Development of Tension Leveler for Advanced High-Strength Steel

The production of advanced high-strength steel requires rapid cooling, which results in undesirable flatness and/or excessive residual stress of products. Those defects cause adverse effects to automobile production processes. Therefore, high-performance levelers are required for eliminating those defects. JP Steel Plantech Co. has developed a new tension leveler to meet market demands. This paper discusses the new tension leveler.

Advanced high-strength steel (AHSS) sheet has been applied to vehicles for the reduction of weight and enhancement of safety for chassis systems. And such demand is increasing year by year. The material is referred to as high-strength steel sheet or ultrahigh-strength steel sheet. The former indicates steel sheet having yield stress of 460 to 800 MPa, and the latter having yield stress of 800 to 1,600 MPa. In particular, steel sheet having high yield stress and superior mechanical properties is referred to as advanced high-strength steel.

In the production process of the high-strength steel sheet, the materials are rapidly cooled by water quenching. At this time, shape defects or residual stress may occur in the materials. If so, the automotive production line is greatly affected. The tension leveler developed by JP Steel Plantech Co. is specially designed for such advanced materials.

Fig. 1 shows a target range of cold-rolled sheet to be leveled, as requested from a certain steel manufacturer. It indicates that the leveling of ultrahigh-strength steel sheet having thickness range from 0.8 to 2 mm is required. The steel sheet quenched by water quenching cannot be leveled by only a skinpass mill installed in a continuous annealing line. Therefore, a tension leveler must be installed in a continuous annealing line.

In order to produce steel sheet having high performance and high quality such as the above examples, it is necessary to respond to not only the high strength and high toughness, but also high dimensional accuracy, favorable shape, improvement of surface quality and the like,

Figure 1

Target range of leveling of cold-rolled sheet.


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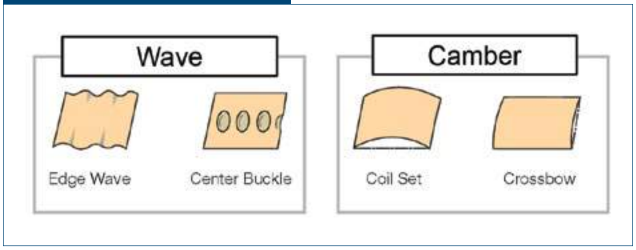
Figure 2

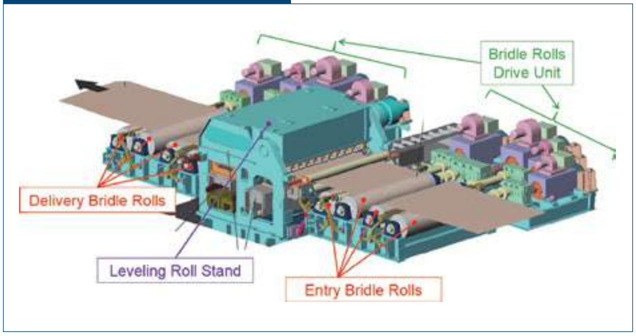


Types of shape defects occurring in steel sheet.

Figure 3

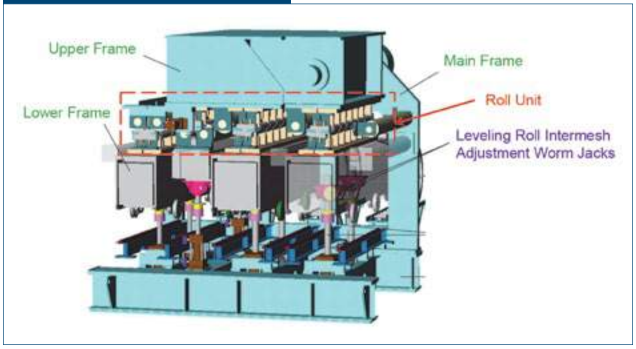
New tension leveler for advanced high-strength steel (AHSS).

Figure 4



Entire configuration of tension leveler.

Figure 5



Leveling roll stand.

which can suit automation for automobile production. Various technological requirements to be adopted for the manufacturing of materials such as AHSS have been increasing year by year.

In order to level material having an extremely high yield strength, the newly developed tension leveler is designed to apply strip tension that is three times or more of the conventional tension. In this paper, the newly developed tension leveler for AHSS is described.

