Fault Detection of Tripod Shaft using Dual Strain Sensor

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ABSTRACT

Tripod shafts used in high-speed trains transmit power of motor reduction unit to axle reduction unit. Since the load applied to the reduction units is very large during operation, it is designed as the shaft with a fuse to protect gears of reduction units. Failure of the fuse can lead to accidents and economic loss such as train service interruption and repair problem in accident site. However, it is difficult to inspect the fuse covered by the tripod shaft housing. So, it is necessary to detect the fuse of the tripod shaft in advance. In this study, torsion fatigue tests considering failure mode were carried out and strain data were collected by strain sensors at around weak point of that. Thresholds for the damage detection of the tripod shaft fuse were defined by feature extraction from sensor data. We evaluated the detection performance of the thresholds.

1. INTRODUCTION

Reduction units for a high-speed train transmit the rotational force of the driving motor to the wheel through tripod shafts as shown in Figure 1(see square dotted lines). Safety, durability and reliability of the motor gear are very important because the load applied to the reduction unit for the high-speed railway is large when the train is operated. There is a fuse with embedded-type in the tripod shaft to prevent a traction motor. However, it is difficult to inspect the fuse covered by the tripod shaft housing. Thus, it is necessary to monitor the fuse of tripod shaft to detect damage.

Research on tripod shaft of reduction units for high-speed trains is being conducted (Kim et. al, Lee et. al). Moon, Lee, Kim, and Ji (2013) analyzed vibration characteristics of reduction gear units for monitoring reduction units. Their work covered the analysis of the vibration characteristics of the first and second reduction gears under normal operating conditions. Therefore, further analysis of the vibration characteristics of defective reduction units under abnormal conditions is needed and monitoring techniques should be developed.

We attempted to monitor the tripod shaft using strain data without using complex equations and evaluated damage detection performance.

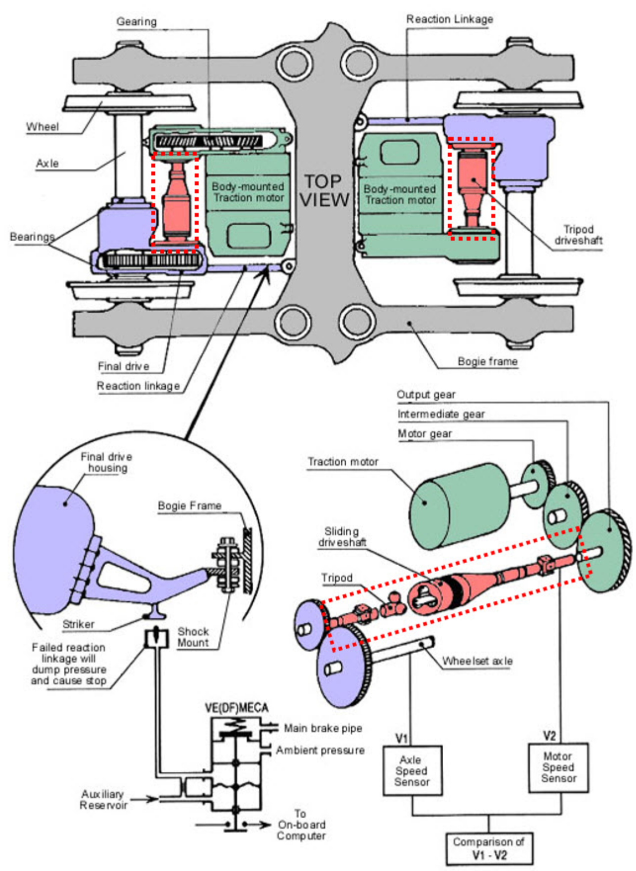

Figure 1. Tripod shafts in a high-speed train (source: http://www.skyscrapercity.com/showthread.php?p=18412262)

2. MATERIALS AND METHODS

For monitoring the tripod shaft for high-speed trains, the torsion fatigue tests considering the failure mode were carried out as shown in Figure 2. This test bed consisted of a Hottinger Baldwin Messtechnik data acquisition system (HBM-DAQ) and jigs on the tension-compression testing machine. The experiment was conducted at 1 Hz and strain data were collected with a sampling rate of 100 Hz. The experiment schedule for monitoring tripod shafts and detecting the damage as given in Table 1 was composed of three groups.

