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New Products & Technologies

Direct-Softened Alloy Steel Rod for Cold Forging Uses*

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1 Introduction

Conventional as-rolled alloy steel rods for cold forging have a hard structure containing a great deal of bainite. Annealing is required to lower the hardness of this as-rolled product and increase its ductility for cold drawing. With the aim of lowering production costs, attempts have been made in recent years to obtain properties equivalent to those annealed material after hot rolling, thereby eliminating the need for annealing.[1,2,3] The process is shown in **Fig. 1**.

Alloy rods are generally considered difficult to soften. Kawasaki Steel Corp., however, is now producing direct-softened alloy steel rods using a retarding cover to control the cooling rate after hot rolling.[4] The cover is installed in the block mill line at the rod-rolling mill at Mizushima Works. This paper describes the commercial product of this process, SuperECOS.

2 Production Process

At Mizushima Works, the material for alloy steel rods is produced by a converter–vacuum degassing–continuous casting route and rolled into 150-mm-square billets at the billet rolling mill. The billets are then rolled down to specified sizes at the rod-rolling mill. At this point, the retarding cover is applied, reducing the cooling rate of the hot-rolled rods. By this process direct-softened alloy steel rods are produced. Throughout the integrated process of steelmaking, billet rolling, and rod rolling, these rods for cold forging applications are subjected to strict quality control.

3 Product Type and Properties

3.1 Product Type

Table 1 shows the types and sizes of SuperECOS, the direct-softened alloy steel rod developed by Kawasaki Steel. The product SCM435, which has the highest degree of hardenability of those listed in Table 1, will be used by way of example in the following discussion. **Table 2** shows the chemical composition of SCM435.

3.2 Microstructure and Mechanical Properties

Photo 1 shows the microstructure of conventional and direct-softened SCM435 steels of a 14-mm diameter.

Table 1 Types of direct-softened steel products

Type	Size (mmϕ)	TS (kgf/mm²)
SCM 415 ~ 435	11 ~ 19	≤85
SCR 415 ~ 440		

Note 1. SCM435 generally corresponds SAE4135.
2. SCR 440 generally corresponds SAE5140.

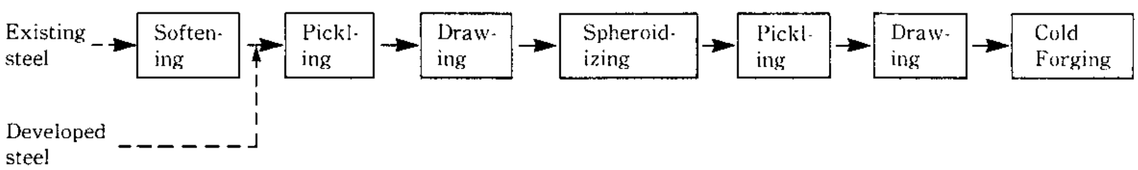

Fig. 1 Secondary process for existing steel and newly developed steel

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Table 2 Chemical composition of SCM 435 (wt.%)

C	Si	Mn	P	S	Cr	Mo
0.33~0.38	0.15~0.35	0.60~0.85	≤0.030	≤0.030	0.90~1.20	0.15~0.30

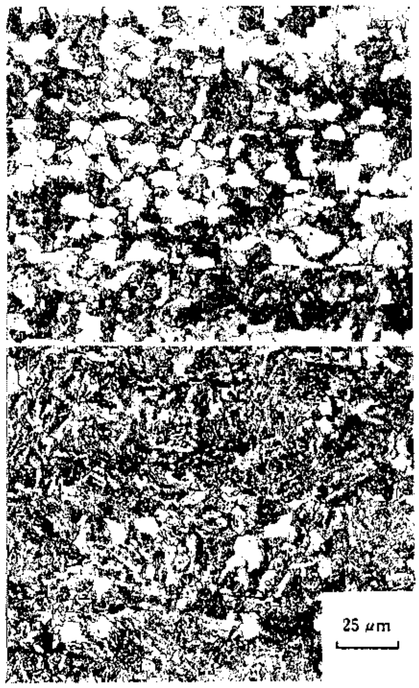

Photo 1 Comparison between microstructures of direct-softened steel (a) and that of existing steel (b)