Necessity of Tension Leveler

Generally speaking, in the rolling process, dead flat sheets cannot be manufactured due to a variety of rolling conditions and material characteristics. In order to rectify such flatness defects, leveling machines have been installed after rolling mills. Particularly, tension levelers have a great capability to improve strip flatness, even after being divided to steel sheets.

There are important factors to determine the quality of rolled steel products, such as flatness, residual stress, surface quality, etc. As shown in Fig. 2, there are two types of shape defect of the steel material: one is wave by rolling and the other is camber. Actually, shape defect occurs due to a complex combination thereof; among those, the two types of flatness defects are discussed separately.

Residual stress may cause the steel sheet to be warped after slitting to narrow band. The tension leveler has a role of making the residual stress distribution uniform.

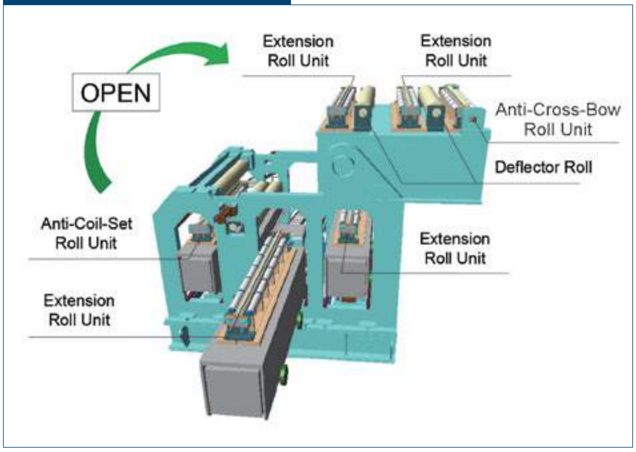
Surface quality of a rolled steel is evaluated taking into account scratches, small holes, waves and the like, and is directly related to the value of the product.

Outline of Newly Developed Tension Leveler

Configuration of Tension Leveler — Fig. 3 is a photograph of a new tension leveler for AHSS. The entire configuration, the configuration of the leveling roll stand and roll units are shown in Figs. 4–6, respectively.

In order to apply tension to the strip, bridle rolls are installed at the entry side and the exit side of the leveling roll stand. The leveler roll stand consists of roll units and a gap-adjusting mechanism for controlling the intermesh of the roll units. There are three

Figure 6



Roll units of tension leveler.

groups of roll units: the extension roll unit, anti-cross-bow roll unit and anti-coil-set roll unit.

Study of Roll Units Arrangement — Fig. 7 shows an arrangement of roll units at JP Steel Plantech Co. Also, Table 1 shows the features of each roll arrangement and targeted materials to be leveled, respectively.

The Type A arrangement is applied to carbon steel and stainless steel materials. Those materials require relatively low tension for leveling since their yield strengths are low. Therefore, the Type A arrangement has enough leveling capability for the said materials, owing to its cross-bow leveling unit.

The Type B arrangement is designed to level carbon steel and stainless steel as well, for harder materials having yield strength up to 800 MPa, which require higher tension for leveling. In this arrangement, cross-bow and coil set on the strip may appear due to higher tension value. Therefore, an anti-coil set roll unit is adopted in addition to an anti-cross-bow roll unit.

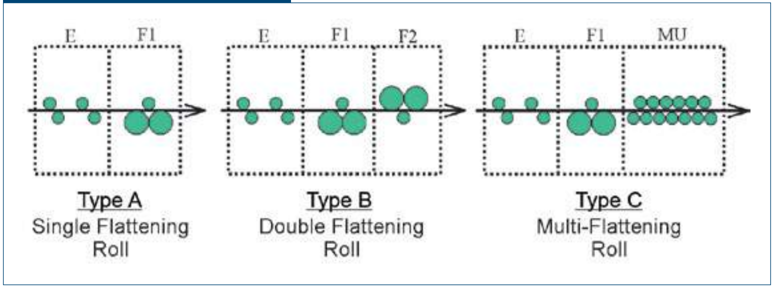
The desired materials for the Type C arrangement are also carbon steel and stainless steel, however, having yield strength higher than 800 MPa. This arrangement is also employed for a line having 800 mpm or faster to achieve a more stable leveling operation. The leveling concept of Type C is the same as Type B in terms of high tension value applied to cross-bow and coil-set leveling; however, Type C is designed to regulate uniform residual stress of the strip after slitting to narrow bands. For this purpose, the multi-roll unit of roller-leveler-type is adopted for coil-set leveling.

