

Development of High Strength and High Formability Steel Sheets for Can Materials: JATT™

1. Introduction

Tin mill products are thin gauge steel sheet with a sheet thickness of approximately 0.20 mm that are used in steel cans produced as beverage cans and food cans, and tin plating treatment, called tinplate and electrolytic chromium coated steel, called tin-free steel are practically applied as coated steel sheets¹⁾.

From the viewpoint of global environmental protection, customers require light weight in transportation, which is achieved by downgauging tin mill products. However, to compensate for the decrease in can body strength due to downgauging, high-strength steel sheets are necessary. In addition to reducing CO₂ emissions during transportation, downgauging also reduces the amount of steel used, which has the effect of reducing CO₂ emissions per can in the steel sheet production process. Moreover, in order to respond to the recent diversification of needs, improvement of can designability by improving formability is also demanded²⁾. This paper introduces the design concept and mechanical properties of newly-developed tin mill products of the JATT™ series, which simultaneously satisfy both high strength and high formability.

2. Design Concept and Mechanical Properties of Developed Steel

2.1 Design Concept

In the technology conventionally used to achieve high strength in tin mill products, cold-rolled steel sheets were first subjected to recrystallization annealing in the continuous annealing line (CAL), followed by work-hardening by cold rolling to achieve high strength (double reduced; DR method)³⁾. However, as issues of the DR method, while double cold reduction achieves high strength, plastic deformation reduces elongation, resulting in cracking in rivets, flanges, bead parts, etc. during forming of easy-open end cans and 3-piece can bodies, in which high formability is required.

To solve these problems, addition of solid solution strengthening elements such as C, Mn, etc. or precipi-

tation strengthening elements such as Nb, Ti, etc. are conceivable. However, from the viewpoint of the deterioration of corrosion resistance, the ASTM standard (ASTM A623M) strictly limits the alloying element content of tin mill products used in food cans, etc. Thus, there are limits to the application of strengthening methods based on heavy addition of strengthening elements, like those applied in automotive materials, building materials, etc. Therefore, with the conventional method, it was impossible to supply tin mill products that satisfied both high formability and high strength to enable downgauging.

By optimizing the strengthening mechanism based on a review of strengthening elements, and maximizing expression of the strengthening mechanism by optimizing manufacturing conditions, JFE Steel developed a new series of steel sheets, the JATT series, for tin mill products that satisfy high strength and high formability with minimum addition of strengthening elements within the ASTM standard, and has begun mass production.

2.2 Properties of Base Sheet

Table 1 shows the target ranges of the hardness, yield strength and elongation of the developed steels, and **Fig. 1** shows the balance of yield strength and elongation of the developed steels. While the strength levels of JATT7 to JATT8 are comparable to those of the DR7 and DR8 grade steels, which are conventional high-strength steels, high elongation was achieved in the JATT series. In addition, in comparison with the T4 and T5 grades until now, significantly higher strength was achieved by maximizing the solid solution and precipitation strengthening effects.

Figure 2 shows the results of an investigation of the formability improvement effect of JATT by the Erichsen test. Compared to the DR8 material, the developed JATT8 showed a remarkable increase in the Erichsen value, which is an index of stretch-formability. Compared to the average elongation of 3 to 5% of the conventional material, the developed steel achieved a maximum elongation of 15% or more, while maintaining high strength comparable to that of DR materials. This was achieved by an original materials design concept, as mentioned above, in which the effect of the

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Table 1 Target range of mechanical property of developed steel

	Grade	Rockwell hardness, HR30T	Yield strength (MPa)	Elongation (%)
JATT™	6	67±4	460±50	≥15
	7	69±4	480±50	≥15
	7.5	71±4	520±50	≥15
	8	72±4	550±50	≥10

