INFLUENCE OF ULTRASONIC-SHOT PEENING ON FATIGUE LIFE OF TINI SHAPE MEMORY ALLOY

K. Takeda[1], R. Matsui[1] H. Tobushi[1] and K. Hattori[2]
[1] Aichi Institute of Technology, Toyota, Japan
[2] Toyo Seiko Co., Ltd., Yatomi, Japan

1. Introduction

The shape memory alloy (SMA) is expected to be applied as intelligent materials since it shows the unique characteristics of the shape memory effect and superelasticity. In the growing number of TiNi SMA applications, these materials should fulfill high requirements of fatigue, corrosion and wear resistance. On the other hand, the application of SMA has some limitations, particularly in thermomechanical cyclic loading cases. In these cases, fatigue of SMA is one of the important properties in view of evaluating functional characteristics as SMA elements. The study on enhancement of the fatigue life for TiNi SMA by ultrasonic-shot peening (USP) has not been investigated till now. In particular, since impressions appear little by USP in the region of superelasticity, the influence of USP on the fatigue life is not clear. In this paper, we report and discuss the influence of USP shot media diameter d and coverage c on the bending fatigue life of TiNi SMA tape which shows superelasticity.

2. Fatigue life curve

The relationships between the bending strain amplitude ε_a and the number of cycles to failure N_f for five kinds of tapes obtained by the alternating-plane bending fatigue test under a constant frequency f = 150 cpm at room temperature are shown in Fig. 1. The bending strain amplitude ε_a was obtained from the bending strain on the surface of the specimen at the fracture point. The specimen was fractured at the midpoint of two grips. As can be seen in Fig. 1, the larger the bending strain amplitude, the shorter the fatigue life is. The fatigue life of polished and shot-peened tapes is longer than that of the as-received tape. The fatigue life of the tape USP-treated with d = 0.8 mm and c = 2000% is almost the same as that with d = 1.2 mm and c = 2000%. The fatigue life of the tape USP-treated with d = 0.8 mm and c = 4000% is longer than that of other shot-peened tapes. The fatigue life of the tape USP-treated with d = 0.8 mm and c = 4000% is 2.6 times at ε_a = 3% and 10 times at ε_a = 1% longer than that of the as-received tape, respectively.

3. Fatigue surface

3.1 As-received material

Figure 2 shows the SEM photograph of a fracture surface of the as-received tape obtained by the fatigue test for ε_a = 1.26%. In Fig. 2, F_c denotes the point of the fatigue crack initiation. The crack nucleates at a certain point F_c in the central part of the flat surface of the tape and propagates toward the center in a sinuous radial pattern. Although small cracks are observed in both flat surfaces of the tape subjected to maximum bending strain, one single crack grows preferentially. Following the appearance of fatigue crack with a semi-elliptical surface, unstable fracture finally occurs. In the case of as-received tapes, the point F_c appears at a central part of the flat surface subjected to the maximum bending strain and the fatigue life is short.

3.2 USP-treated material

SEM photographs of a fracture surface for the USP-treated tape in the case of a bending strain amplitude ε_a = 1.64% are shown in Fig. 3. The tape was USP-treated with shot media diameter d = 0.8

mm and coverage c = 4000%. As can be seen in Figs. 3, the fatigue crack nucleates at a certain point F_c in the corner on the side surface near the flat surface of the tape and propagates toward the center in a sinuous radial pattern. The reason why the fatigue crack nucleates at the corner surface is as follows. Although the maximum bending strain appears on the flat surface of the tape, the flat surface is subjected to USP and therefore it is hard for the fatigue crack to nucleate on the flat surface. The side surface of the tape is subjected to slight USP. As a result, the fatigue crack nucleates at the corner F_c near the flat surface.

4. Influence of hardness on fatigue life

Vickers hardness of the surface for four kinds of tapes was measured by a load of 49 N. The relationships between the number of cycle to failure N_f and Vickers hardness HV for various values of bending stain amplitude ε_a are shown in Fig. 4. In Fig. 4, the data are plotted by several symbols and the relation for each ε_a is connected by the straight line. As can be seen in Fig. 4, the fatigue life N_f of TiNi SMA treated by USP increases in proportion to Vickers hardness HV as same as normal metals. The influence of HV on N_f is slight in the case of large ε_a.