Type C (refer to Fig. 8) is applied to the tension leveler for AHSS. The Type C arrangement of the roll units is developed for the purpose of eliminating cambers, as quality requirements for flatness become higher and higher.

First, the extension roll unit levels the strain caused by water quenching by applying strong plastic bending to the steel strip with tension. Next, the anti-cross-bow roll unit levels the cross-bow generated by the extension roll unit. Finally, the anti-coil-set roll unit performs leveling of the coil set, which is not considered in the anti-cross-bow roll unit and creates uniform residual stress distribution of steel sheet.

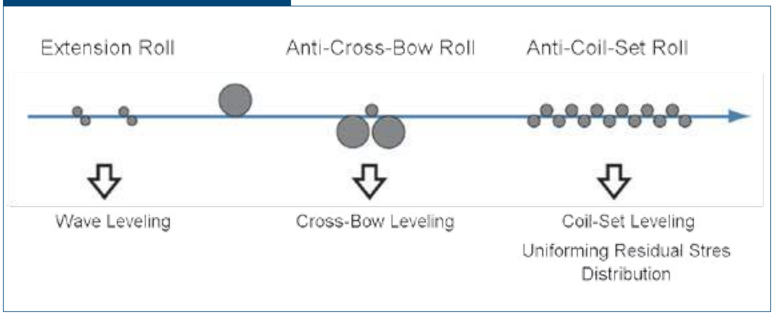
JP Steel Plantech Co. has supplied about 200 tension levelers across the world. Maximum tension value for cold-rolled strip in those tension levelers is about 0.30 MN. Therefore, it was required for JP Steel Plantech Co. to develop a new tension leveler having about 1.0 MN tension in order to study whether the Type C roll arrangement is suitable for the new tension leveler. Its effectiveness has been studied by using an in-house test machine of a tension leveler for AHSS. The results are described in the following section.

Figure 7



Arrangement of roll units at JP Steel Plantech Co.[1]

Figure 8

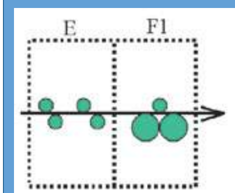
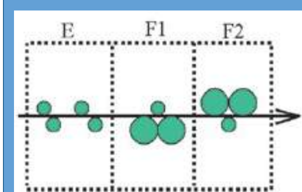


Leveling roll arrangement of tension leveler for AHSS.

Roll Cleaning and Auxiliary Drive of Roll — When steel strip is passed through the tension leveler with metal particles on the surface, they adhere to the leveling roll and repeatedly make dent marks or scratch marks on the surface of the steel strip, and thus the surface quality is

Table 1

Features of Roll Arrangement and Targeted Materials To Be Leveled

	Material to be leveled	Feature
Type A 	Carbon steel Stainless steel	Coil set rarely found because of low tension value – This unit required for cross-bow leveling only
Type B 	Carbon steel Stainless steel (Harder material Ys ≦800 MPa)	Cross-bow generated on the extension roll unit due to higher tension – These units required for cross-bow and coil-set leveling
Type C 	Carbon steel Stainless steel (Harder material Ys > 800 MPa with line speed more than 800 mpm)	(a) Coil set can be stably leveled superior to Type B – Coil-set leveling unit adopts the multi-roll unit (b) Uniforming the residual stress – Countermeasure the shape defect after a variety of processing

