Soft-Nitriding Steel

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Synopsis

Gears for automotive engines and transmissions require strict dimensional accuracy for less noise and higher fatigue strength to make smaller and lighter. Though a soft-nitriding process, if applied on the steel surface, may satisfy the above requirements, the soft-nitriding on ordinary steel gears is not effective enough for improving their fatigue strength. So we examined the effect of alloying elements on hardness depth and core hardness. As a result, new soft-nitriding steels having high fatigue strength and dimensional accuracy have been developed, and commercially used for some gears.

1. Introduction

Gears for automotive engines and transmissions require high fatigue strength and dimensional accuracy to reduce noise as well as to make parts smaller and lighter for high engine performance and fuel cost efficiency. Such gears have so far been manufactured either through a machining-carburizing process, or a thermal refining-machining process in response to required gear properties. To make matters worse, carburized gears lack in dimensional accuracy, and thermally refined gears need more fatigue strength.

Soft-nitriding that is one of steel surface hardening treatments has merit of smaller dimensional change due to lower temperature heat treatment, compared with carburizing. However soft-nitriding on ordinary steel can not improve substantial fatigue strength. Under such circumstances, new soft-nitriding steel has been developed that satisfies both fatigue strength and dimensional accuracy.[1)~3)]

2. Discussion for Development of New Soft-Nitriding Steels

Figure 1 illustrates the development target in terms of relationship between fatigue strength and dimensional accuracy. Effects of alloying elements and microstructure on soft-nitriding were studied aiming at the improvement of case depth and core hardness.

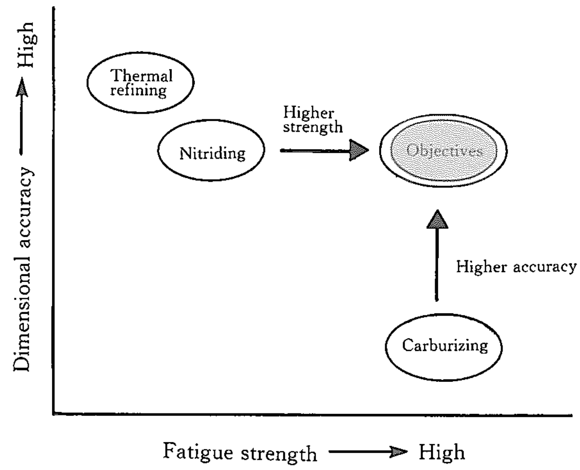

Fig. 1 Development objectives in relation with fatigue strength and dimensional accuracy of gears

2.1 Effects of Alloying Elements on Nitriding

The mechanism of case hardening by soft-nitriding is primarily considered to be solution hardening by infiltrating carbon and nitrogen and precipitation hardening by nitrides and carbides. Therefore, effects of aluminum, chromium and vanadium which are typical nitride and/or carbide formers were studied on soft-nitriding, as shown in **Fig. 2**. Aluminum is effective for increasing surface hardness, while chromium and vanadium increase case depth. **Figure 3** shows that 1.0%Cr-0.1%V steel forms deeper case by nitriding than such ordinary steels as JIS S43C and JIS SCM435.

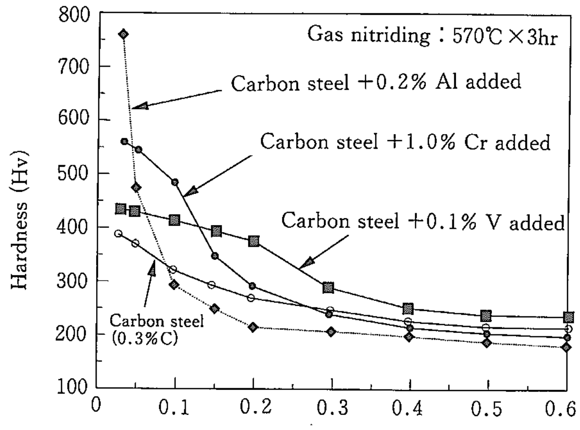

Fig. 2 Effects of alloying elements on hardness distribution of soft-nitrided steels

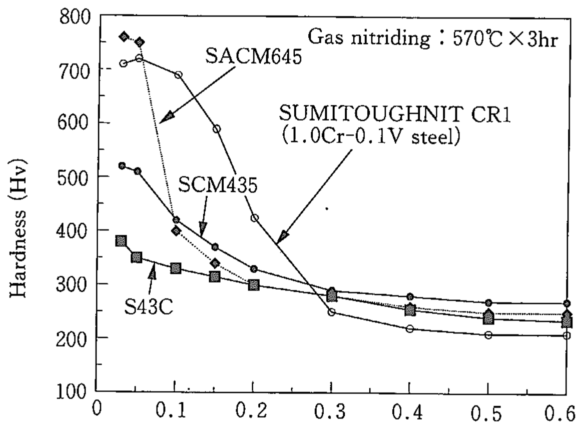

Fig. 3 Hardness distribution of developed soft-nitrided steels(CR1) comparing with common steels for machine structural use

2.2 Effects of Microstructure on Nitriding

The microstructure before nitriding is usually ferrite/pearlite formed through normalizing or tempered martensite formed by thermal refining. **Figure 4** shows that 1.0%Cr-0.1%V steel in a state of bainite microstructure realizes improved core hardness and case depth when compared with that of ferrite/pearlite and martensite microstructure.

