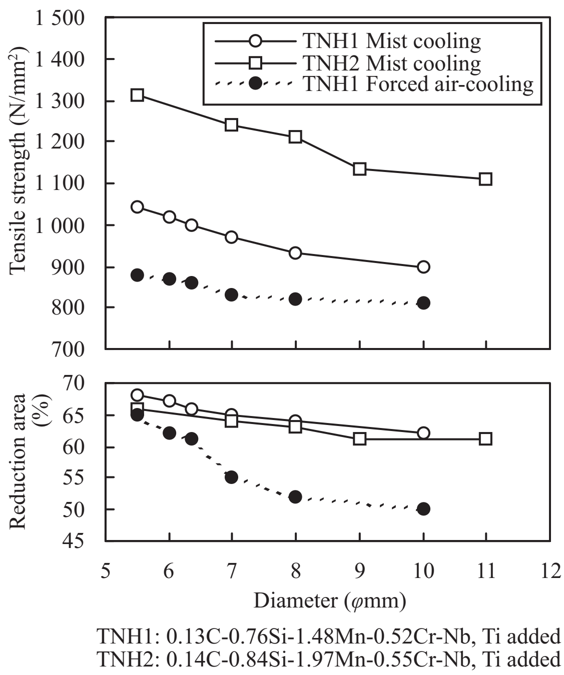

Fig. 4 Tensile properties of developed steels

Table 2 Comparison of weldability between developed steels and conventional steels

Steel	Wire size (φ mm)	Annealing	Tensile test		Bending test	
			TS of bond (N/mm²)	Rupture part	Bond	HAZ
TNH1	3.2	Not	1 422	HAZ	Good	Good
	3.2	Done	1 191	HAZ	Good	Good
SWRH62A	3.2	Not	1 393	HAZ	Inferior	Inferior
	3.2	Done	1 152	HAZ	Good	Good

TS: Tensile strength HAZ: Heat-affected zone

developed steels are based on a low carbon-Mn-Cr steel composition design with high Si to improve sag resistance. TNH1 and TNH2 are equivalent in strength to SWRH62A and SWRH82B class steels, respectively. In TNH1, the strength of the mist cooling material is approximately 100 N/mm^2 higher than that of the forced air-cooling material, and reduction of area is also improved by more than 10% in large diameter materials of 7 mm diameter or larger. This is due to the fine bainite microstructure of the mist cooling material, and the fact that carbides are also fine.

Table 2 shows the results of a comparison of weldability. Even without annealing, TNH1 displayed no abnormalities in the tensile test and bending test. Unlike SWRH62A, which requires annealing, TNH1 can be used as-welded. Furthermore, because annealing is not necessary, the guaranteed strength of welds is also high.

4. Conclusion

As high tensile steel wire rods which were developed by applying the mist cooling process, this report has introduced (1) high strength, high ductility high carbon steel wire rods (TMP wire rods) and (2) low carbon high tensile steel wire rods (TNH® wire rods). Although not discussed in this report, new non-heat-treated medium carbon steel wire rods have also been commercialized using the mist cooling process[1].

JFE Bars & Shapes is continuing research and development on the mist cooling process, with the aim of applying this cooling technology to adjustment/control of the prior microstructure (before cold forging) in wire rod materials for cold forging use, enabling shortening the processing time of the spheroidizing annealing process at secondary manufacturers and improvement of cold forgeability.

Reference

1) Murakami, Toshiyuki; Ohwada, Noriyoshi; Tamai, Yutaka; Shiraga, Tetsuo. Development of steel wire rods applied mist patenting process. NKK Technical Report. 2001, no. 174, p. 46–51.

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