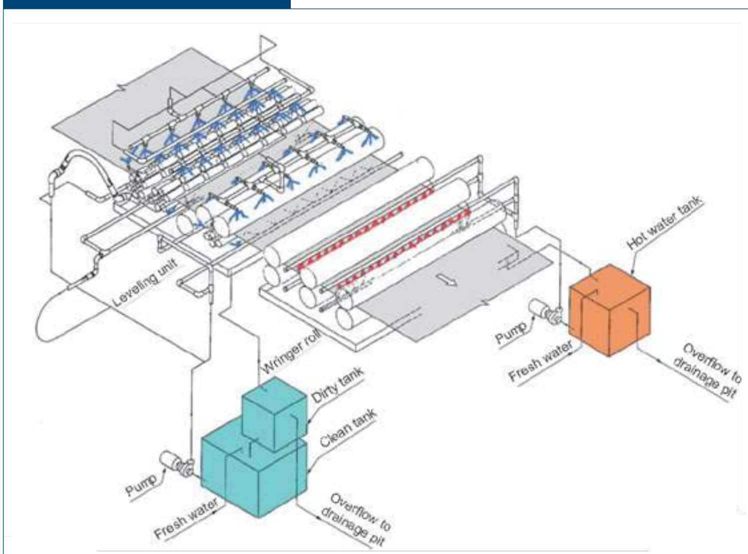
greatly lowered. In order to prevent the strip from such adhesion, a roll cleaning device is adopted. It sprays liquid to the rolls while leveling (Fig. 9). The kind, amount, and method of spraying liquid are experimentally determined according to the type of the steel strip and the state of its surface.

In addition, it is necessary to take the line speed into consideration in performing the roll cleaning. When the line speed is high, the steel strip tends to be slipped on the rolls and they may not be rotated in many cases. Therefore, the rolls are designed to be auxiliary-driven and thus the slip is avoided.

Test Machine of Tension Leveler

In order to confirm that the arrangement of roll units described in the "Study of Roll Units Arrangement" subsection can be applied to the AHSS material, testing was performed by an actual tension leveling line. The test results are described in this section.

Figure 9



Roll cleaning system.

Table 2

Specifications of Test Material

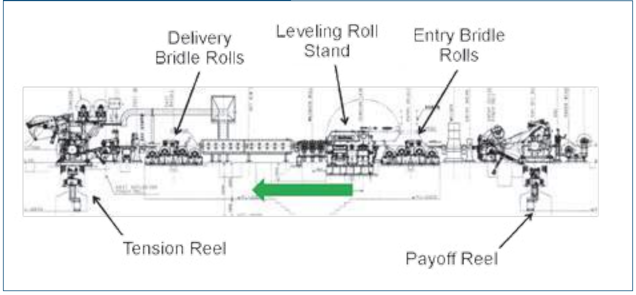
Description	Specification
Material	High tensile steel
Yield strength	1,345 MPa
Strip thickness	1.213 mm
Strip width	400 mm

Table 3

Specifications of Tension Leveling Line

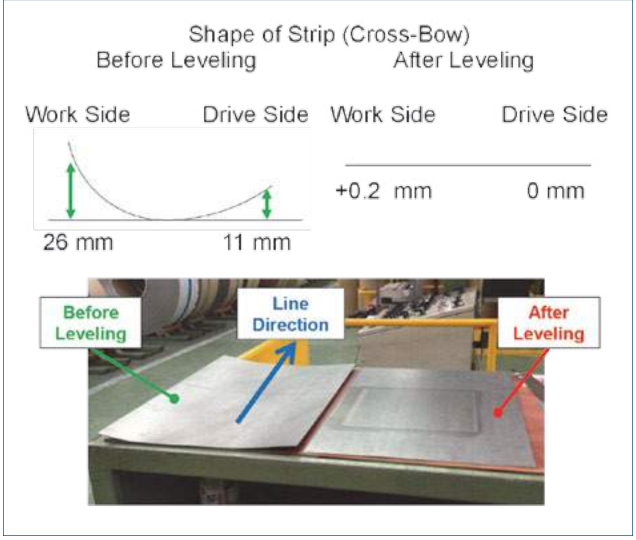
Description	Specification
Line speed	250 mpm
Elongation	Max. 1.2%
Tension	0.23 MN
Width	650 mm

Figure 10



Tension leveling line for the test machine.

Figure 11



Test result of flatness measurement.

Test Material — Table 2 shows the specifications of test material.

Tension Leveling Line for the Test Machine — Fig. 10 shows the layout of the tension leveling line and Table 3 shows the specifications of the tension leveling line. A payoff reel is installed at the entry side and a tension reel is installed at the delivery side. In addition, bridle rolls are arranged at the entry side and the delivery side of the leveling roll stand, and thus the tension required for the leveling is applied. The roll arrangement is the same as in Fig. 8.

