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Development of High Strength Spring Steel with Excellent Fatigue Property by Suppressing Decarburization†

1. Introduction

Steel bars with a comparatively large diameter exceeding 20 mm are used as the material for coil springs applied in railway rolling stock, industrial machinery, construction machinery, etc. The steel bars that make up coil springs are subjected to torsional stress and bending-unbending stress accompanying repeated compression and tension of the springs. Because these forms of stress both reach their maximum values at the spring surface, the surface condition of the steel material has a large influence on the fatigue strength characteristics of springs. **Figure 1** shows the appearance of the fracture surface after a spring fatigue test. The origin of the fracture was on the inside diameter surface of the coil.

Many processes exist for forming coil springs under a hot condition, and imparting strength by direct quenching after the steel is formed into a coil shape. Those springs are used without removing the residual decarburization remaining at the surface after heat treatment, but this results in problems of reduced surface hardness due to decarburization and, in addition, reduced fatigue strength in the spring caused by reduced surface hardness. In other words, in many coil springs, it is important to suppress decarburization after hot forming and quenching.

This report examines a technique for suppressing decarburization after quenching by adding Sb and Sn to spring steel, and describes the decarburization reduction effect and influence on the fatigue characteristics of actual springs.

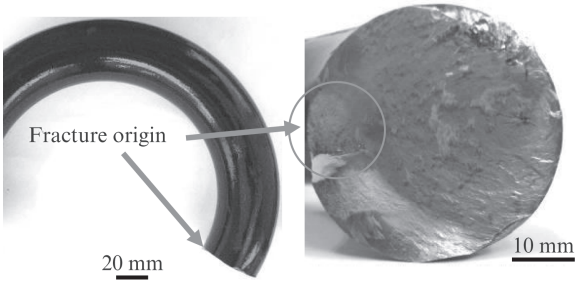

Fig. 1 Appearance of broken coil spring

2. Suppression of Decarburization by Trace Element Addition

Table 1 shows the chemical composition of the steels examined. The sample steels were prepared by adding Sb and Sn (SbSn added steel) or not adding those elements (SbSn free steel) to spring steel having the same chemical composition. **Figure 2** shows the results of observation of the cross-sectional microstructures of the sample steels after hot rolling, heating at 900˚C for 15 min, and oil quenching at 60˚C, and the distribution of the C concentration obtained from the results of Electron Probe Micro Analyzer (EPMA) measurements. From the EPMA measurement results, the C concentration of the surface layer of the SbSn free steel was approximately 0.2% and the decarburization depth was approximately 0.3 mm. In contrast to this, the C concentration of the surface layer of the SbSn added steel was approximately 0.45% and the decarburization depth was approximately 0.1 mm, con-

Table 1 Chemical compositions of steel examined (mass%)

	C	Si	Mn	Cr	Sn	Sb	Others
SbSn free	0.54	0.26	0.35	1.06	—	—	Mo, Nb
SbSn added	0.53	0.26	0.35	1.03	added		

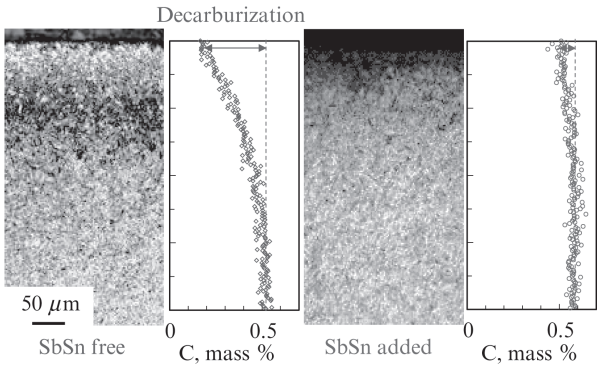

Fig. 2 Effect of Sb and Sn addition on decarburization after quenching and tempering

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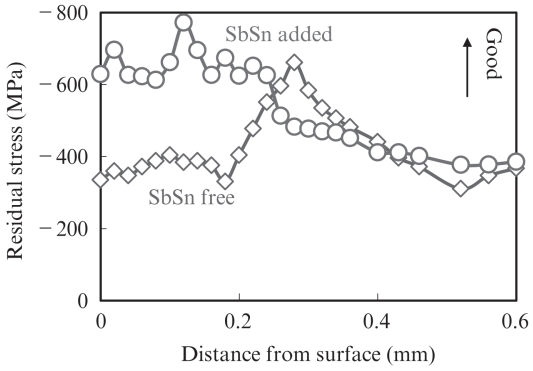

