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High Carbon Hot-Rolled Sheets with Excellent Formability "SUPERHOT™-G"

1. Introduction

High quality, including high strength, abrasion resistance, dimensional accuracy, etc., is required in automotive driveline parts and chassis parts, some of which are manufactured by joining individual parts which are machined after hot forging. In order to eliminate joining step and achieve single-piece forming[1] of parts, JFE Steel developed soft high carbon steel sheets "SUPERHOT™-G" with excellent press formability. The development target was a soft high carbon steel with excellent formability for machine structural use, considering tooth forming, local thickening, double-action forming, etc. incorporating elements of forging under high forming pressure conditions. This article introduces the product features of high carbon hot-rolled steel sheets "SUPERHOT™-G" with excellent formability as an original JFE Steel composition standard, with the aim of expanding single-piece press formed parts.

2. Product Design

2.1 Features of SUPERHOT™–G

SUPERHOT™-G is a steel which possesses high thickness accuracy and provides excellent formability while maintaining hardenability on the same level as the JIS material (SC material) of the same carbon content.

2.2 Alloy Design

With the aim of securing hardenability equal to that of S35C and S45C, two steels with 0.35 mass % C and 0.45 mass % C, respectively, were developed as SUPERHOT™-G (standard name: J35C, J48C). Examples of the chemical compositions of the developed steels are shown in **Table 1**. To create steels with superior press formability, addition of Si and Mn was reduced from that of the JIS steels. B was added to compensate for the decrease in hardenability accompanying this reduction of Si and Mn, realizing hardenability equal to that of the JIS steels.

2.3 Microstructure Control for Formability Improvement and Softening

In order to improve the press formability of high carbon steel sheets, appropriate control of the morphology and distribution of carbides after spheroidizing is necessary. In general, press formability is improved by uniformly dispersing spherical cementite at the grain boundaries of equiaxed ferrite[2], and for softening, the cementite and ferrite grains are coarsened[3, 4]. On the other hand, coarsening of cementite invites a decrease in quenched hardness due to the cementite left after short-time heating in high frequency induction hardening[5]. **Photo 1** shows the microstructures of J35C SUPERHOT™-G and S35C after hot rolling and after spheroidizing. In the as-hot-rolled S35C material, a heterogenous microstructure was formed by spheroidizing because coarse ferrite and pearlite were formed. In contrast, in the as-hot-rolled J35C SUPERHOT™-G material, uniform equiaxed ferrite grains with a grain size of over 10 μm, which contain little cementite in the grains, were formed by spheroidizing because fine ferrite was dispersed between uniform pearlite structures.

Table 1 Chemical compositions of "SUPERHOT™-G"steels

(mass%)

Designation	C	Si	Mn	P	S	Others
J35C	0.35	0.01	0.35	0.017	0.004	B
【JIS】S35C	0.32-0.38	0.15-0.35	0.60-0.90	≦0.030	≦0.035	-
J48C	0.48	0.01	0.35	0.009	0.003	B
【JIS】S45C	0.42-0.48	0.15-0.35	0.60-0.90	≦0.030	≦0.035	-

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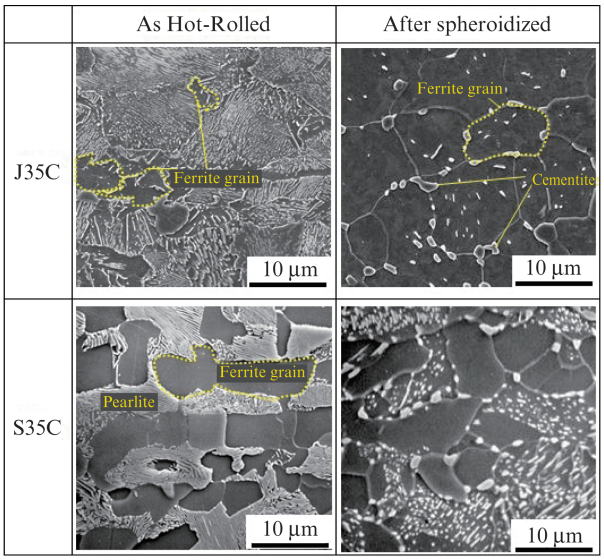

Photo 1 Microstructures of J35C and S35C after hot-rolled and spheroidized steels

Table 2 Mechanical properties of "SUPERHOT™-G"steel sheets

Designation	YP (MPa)	TS (MPa)	El (%)	HRB
J35C	261	419	40	71
【JIS】S35C	315	510	35	79
J48C	315	455	36	75
【JIS】S45C	345	532	30	81

Test piece: JIS No. 5 Thickness: 4.0 mm
YP: Yield point TS: Tensile strength El: Elongation
HRB: Rockwell hardness

3. Product Properties

Table 2 shows the mechanical property values (after spheroidizing) of SUPERHOT™-G (standard name: J35C, J48C) with a sheet thickness of 4.0 mm. In comparison with the corresponding JIS standard materials, the tensile strength of both SUPERHOT™-G steel sheets was reduced by approximately 90 MPa and elongation was improved approximately 5%. As a result, these materials are suitable for the severe forming in single-piece forming. **Figure 1** shows the hardness curves from the quenched end in induction hardening (heating temperature: 1 000˚C). With J48C, a quenched hardness and depth equal to those of S45C were obtained.

4. Applicable Parts

Among automotive driveline parts, the object parts for SUPERHOT™-G are mainly rotary parts such as the clutch hub/drum of automatic transmissions (AT), the piston/cylinder of continuously variable transmissions (CVT), the rotor holder of starter-generators, etc.

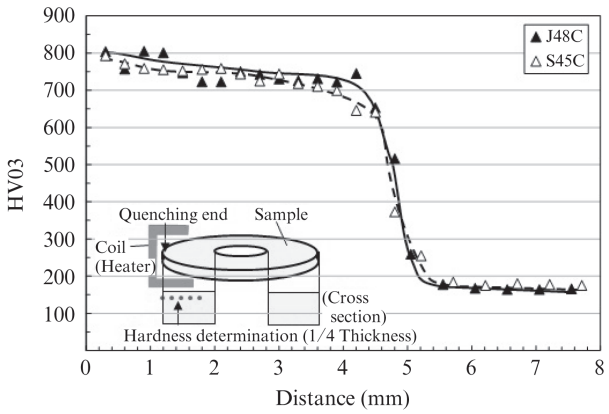

Fig. 1 Hardness curve of induction hardening sample

(a) J48C (b) S35C

Photo 2 Rotor holder parts made of J48C hot rolled steel sheet and S35C hot rolled steel sheet (by NICHIDAI Co., Ltd.)

At present, trial assessments are being carried out with several auto makers and auto part makers.

An example of application to a part simulating a rotor holder (**Photo 2**) will be presented here. Cold press forming was performed using a J48C hot-rolled steel sheet and an S35C hot-rolled steel sheet, both with thicknesses of 4.0 mm. The trial part is cylindrical in shape with a high hollow boss (outer diameter: 110.6 mm, height: 43.8 mm). With the S35C material, cracks occurred from the root of the boss part during thickening of the hollow boss. In contrast, crack-free press forming was possible with J48C with excellent formability.

5. Conclusion

SUPERHOT™-G products are suitable steel sheet materials for parts for machine structural use, which had been difficult to produce by press forming until now. Many customers are conducting ongoing assessments of application to various types of parts, and expanded adoption is expected in the future.

References

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