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A Highly Rigid Titanium Alloy for Golf Club Faces "SP-700HM"†

1. Introduction

"SP-700"[1–3] is a high-strength, high-formability titanium alloy for general-purpose applications, developed by JFE Steel in 1990. The alloy has excellent superplastic formability (**Fig. 1**) and fatigue strength (**Fig. 2**) compared to the general-purpose titanium alloy Ti-6Al-4V. Taking advantage of these properties, SP-700 is used to fabricate airframe parts and high-performance auto engine parts. SP-700 is also well recognized and widely used as a representative material for today's highly popular titanium golf clubs. The light weight, low Young's modulus, and high durability of the alloy make it ideal as a face material.

Recently adopted rules, however, restrict the use of golf clubs with face materials designed to deliver spring-like effects. Instead, the face materials now adopted must provide light weight and high stiffness. With the materials of these characteristics, engineers can design golf clubs in which the center of gravity of the head is positioned in a rear part to ensure high inertia, and with properties to facilitate the striking of the ball by the club. To respond, JFE Steel has developed SP-700HM, a new material ideal for golf club heads with high stiffness. SP-700HM maintains the excellent properties of the conventional SP-700 while complying with the spring-like effect (SLE) rule. This article describes this new material, SP-700HM.

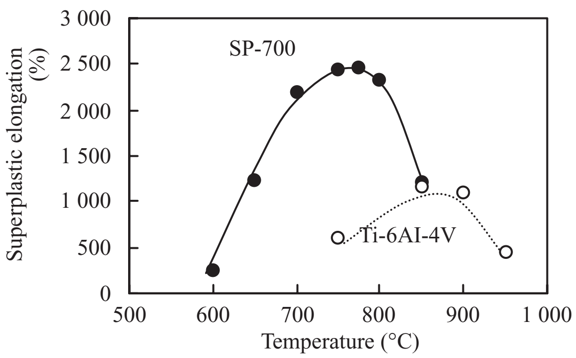

Fig. 1 Superplastic elongation of SP-700 and Ti-6Al-4V

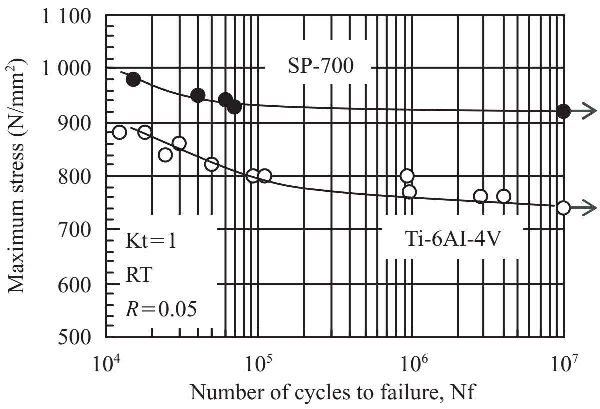

Fig. 2 Fatigue strength of SP-700 and Ti-6Al-4V

2. Properties of SP-700HM

2.1 Tensile Properties and Physical Properties

SP-700HM has a chemical composition of Ti-4.5Al-3V-2Fe-2Mo, the same composition as the general-purpose SP-700. But SP-700HM is designed to confer higher stiffness for the faces of golf clubs (the face stiffness) by controlling the texture formed by rolling. The face stiffness is proportional to the cube of the plate thickness and to the modulus of longitudinal elasticity (Young's modulus). **Table 1** shows examples of the room-temperature tensile properties of SP-700HM and SP-700.

In SP-700, the tensile properties and the Young's modulus in the final rolling direction, hereinafter referred to as "the longitudinal direction," are more or less equal to

Table 1 Tensile properties of SP-700 and SP-700HM

Material	Direction	UTS (N/mm^2)	0.2%PS (N/mm^2)	El (%)	Young's Modulus
SP-700HM	L	965	886	13	109
	T	1 175	1 143	15	137
SP-700	L	1 093	1 029	16	115
	T	1 097	1 059	16	118

L : Longitudinal T : Transverse UTS : Ultimate Tensile Strength
0.2%PS : 0.2% Proof Stress El : Elongation

