Residual Stress Analysis of Aircraft Part using Neutron Beam

Eunjoo Shin*, Baek-Seok Seong, Cheul Muu Sim
Neutron Science Division, Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: it-sej@kaeri.re.kr*

1. Introduction

A precise measurement of the residual stress magnitude and distribution is an important factor to evaluate the lifetime or safety of the materials, because the residual stress affects the material properties, such as the strength, fatigue, etc [1-4]. In the case of a fighter jet, the lifetime and safety of the parts of the landing gear are more important than that of a passenger airplane because of its frequent take offs and landings. In particular in the case of training a fighter jet, a precise evaluation of life time for the parts of the landing gear is strongly required for economic reason. In this study, the residual stress of a part of the landing gear of the training fighter jet which is used to fix the landing gear to the aircraft body was investigated. The part was used for 2000 hours of flight, which corresponds to 10 years. During this period, the fighter jet normally takes off and lands more than 2000 times. These frequent take off and landing can generate residual stress and cause a crack in the part. By measuring the neutron diffraction peaks, we evaluated the residual stress of the landing gear part[5-7].

2. Experimental

The sample is a steel bar used to fix the main landing gear to the aircraft body. In Fig.1 the sample was presented schematically. The sample is a cylindrical steel bar with a 22.2 mm outer diameter, 9.7 mm inner diameter and 55 mm length. It has a pin hole across the steel bar vertically with an 8 mm diameter. The material of the sample is a 4340 series stainless steel. Its yield strength is about 1800~1900 MPa. We used 2 samples for the measurements. Bar U is a used sample for 2000 hours and bar R is a new one as a reference sample. For the residual stress measurement, we used STRESS-SPEC in FRM2. The neutron wave length is about 0.168 nm, and the beam size is 2 mm $\times$2 mm. The crystal structure of the sample is BCT (martensite) and the Bragg plane used for the measurement is (211), $2\theta \approx 92^o$.

3. Results and discussion

The sample bar R is a new bar not used in an aircraft, so we used it as a reference sample to evaluate the used sample bar U. From the measured 2θ values, the lattice distances, d_o, of the (211) plane were calculated. To minimize the statistic error occurred during measurement, the mean value was calculated from several point measurements. The measurement positions are P1and P2 as like in Fig. 1. For the P1 position, two points of +10 mm and -10 mm from the pin hole(0 mm) were measured. And for the P2 position, three points of +10, 0, -10 mm were measured. In each point, 2 mm and 4 mm depth from the surface were measured. Total measurement points were 10 for each direction, radial, hoop and axial.

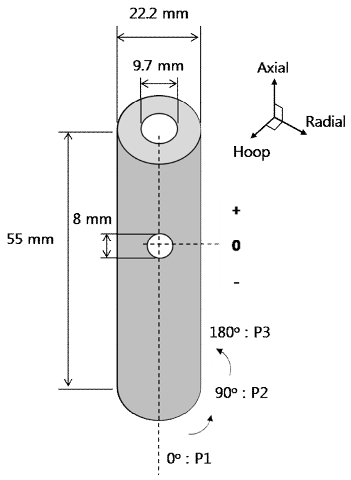

Fig. 1. Sample diagram

The values of each point in radial, hoop and axial direction showed similar values in error bound and did not presented any particular trend.

With same manner, we measured the 2θ values of sample U and calculated the strained lattice distances, *d'*. The measured points for radial, hoop and axial directions are like these. For the P1 position, 20 points, from +24 mm to -24 mm except pin hole, were measured. For the P2 position, 25 points include 0 mm were measured. Also for all point, 2 mm and 4 mm depth from the surface were measured. Especially for the axial direction, the points of the 0.5 mm depth was measured additionally.

In the Fig.2, the strains for the (211) plane of bar U were presented. The x-axis shows the position from the pin hole (0) and y-axis shows the strain value. In the case of radial direction, there is only small fluctuation within error bound independently of P1 and P2 also 2 mm depth and 4 mm depth position. Also, there isn't any particular trend. It's similar in the case of hoop direction. However the strain values of axial direction for P1 position showed relatively large difference. The trend of strain value along the bar length showed similar trend independently of the sample depth, and the strain presented a little larger value in the 0.5 mm depth position. The strain values showed about 400μ in the point around -15 mm and about -400μ in the point around 18 mm. That means the upper part of the sample was compressed a little and the lower part of sample was extended a little. But the strain values of axial direction for P2 positions showed only fluctuation in error bound. For the more investigation, we measured the strain for the axial direction of the P3 position which is opposite position of P1 include pin hole. As similar as P2, the strain values of P3 position showed just fluctuation.

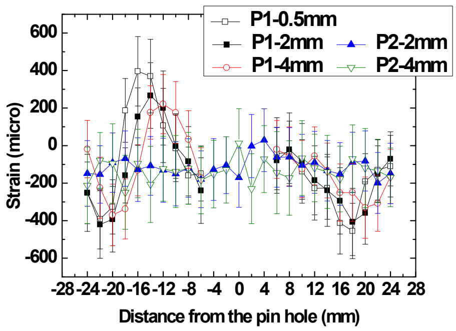

Fig. 2. Strain of sample bar U for axial direction

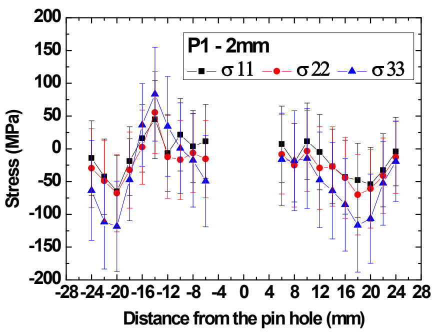

Fig. 3. Residual Stress of sample bar U; 2mm depth of P1 position

The residual stress is presented in Fig. 3. Only P1 position showed small stress, the maximum and minimum value of stress is about ±100 MPa. The positions of maximum and minimum value are about -15 and +18 mm point from the pin hole. It means that there was a compressive stress in the upper part of pin hole and a tensile stress in the lower part. On the other hands, P2 position presented only small fluctuation.

From the result, it can be surmised that the steel bar had been received a steady force for the one direction around the pin hole. The aircraft has one main wheel in front part of body and a pair of wheel in rear part. These wheels are hanging at the end of each landing gear. The sample U had been used for fixing the main landing gear to aircraft body by inserting another small pin across the pin hole of the sample. Actually the main landing gear had received an impact at the every taking off and landing. So the several times of taking off and landing more than 2,000 can occur the force to the sample especially around the pin hole because of the small pin inserted across the pin hole. However the force was probably weak and affected the small limited area so that it didn't affect the steel bar on the whole.

4. Conclusion

The residual stress for the part of landing gear of fighter jet was measured by neutron diffraction. The measure sample was a steel bar used to fix the main landing gear to the aircraft body for about 10 years. The residual stress was calculated from the strain measured for the lattice parameter of (211) plane. The strain appeared around one pin hole position (P1) for the axial direction. The strain presented a little lager value in the area closed surface. However, there was no strain in the opposite pin hole position and the other position. The maximum residual stress calculated from strain was about 100 MPa. There was a compressive stress in the upper part of pin hole and a tensile stress in the lower part. That means the steel bar received a steady force for the one direction around the pin hole.

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