Fig. 3 Distribution of residual stress after shot peening

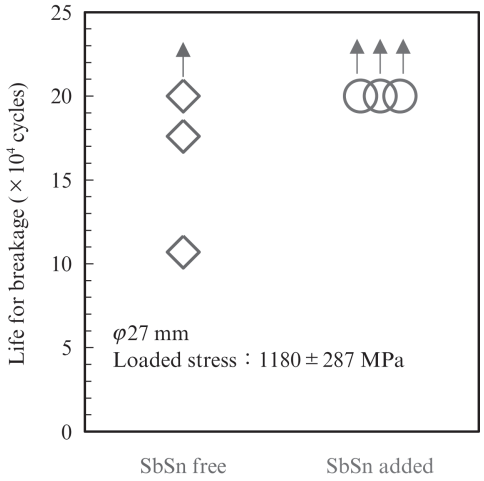

Fig. 4 Fatigue property of actual coil spring

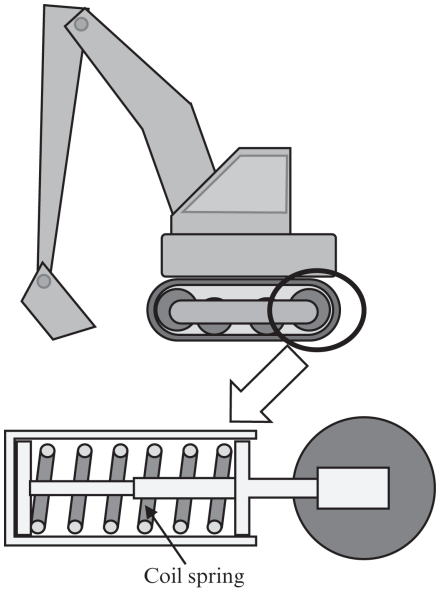

Fig. 5 An example of coil spring application

firming the decarburization suppression effect of Sb, Sn addition. It is thought that addition of Sb and Sn suppresses decarburization by reducing the diffusion coefficient of C.

3. Properties of Decarburization–Suppressed Steel

3.1 Addition of Residual Stress by Shot Peening

Shot peening is a generally used as a treatment for improving the fatigue characteristics of coil springs[1]. However, in the decarburized layer, yield stress decreases sharply by shot peening, and addition of residual stress also deteriorates remarkably. **Figure 3** shows the distribution of compressive residual stress after quenching and tempering and shot peening. In the SbSn added steel, the compressive residual stress of the maximum principal stress direction was −600 Mpa to −800 MPa in the region from the surface to a depth of 0.2 mm, but in the SbSn free steel, the range was −300 MPa to −400 MPa. That is, the compressive residual stress value of the SbSn added steel was about 300 MPa higher than that of the conventional material. As described in the previous section, in the SbSn added steel, decarburization was clearly recognized in the same region. This result is considered to show the effect of Sb and Sn addition in reducing decarburization.

3.2 Fatigue Characteristics of Coil Springs

In a joint development project with Sumihatsu Co., Ltd., coil springs were manufactured by Sumihatsu using a steel material based on this technology. **Figure 4** shows the results of a cyclic compression-tension fatigue test of actual springs manufactured using the SbSn added and SbSn free steels. The fracture life of the SbSn free steel was unstable, but in contrast, the SbSn added steel showed a stable, excellent fracture life.

The outstanding properties of the developed steel were confirmed, and the steel was adopted in suspension parts of construction machinery, as illustrated in **Fig. 5**.

4. Conclusion

This report introduced a new high strength spring steel utilizing a decarburization mechanism by addition of trace elements. Although the influence of alloying elements such as Si, Cr, etc. on the decarburization characteristics of steel materials has been investigated in many studies in the past, these elements have a large influence on material properties as such, beginning with hardenability, and it is not necessarily easy to control the amount of addition in practical steels. On the other hand, by adding trace elements, it is possible to suppress the change of other properties of the steel to a small level, and application to various types of steel materials is also possible. In the future, we will work to

ensure that customers can realize high functions in spring steel products, and will actively develop, produce and sell high performance spring steels that will enjoy the patronage of our customers.

Reference

1) Tange, A.; Akutsu, T.; Takamura, T. Transactions of JSSE. 1991, vol. 1991, no. 36, p. 47–53.

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