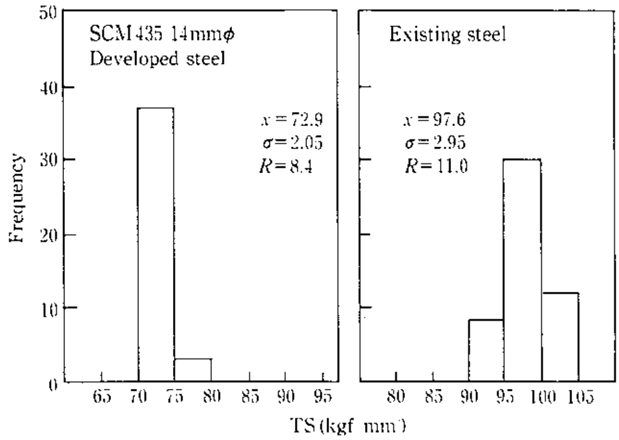

Fig. 2 Tensile strength distribution in coils made of existing steel and newly developed steel

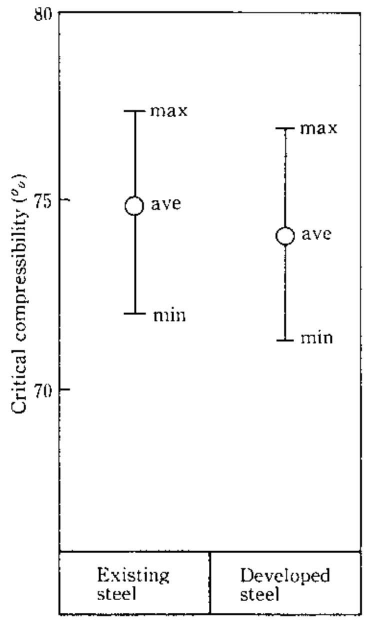

Fig. 3 Critical compressibility of existing steel and newly developed steel

The microstructure of the conventional steel is mainly bainite, while that of the direct-softened steel is ferrite and pearlite.

The direct-softened steel, which is subjected to cold drawing in the as-rolled state, is susceptible to rupture during drawing if the inner portion is very hard. Thus, from the viewpoint of mechanical properties, not only low tensile strength but also uniform tensile strength is essential. **Figure 2** shows example of the distribution of tensile strength in rods of the conventional and direct-softened steels. The tensile strength of the softened steel is low at 73 kgf/mm^2, which is about 25 kgf/mm^2 lower on average than that of the conventional steel. Further, no portion of the material has a tensile strength exceeding 80 kgf/mm^2, and the dispersion of tensile strength values is small.

3.3 Cold Forgeability

In consideration of the secondary processing to which this material is normally subjected, a cold compression test of the conventional and direct-softened steels was conducted. A cold drawn and spheroidally annealed specimen of 10 mmϕ × 13 mm$L$ was given compression working. The value for critical compressibility (compressibility when crack generation is 50%) was used as an indication of the cold forgeability of the two steels. As **Fig. 3** shows, the cold forgeability of the newly developed steel is almost identical to that of annealed conventional steel.

3.4 Example of Application to Actual Parts

A 14 mm ϕ direct-softened steel rod of standard SCM435 was made into a socket bolt (**Photo 2**). Without the annealing usually applied before cold drawing, the steel rod was cold drawn and cold forged. The

Photo 2 Socket bolt made of direct-softened steel

process was carried out as smoothly as the conventional process (annealing, cold drawing, and spheroidizing annealing), and the required properties were obtained through thermal refining after forging.

4 Concluding Remarks

A retarded cover installed in the block mill line has made possible the production of a new type alloy steel rod product, direct-softened SuperECOS. This direct-softened alloy steel is expected to contribute to a drastic lowering of costs thanks to the elimination of annealing from the manufacturing process.

References

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