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# High Strength Steel for Hot Forged Gears with Precipitation Hardening in Soft-Nitriding Process†

## 1. Introduction

With the growing popularity of electric and hybrid vehicles in recent years, there has also been heightened demand for high strength steel in low strain soft-nitriding treatment of gears and other automotive components from the viewpoints of quietness by improved dimensional accuracy and process improvement by omission of gear grinding[1)].

However, the applications of soft-nitriding technology had been limited due to the low fatigue strength of parts after soft nitriding when using conventional materials. To overcome this problem, JFE Steel investigated techniques for achieving high strength in soft-nitriding steels, and developed a high strength soft-nitriding steel with high fatigue strength. This report introduces the developed steel.

## 2. Features of Developed Steel

As target applications for the developed steel, gears and shafts of automobiles, construction machinery and other types of equipment processed by hot forging, gear cutting and soft nitriding of chrome steel (SCr420) as provided in the JIS standard for steels for machine structural use can be mentioned.

**Table 1** shows the chemical compositions of the developed steel and SCr420. The aim of the developed steel is precipitation hardening including the core, which cannot be achieved by nitrogen diffusion from the surface, as well as the outermost surface layer by soft-nitriding by addition of V and other carbonitride forming elements. Furthermore, low carbon bainite is secured as the microstructure after hot forging by addition of hardenability improving elements, namely, Mn, Cr and Mo, and adoption of a low C, low Si composition design. The bainite microstructure simultaneously increases the precipitation hardening capacity during soft nitriding and also improves machinability.

Talbe 1 Chemical Composition of developed Steel

| | C | Si | Mn | Cr | Others |
|---|---|---|---|---|---|
| developed | reduced | reduced | 1.80 | 1.25 | Mo, V |
| SCr420 | 0.20 | 0.25 | 0.80 | 1.15 | — |

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## 3. Properties of Developed Steel

**Figure 1** shows optical micrographs of the developed steel and the conventional SCr420 steel after hot forging. The developed steel has a bainite microstructure, whereas the SCr420 has a ferrite-pearlite microstructure. The Vickers hardnesses of the respective steels are Hv187 for the developed steel and Hv231 for SCr420.

The conditions of the machinability test are shown in **Fig. 2**. The cutting tool was a JIS P20 cemented carbide tool (SNGN120408 UTi20). The test was conducted under the conditions of a cutting speed or 200 m/min, cutting depth of 1.0 mm and feed of 0.25 mm/rev without lubrication, and the length of tool flank wear (VB) was evaluated.

**Figure 3** shows the results of the machinability test of the SCr420 steel and the developed steel. Although the developed steel is harder than SCr420, the flank wear of the tool in outer periphery turning was small, showing that the developed steel has excellent machinability and can withstand machining of the object part.