Molybdenum was chosen to put steel in a state of bainite microstructure before nitriding. **Figure 5** shows the effect of molybdenum on stabilization of normalized hardness. 1.0%Cr-0.1%Vsteel satisfying the present objective is obtained over a wide range of cooling rates by addition of 0.2% molybdenum. As a result, 1.0%Cr-0.2%Mo-0.1%V steel was obtained that realizes stabilization of bainite transformation under air cooling.

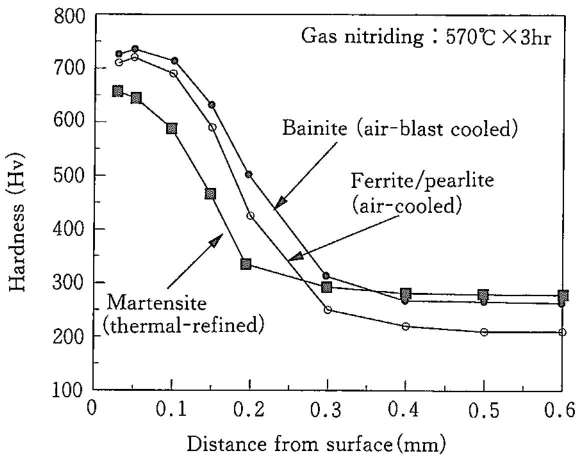

Fig. 4 Effects of microstructure on nitriding property

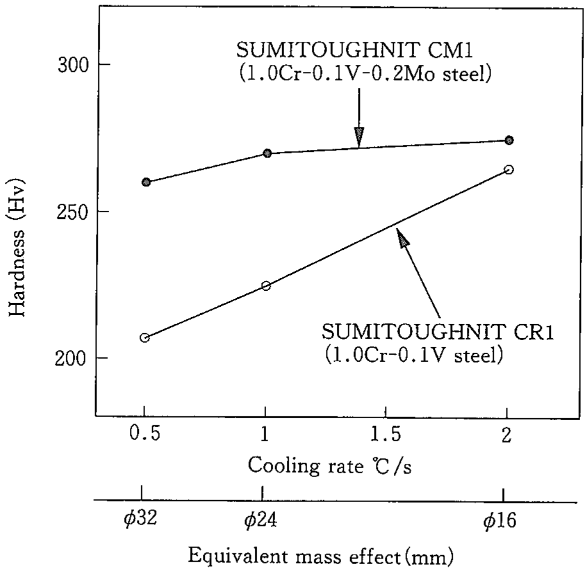

Fig. 5 Effect of Mo on stabilization of normalized hardness

2.3 Characteristics of Fatigue Strength

Figure 6 shows results of gear fatigue tests. SUMITOUGHNIT CM1(Cr-Mo-V steel) and SUMITOUGHNIT CR1(Cr-V steel) provide greater fatigue strength than that of the other carburized steels prepared for comparison. The high fatigue strength of SUMITOUGHNIT is considered to be due to its good hardening property and resultant high residual compressive stress.

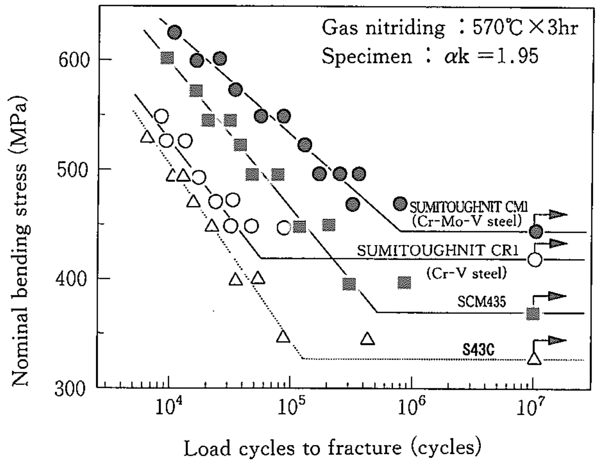

Fig. 6 Fatigue strength of soft-nitrided steels

3. Achievements and Possibility

Table 1 shows the characteristics of the developed soft-nitriding high-strength steel. It is hoped that these new soft-nitriding steels will be applied to various types of high strength machine parts, for example, gears of automotive engines and transmissions, many kinds of precise gears for industrial machines, and so on. Furthermore, for more dimensional accuracy, new soft-nitriding steels for cold forging are now dynamically being developed.

Table 1 Characteristics of developed steels

Steels	Heat treatment distortion	Mass effect	Fatigue strength of tooth root	Impact strength of tooth root	Pitting strength	Economical advantage	Chemical composition
SUMITOUGHNIT CM1	◎	Less	◎	△	△	◎	Cr-Mo steel +Micro alloying
SUMITOUGHNIT CR1	◎	More	◎	△	△	◎	Cr steel +Micro alloying

(Compare to SCM420 ◎ : Excellent ○ : Good △ : Poor)

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