Preventing Fatigue Breakage of Contact Wires

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Contact wires are subject to a bending strain every time a pantograph slides along them. As the bending strain increases with an increase in train speed, it may cause fatigue breakage of the contact wires. This paper describes measures implemented to prevent fatigue breakage, such as measurement of the bending strain in contact wires and evaluation of the fatigue properties of contact wire materials.

The strain in contact wires is measured with a strain gauge fixed to the top surface as shown in Fig. 1. Since overhead contact wires normally carry a high voltage, the measurement signal is transmitted through a radio telemetry device. In the measurement process, a strain waveform in response to the passage of a pantograph is obtained, typically with the form shown in Fig. 2.

In evaluating the measured strain, the value of 500×10^{-6} is taken as the maximum allowable strain[1]. This value is the fatigue limit of a typical contact wire made of hard-drawn copper under no tensile load, which is compensated by the decrease in the fatigue limit due to the mean tensile stress imposed by the tensile load. The mean tensile stress assumes the value at the wear limit of the contact wire, or the maximum value generated in actual applications.

On the other hand, the fatigue properties of newly-developed materials for contact wires are often measured by implementing fatigue tests applied with an actual tensile load. The example introduced below uses high strength copper-tin alloy contact wires (SN-W contact wires). In a high-speed train application on the Shinkansen, the high-strength SN-W contact wires are manufactured by increasing the tin component of the conventional wear-resistant copper-tin alloy contact wires (SN contact wires with a tin component of 0.3%) to 0.35%, thereby increasing the degree of work hardening. Table 1 shows the characteristics of SN-W and two other types of wire.

Figure 3 shows a conceptual drawing of a fatigue test device for a contact wire, which is used to excite a contact wire vertically at the centre under a tensile load to generate bending strain repeatedly and measure the cumulative excitation frequency until it breaks or reaches the fatigue life.

Figure 4 shows the results of the fatigue tests, in which the mean tensile stress is set in consideration of a wear limit. That is, the mean tensile stress is set at a value not exceeding the tensile strength of contact wires divided by 2.2, the safety factor applied to copper and copper alloy contact wires in Japan. Figure 4 indicates that the fatigue resistance of SN-W contact wires is slightly higher than that of hard-drawn copper contact wires, as the evidence for the generally accepted view that fatigue resistance is correlated with tensile strength and other properties.

Regarding the SN-W contact wires, the author determined two semi-logarithmic approximate expressions, one in the long-life region and the other in the short-life region, to combine as a presumed 50% probability line for fatigue breakage. In the long-life region, the author also determined the standard deviation $\hat{\sigma}(\varepsilon_a)$ of strain amplitude ε_a from the approximate expression to draw a (approximate expression - $3.09\hat{\sigma}$) line or presumed 0.1% probability line for fatigue breakage. This is illustrated in Fig. 5. Strictly speaking, however, many more measurements are required to estimate the values of extremely small probabilities. The strain amplitude is 728×10^{-6} at the intersection between the 0.1% probability line for fatigue breakage and the line of cumulative excitation frequency of 10^7. When the cumulative frequency of excitation is regarded as the total number of pantographs that have slid along the contact wires, the strain amplitude of 700×10^{-6} seems allowable for SN-W contact wires with some margin, as the contact wires reach the wear limit before the cumulative excitation frequency of 10^7.

The Railway Technical Research Institute will collect data further on the fatigue of different contact wire materials and implement tests to study the effect of strain waveform on the fatigue life.

1) Railway Bureau of Ministry of Transport and Railway Technical Research Institute: "Manual for Speed-up Tests of Conventional Lines" (in Japanese), 1993

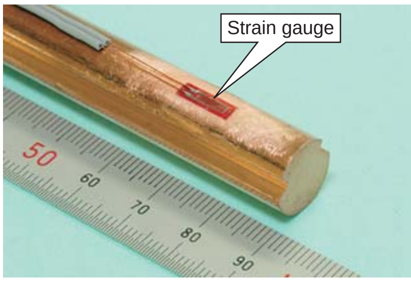

Fig. 1 A strain gauge fixed to a contact wire

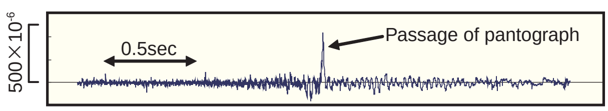

Fig. 2 A strain waveform in a contact wire

Table 1 Properties of three types of contact wires (comparison at a nominal sectional area of 170 mm^2)

	SN-W	SN	Hard-drawn copper
Cross section (mm^2)	169.7	169.4	170.0
Mass (kg/km)	1509	1506	1511
Minimum breaking load (kN)	74.5	58.8	57.8
Conductivity (%IACS)	≧70	≧70	≧97.5

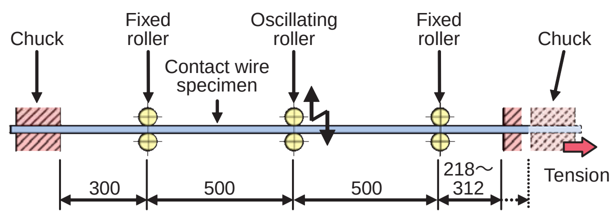

Fig. 3 Contact wire fatigue test device

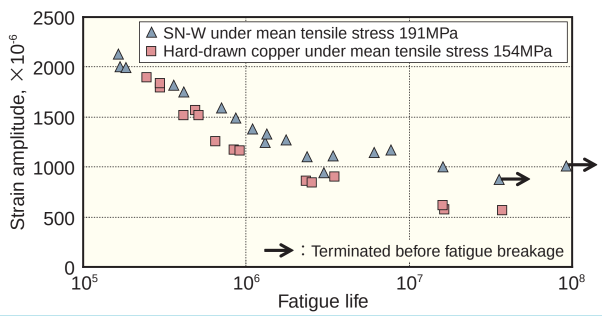

Fig. 4 Results of fatigue tests

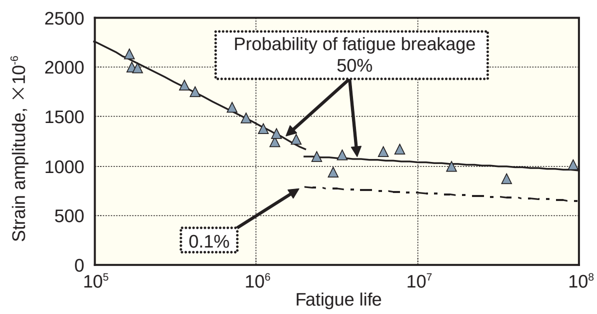

Fig. 5 Approximation of fatigue life property of SN-W contact wire