In order to secure the fatigue strength of gear parts,

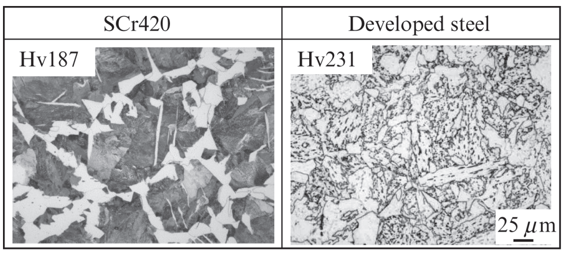


Fig. 1 Optical micrographs of steels after hot forging

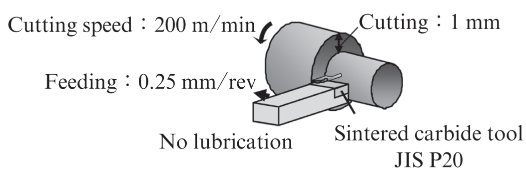


Fig. 2 Condition of machinability test

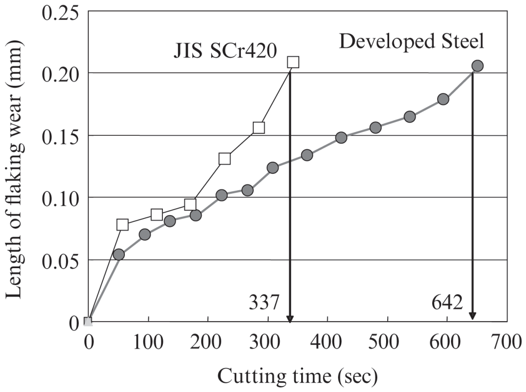


Fig. 3 Result of machinability test of JIS SCr420 and developed steel

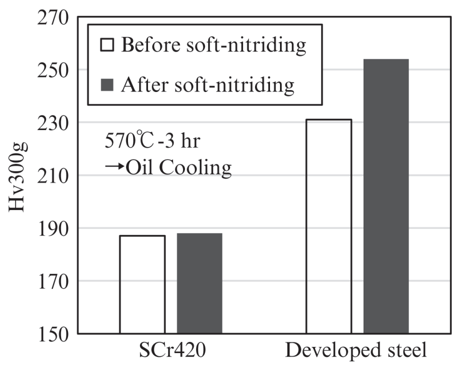


Fig. 4 Precipitation hardening of JIS SCr420 and developed steel

it is also important to increase core hardness. **Figure 4** shows the core hardness of the SCr420 steel and the developed steel before/after soft nitriding. As mentioned above, the core hardness of the developed steel before soft nitriding is higher than that of SCr420. The hardness of the core is increased by a further amount of approximately Hv25 by precipitation hardening after soft nitriding, thereby contributing to improved fatigue strength when the steel is used in parts.

**Figure 5** shows the surface hardness of the SCr420 and the developed steel after soft nitriding. In the developed steel, the amount of precipitation hardening is increased by the addition of nitride forming elements, and as a result, higher surface hardness than that of SCr420 can be obtained.

**Figure 6** shows the results of a rotating bending fatigue test of the developed steel. Due to the large increase in the hardness of the surface layer, the developed steel is greatly superior to the soft-nitrided SCr420 steel in rotating bending fatigue strength, and has strength equal or superior to that of carburized SCr420.

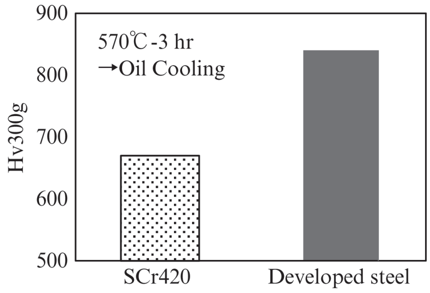


Fig. 5 Surface hardness of JIS SCr420 and developed steel after soft-nitriding

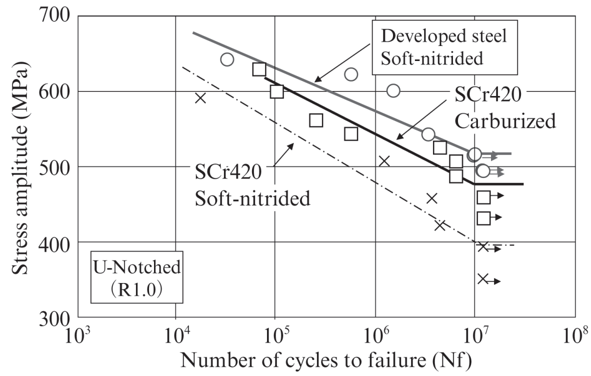


Fig. 6 Results of rotating bending stress fatigue stress of developed steel

## 6. Conclusion

It is considered possible to omit various processes by applying the developed steel. For example, in the gear manufacturing process, omission of the normalizing treatment before machining, and omission of the gear tooth face polishing process, which has been considered necessary after the general heat treatment processes of carburizing and high frequency induction hardening is expected to be possible, making an important contribution to reduction of part manufacturing costs.

Moreover, by making it possible to produce various types of shapes, not only of gears but also shafts and other parts, it is thought that the developed steel will make it possible to respond to diverse part designs. JFE Steel will work to further expand the use of this product based on a clear understanding of customers' applications and processing processes.

### Reference

1) T. Takase. Tetsu-to-Hagané. 1980, vol. 66, no. 9, p. 1423.

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