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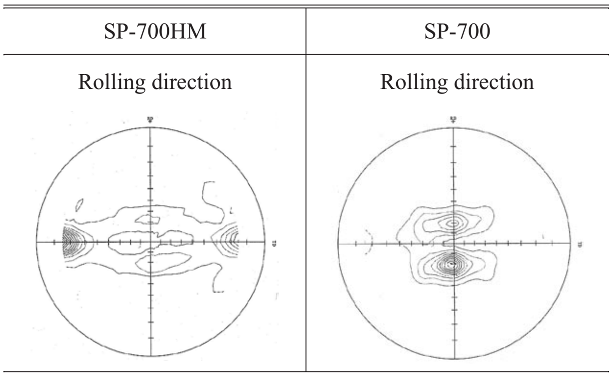

Fig.3 (0002)α pole figure of SP-700HM and SP-700

those in a direction perpendicular to the rolling direction, hereinafter referred to as “the transverse direction.” In SP-700HM, however, both the strength and Young’s modulus have larger values in the transverse direction than in the longitudinal direction. Specifically, the 0.2% proof stress and the tensile strength increase by 7% and 9.5%, respectively. Young’s modulus decreases in the longitudinal direction, whereas it increases by as much as 18% in the transverse direction. This Young’s modulus is far in excess of this figure. No significant difference in the ductility is observed between the two directions.

2.2 Texture

In order to study the cause of the directionality in strength and Young’s modulus in SP-700HM, the texture of SP-700HM and SP-700 was investigated. Pole figures of (0002)α of SP-700 and SP-700HM are shown in **Fig. 3**. In SP-700HM, the C-axis of the α-phase, an HCP structure, is coordinated in a direction inclined about 70° from the vertical direction in a plane perpendicular to the rolling direction. In SP-700, on the other hand, (0002)α plane is nearly parallel to the plane of this plate. This difference in the deformation texture is attributable to the strong directionality in SP-700HM and uniformity in the conventional SP-700.

3. Computer Simulation

JFE Steel conducted a computer simulation to confirm the benefit of using SP-700HM as a material for golf club faces. The simulation was executed with ANSYS, a finite element code. Three cases were analyzed. In the first case, the transverse direction of SP-700HM, which has higher Young’s modulus than the other, was arranged parallel to the horizontal direction of the face. In the second, this direction was arranged in the vertical direction. In the third, the longitudinal direction of SP-700 was arranged in the horizontal direction of the face.

In advance of the simulation, modulus of longitudinal elasticity (Young’s modulus) and Poisson’s ratio in three directions, longitudinal, transverse, and 45°, were measured by tensile tests. With these values, face stiffness was calculated as the displacement occurring when a fixed load of 1 N was applied to the center of a golf club face. The results of the calculation are shown in **Table 2**. In the case where the longitudinal direction of SP-700HM was arranged parallel to the horizontal direction of the face, the face stiffness increased by about 12% compared to the case with SP-700. When the longitudinal direction of SP-700HM was arranged in the vertical direction of the face, the face stiffness increased by about 8%.

Table 2 Face stiffness of SP-700HM by computer simulation

Material	Direction	Stiffness
SP-700HM	L	1.12
	T	1.08
SP-700	L	1

Photo 1 Golf club face application of SP-700HM (Courtesy of YONEX Co., Ltd.)

4. Examples of Application

A specific model was designed and manufactured with SP-700HM of 2.95 mm as a faceplate, and the golf club conformed to the R&A[i]/USGA[ii] Rule[4]. The same model was made with a faceplate of a β type titanium alloy, and the faceplate needed to be 3.15 mm in thickness in order to comply with the regulation. SP-700HM can then reduce the thickness of the faceplate by 0.2 mm, and the weight of face portion by 5 to 6 grams. The extra weight can be sophisticatedly distributed for lower and backward location of the center of gravity in the head, and as a result, high-trajectory and low-spin balls can be attain a long carry with ease.

Photo 1 shows an example of a golf club with a face

[i] The Royal and Ancient Golf Club of St Andrews
[ii] United States Golf Association

made from SP-700HM (courtesy of YONEX Co., Ltd.).

5. Concluding Remarks

This report presented the properties of SP-700HM, an alloy well suited for golf club faces. By using this material it becomes possible to increase stiffness, with the face plate thickness kept small, without any changes in the chemical composition or handiness. SP-700HM is expected for use in wider applications as a new, lightweight material capable of conforming to the spring-like effect (SLE) rule of golf club heads. New applications are also likely to be developed to fully exploit the excellent fatigue strength, the strength-reinforcement via texture control, and the anisotropy of stiffness of this new material.

References

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4) YONEX Co., Ltd. Private communication.

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