Effect of Surface Condition and Lubrication on Flange Climbing of Turned Wheels

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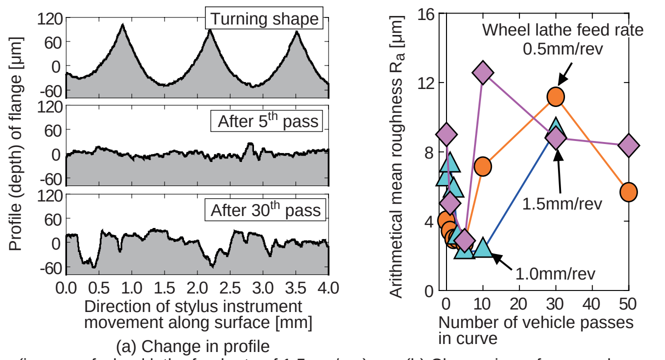
Flange climb derailments occur sometimes when vehicles run at low speed in sharp curves or in curves with turnouts soon after wheel turning (re-profiling). Those kinds of incidents raise concerns about the relationship between flange climbing and the surface condition of turned wheels. Thus, the author a) examined changes in the surface profile and roughness after turning, b) studied the characteristics of the coefficient of friction between wheel and rail, and c) verified through various techniques the effectiveness of the application of lubricant on wheel flanges just after wheel turning to prevent flange climb derailments.

Running tests involving the repeated passage of a vehicle were performed in a sharp curve of 200 m radius on yard track. Figure 1 shows the changes in the profile and roughness of the leading wheel's flange on the outer rail in relation to the number of vehicle passes in the curve. The figure indicates that the wheel surface, which began the test with significant roughness from wheel turning traces, became smoother after five to six passes in the curve and increased unevenness again thereafter. This trend is similar for different wheel lathe feed rates.

Figure 2 shows the results of another test using a twin-disc rolling contact apparatus to evaluate the effects of the environment and surface roughness on the coefficient of friction. A wheel-equivalent disc was tested under two roughness conditions and we obtained the following findings: (1) the equivalent coefficient of friction is larger under smooth than under rough surface conditions of the wheel disc and (2) for the smoother surface of the wheel disc, the equivalent coefficient of friction tends to increase when the relative humidity decreases. From the test results summarized in Figure 1, Figure 2 and other tests, we infer that there are increases in the coefficient of friction between wheel and rail due to an increase of the real contact area on the smooth surface and due to the wearing down of the peaks of the metallic substrata on the surface resulting from wheel turning. This phenomenon provides some understanding of the occurrence of flange climb derailments of turned wheels after running short distances. Application of lubricant on the flat section between the flange root and toe just after wheel turning is one of the practical methods to suppress the increase in coefficient of friction due to the changes in the wheel surface condition. Figure 3 shows the results of a numerical simulation of a vehicle running in a turnout's lead curve with a radius of 100m. The coefficient of friction of lubricants such as oil is around 0.1. Therefore, it is considered that lubrication on the flange suppresses flange climbing even if the value of the coefficient of friction on inner rail is large. Running tests using lubricated wheels with oil under a test vehicle that ran repeatedly over turnouts were also performed on test tracks. The results validated the assertion that lubrication on flanges suppressed wheel climbing whereas in the case of no lubrication and dry conditions the vertical displacement of the leading wheel on the outer rail increased with the number of passes over turnouts. And the tests also confirmed the lasting effect of lubrication in a short distance (Fig.4). Furthermore, we collected and analyzed substances attached to the wheel flanges of vehicles in commercial use. We found that more than 90% of the solid matter in the substances was ferrum (Fe) which was considered as wear debris from the wheel and rails. And a laboratory test to evaluate the coefficient of friction of the substance showed that oil mixed with substances such as wear debris maintains the effectiveness in preventing flange climbing.

In summary, lubrication is an effective countermeasure to flange climb derailment at low speeds when applied to the flat section between the flange root and toe just after wheel turning. The lubrication is effective since it is able to prevent the coefficient of friction from increasing during the period of dynamic change in the wheel surface. Some railway operators in Japan have already adopted this technique for practical purposes.



(a) Change in profile (in case of wheel lathe feed rate of 1.5mm/rev) (b) Change in surface roughness

Fig. 1 Change in profile and surface roughness of wheel flange's flat section after number of vehicle passes in curve

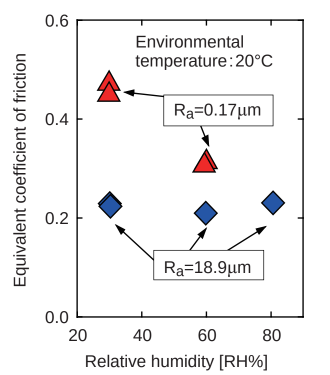


Fig. 2 Relationship between equivalent coefficient of friction and surface roughness Ra/environmental relative humidity

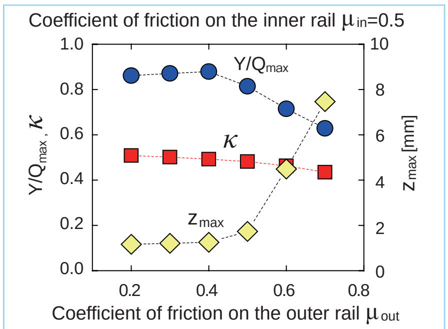


Fig. 3 Evaluation of running safety in relation to wheel/rail coefficient of friction based on numerical simulation for running on turnout

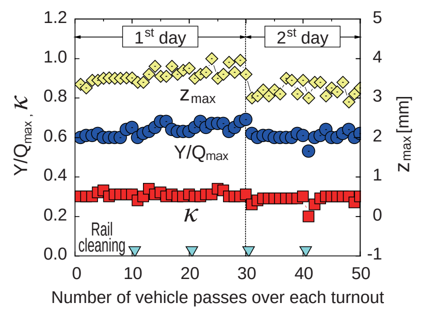


Fig. 4 Result of running test for repeated passage on turnout (in case of lubrication before running)

Y/Q_{max} : Maximum value of derailment quotient
κ : Ratio of lateral force and wheel load on the inner rail
z_{max} : Maximum value of vertical displacement of wheel on the outer rail