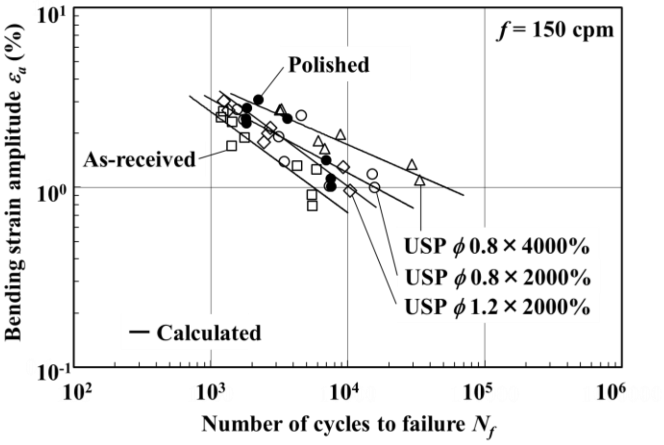

Fig. 1 Relationship between bending strain amplitude and the number of cycles to failure

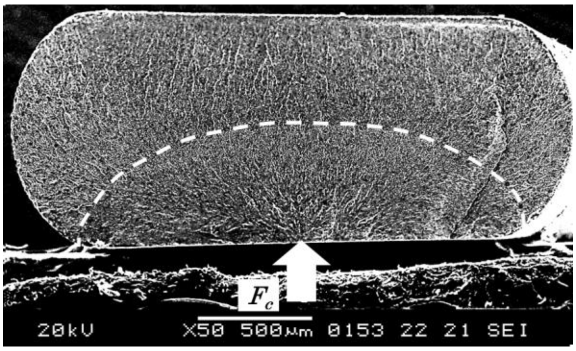

Fig. 2 SEM photograph of fracture surface of as-received tape for ε_a = 1.26% and N_f = 5906

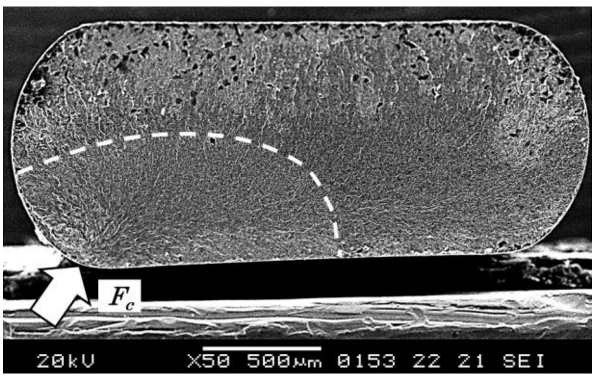

Fig. 3 SEM photograph of fracture surface of USP-treated tape for ε_a = 1.68% and N_f = 6788

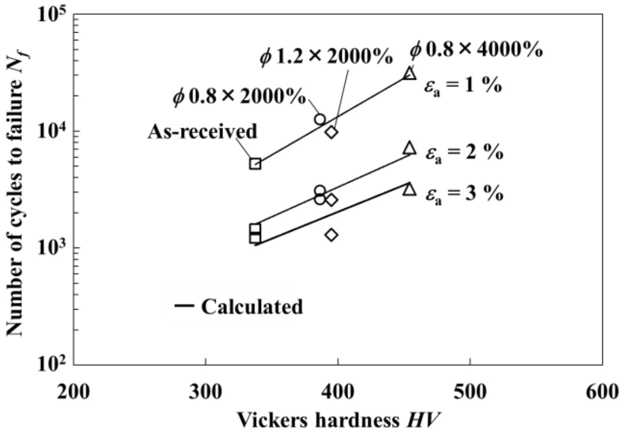

Fig. 4 Relationship between number of cycles to failure and Vickers hardness for various strain amplitudes ε_a