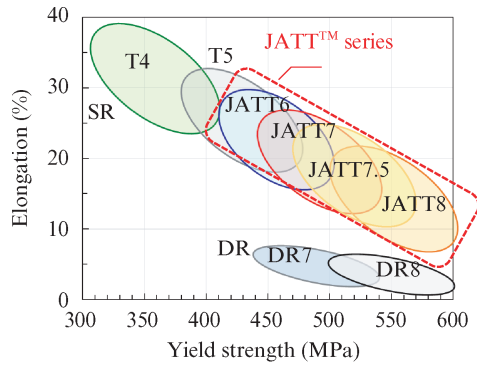


Fig. 1 Yield strength — elongation balance of developed steel

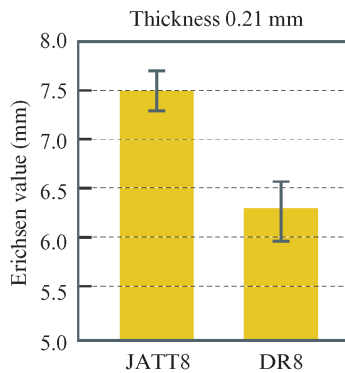


Fig. 2 Erichsen value of developed steel

strengthening mechanism is maximized by optimizing precipitation elements and manufacturing conditions, while keeping the content of alloying within the range of the ASTM standard.

2.3 Formability Improvement Effect

To evaluate the formability improvement effect of the developed steel, cans with a nominal inner diameter of 52.4 mm without top and bottom can ends were prepared using the developed steel and DR8 with a sheet thickness of 0.23 mm, and circumferential expandability was evaluated by inserting an expansion tool (die) which expands in the can diameter direction inside the can, and expanding the can circumference. Circumferential expandability was evaluated by the Expansion ratio (%) = (Diameter after can expansion – Diameter before can expansion) / (Diameter before can

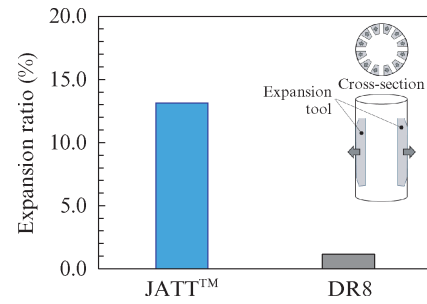


Fig. 3 Expansion ratio of developed steel

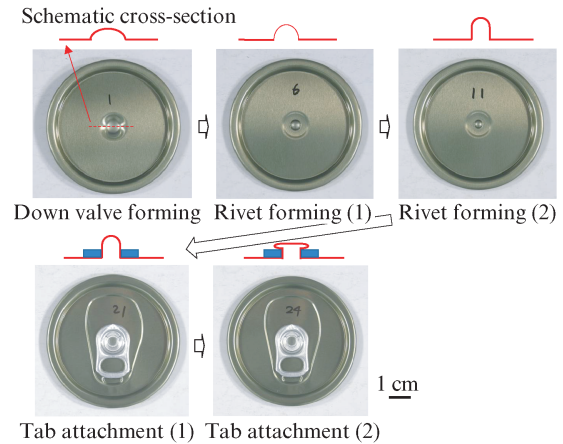


Fig. 4 Forming process of easy-open-end

expansion) × 100, where a high expansion ratio indicates excellent circumferential expandability. **Figure 3** shows the expansion ratio of the developed steel. While DR8 showed an expansion ratio of about 1%, the developed JATT showed a high expansion ratio of approximately 13%, clearly demonstrating the superiority of the developed high-formability steel in comparison with DR8.

Next, the can-end manufacturability of the developed steel was investigated using a #202 can. **Figure 4** shows the forming process of an easy-open-end. The developed steel showed satisfactory formability, as no cracks occurred in the rivet section or crimped section of the tab, which are subjected to the most severe forming.

3. Technical Significance and Practical Application Status of Developed Steel

JATT has already been applied in practical applications, mainly in easy-open-end cans and 3-piece can bodies, in which high formability is required, and mass production began in 2017. **Figure 5** shows examples of application. In some of these items, downgauging from 0.21 mm to 0.18 mm was possible by applying JATT. JATT also offers a higher degree of freedom in forming than the conventional DR materials, expanding the



Fig. 5 Applications of developed steel

possibilities of can design. Since its strength is higher than that of conventional SR materials (single reduced, rolled one time; normal cold rolled—annealed materials), buckling and dent deformation can be reduced, and an increased production volume by further expansion of applications is expected. Thus, JATT not only has excellent mechanical properties, but is also a superior product in terms of global environmental protection by achieving downgauging and weight reduction. Increasingly wide use of the JATT series is expected in

the future, as materials that respond to the diverse needs of global customers.

References

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- 3) Toyo Kohan Co., Ltd. Tinplate and Tin-free Steel. 2nd ed., Agne, 1974, 371 p.

This paper reproduces the paper listed as reference 2), which was written by the same lead author, with revisions of some expressions.

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