2.1. Correlation coefficient for detection of damage

A crack will begin at any weak point on the shaft preferentially while torque is applied to the shaft. Therefore, it was concluded that strain values at the less weak point and one at the starting point of the crack are closely related to each other. Thus, correlation coefficients (Cc) using the strain value was determined as a feature value for detecting an abnormal signal in order to detect an abnormal signal. The Cc of two variables of strain data, x = (SG1 + SG2) / 2, y = (SG3 + SG4) / 2 is defined as (Figure 3):

$$K = \frac{\sum_{i=1}^{n}(x_i - \bar{x})\cdot(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{1}$$

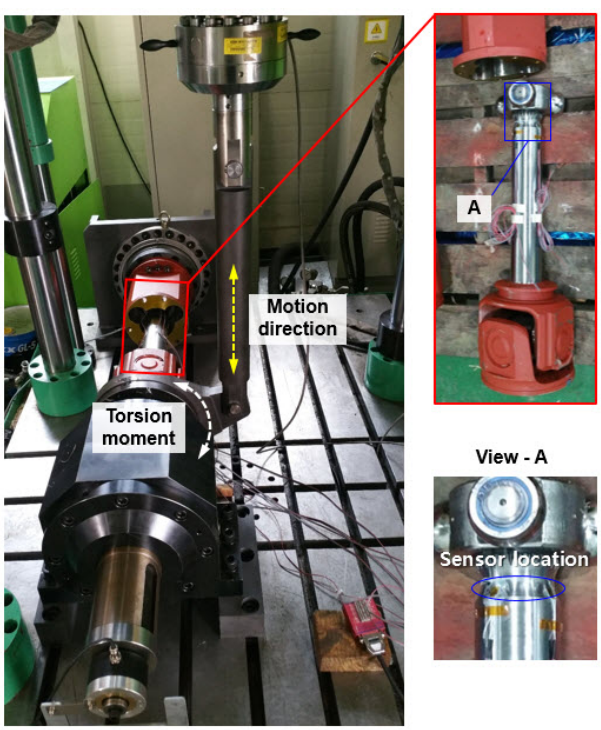

Figure 2. Test bed for torsion fatigue tests of tripod shafts

Table 1. Experiment schedule for torsion fatigue test

Torque	20 kNm	18 kNm	13.5 kNm
# of Sample	2	2	2

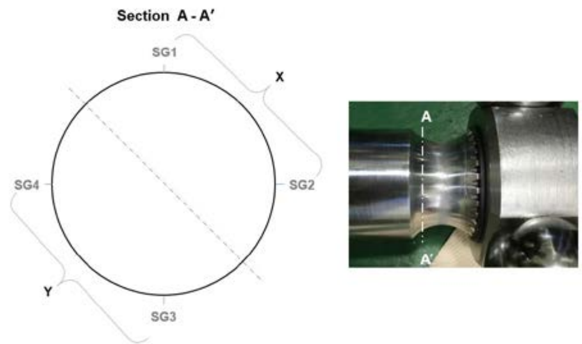

Figure 3. Sensor layout of tripod shaft fuse area

The correlation coefficient ranges from -1.0 to + 1.0. A Cc of -1.0 and +1.0 are called a perfect negative relationship and a perfect positive relationship between two variables. A Cc of 0.0 indicates no relationship between the two variables.

3. RESULTS AND DISCUSSION

Damage detection was conducted using dual strain sensor to detect abnormal signals under torsion fatigue test. The abnormal detection performance with the Cc is shown in Figure 4 and the health index was defined as the Cc of 0.98 which the point where a slope of its curve increases, was selected. The performance of this detector could detect damage of tripod shaft under torsion fatigue test as the life of 69.5% in remaining useful life between crack initiation and fracture.

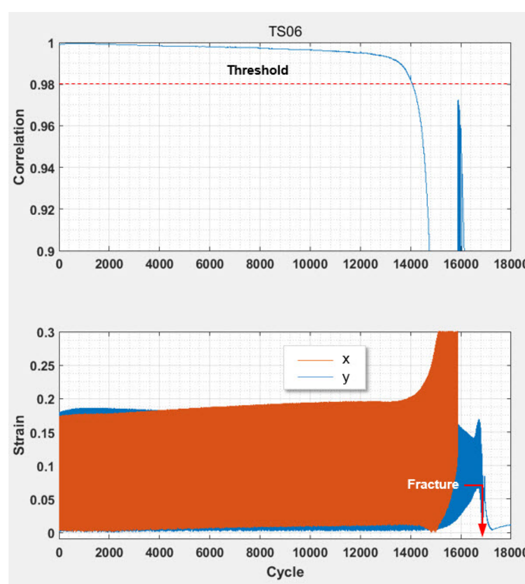

Figure 4. Performance of the abnormal detection using correlation coefficient

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