Test Result — Fig. 11 shows the test result of flatness measurement in comparison with the cambering of test material before and after leveling; the measured gap on work side of the tension leveler is 0.2 mm from 26 mm, and that on drive side is 0 mm from 11 mm, and thus it can be said that the flatness is improved.

According to the test result shown in Fig. 11, it is verified that sufficient leveling can be performed on the AHSS material especially with water quenching. Appropriate conditions of such operation are researched by this test.

Leveling Performance of Tension Leveler for AHSS

According to the test result described in the "Test Machine of Tension Leveler" section, the tension leveler for AHSS should be designed to have approximately 1.0 MN of total tension. Therefore, a tension leveler for AHSS was required to be newly designed.

Fig. 12 shows the result of leveling effect of tension leveler for AHSS. Also, Table 4 shows the specification of material to be leveled. The strip width is 1,119 mm, thickness is 1.811 mm, and yield strength is 1,500 MPa. In addition, the tension value and elongation are 0.75 MN, 0.64%, respectively.

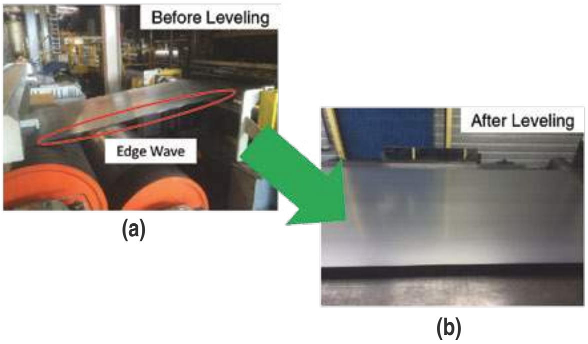
Fig. 12a is the strip before leveling. The photograph indicates edge wave on the strip edge. Fig. 12b shows a strip with better flatness after leveling operation by the newly developed tension leveler for AHSS.

This tension leveler has been in operation since October 2014 with excellent performance for producing AHSS with high-grade flatness.

Conclusions

JP Steel Plantech Co. has developed a tension leveler having about 1.0 MN of tension, which is used for ultrahigh-strength thin steel sheet for automotive use. The tension leveler is able to increase the leveling range. It has been smoothly operated and the

Figure 12



Strip before leveling (a) and strip with better flatness after leveling operation by the newly developed tension leveler for AHSS (b).

production of required materials has been stably performed.

Again, the demands for high-strength sheet, required by the end user's needs such as improving quality and saving energy, are rapidly expanding.

Table 4

Specifications of Material To Be Leveled

Description	Specification
Strip width	1,119 mm
Strip thickness	1.811 mm
Yield strength	1,500 MPa
Tension	0.75 MN
Elongation	0.64%

The technology of high-strength steel production has been developing until today, and it will continue to be further developed in the future.

Reference

1. Y. Keiji and A. Keizo, "Progress of Leveler," *Journal of the Japan Copper and Brass Research Association,* Vol. 31, 1992, p. 29. ✦

To nominate this paper for the AIST Hunt-Kelly Outstanding Paper Award, visit AIST.org/huntkelly.

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Did You Know?

Steel Researchers Enter New Phase of Belt Casting Study

Researchers in the United Kingdom and Canada are undertaking a research project that will explore belt casting's potential to lower energy costs and as a production route for certain advanced high-strength steels.

Called ASSURE2, the project is being led by University of Warwick professor Claire Davis, who is part of the university's Advanced Steel Research Center. Collaborating on the project is Rod Guthrie at McGill University in Quebec, Canada, as well as Tata Steel.

In a statement, the university said that the team has already established that the steel microstructures are affected by differing cooling rates associated with belt casting and slab casting. In the ASSURE2 project, they'll look to establish the quantitative relationships between composition, process parameters and microstructure in belt casting.

Trials using their pilot plant facilities will be carried out for steel grades developed in the project, the university said.

"There are a number of potential step change technologies available for steel processing and it is exciting to be working on one of these. We need to ensure we have a good scientific understanding to support any future take up and to maximize the opportunities available," Davis said in a statement.