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RAIL CORRUGATIONS CAUSED BY LOW COEFFICIENT OF FRICTION IN A SUBMARINE RAILWAY TUNNEL

Makoto Ishida[*1], Fusayoshi Aoki[*1], Yasutomo Sone[*1]
Takumi Ban[*1], Kensuke Shirouzu[*2]
*1:Railway Technical Research Institute *2 :West Japan Railway Company
Kokubun-ji-shi, Tokyo, Japan Osaka-shi, Osaka, Japan

ABSTRACT

One of some types of rail corrugations is caused on railway rail surface in a submarine tunnel. It poses a large problem from the aspects of railway vehicle and railway track deterioration. In this paper, the mechanism of the rail corrugations was studied with the focus placed on roll-slip of wheel and rail interface. Traction and vertical force interacting between wheel and rail were investigated by a vehicle/track interaction model, and the coefficient of friction (COF) on rail surface was measured. Also, the rail surface was analysed with infrared to understand the chemical composition of surface layer influenced by salty and very humid atmosphere in the submarine tunnel. ß-FeOOH was found out as a cause of reducing COF on rail surface.

1. INTRODUCTION

There are some types of rail corrugations which are a kind of rail surface irregularity formed in railway track[1]. In this paper, rail corrugations, shown in Fig.1, specifically formed in the ascending slope of a submarine railway tunnel, Shin-Kammon tunnel in San-yo Shinkansen line of West Japan Railway Company, were studied[2]. Since they were causing noise and large interacting forces between wheels and rails to damage vehicle and track components, a large amount of maintenance cost such as frequent rail renewal, rail grinding and so forth has been spent to cope with those problems.

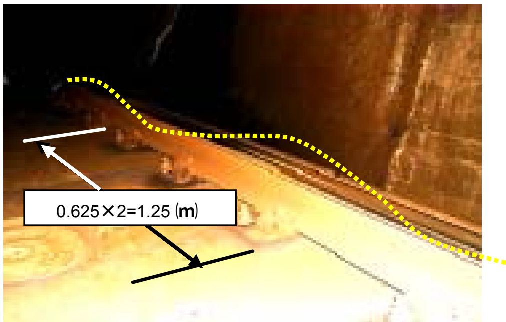

Fig. 1 Rail corrugations in Shin-Kanmon Tunnel

2. CURRENT STATUS OF RAIL CORRUGATIONS IN A SUBMARINE TUNNEL

The rail corrugations formed in the tunnel constructed under the sea described here may have some phase lag between right and left rails. Also, the wavelength of the rail corrugations is about 1.2m whose excitation frequency of vehicle/track dynamic behaviour calculated by the running speed of railway vehicles is about 70Hz which is almost the same as the resonance frequency of unsprung mass of vehicle supported by track stiffness.

With regard to phase lag between right and left rails, there are two cases. One is the same phase of both rails and the other is the phase lag of 180 degree between right and left rails. Considering those facts, the resonance of unsprung mass of vehicle and the rolling vibration of wheelset may have great influence on the mechanism of rail corrugations.

Fig. 2 shows the location of rail corrugations observed in ascending slopes of the tunnel. In this figure, corrugations are generated only in ascending slopes not in descending slopes, and in almost tangent track, which suggests the corrugations must be caused by driving wheels not following wheels.

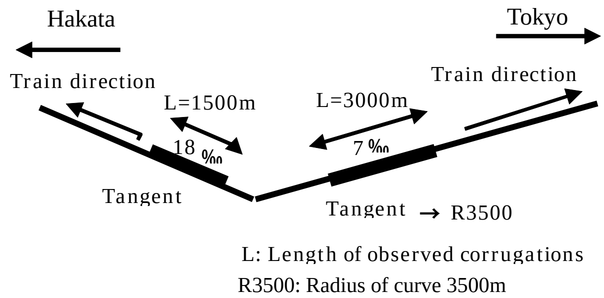

Fig. 2 Location of rail corrugations formed in the Shin-Kanmon Tunnel

3. FORMATION MECHANISM OF RAIL CORRUGATIONS

According to the findings about the rail corrugations, which are formed in the tunnel under the sea described in this paper, the factors of mechanism of rail corrugations are considered to be as follows:

1) Large traction force is generated by driving wheels to climb up the ascending slopes of the tunnel. The maximum traction force which is estimated by wheel load multiplied by the maximum traction coefficient is almost equal to kinetic COF in the case of normal dry condition, changes in proportion to wheel load variation.

2) Wheel load variation is excited at the irregularity of rail welds. The resonance of unsprung mass of vehicle supported by track stiffness are induced due to such an excitation.

3) Wheels drive on rails with some rolling inertia. Rolling inertia of wheel can't always follow the variation of maximum traction force depending on the surface conditions of rail and wheel, which may induce longitudinal roll slip phenomenon along rails.

4) As a result, such a roll slip phenomenon may cause rail corrugations. In fact, driving force can excess over the maximum traction force depending on wheel load variation and kinetic COF, and wheels can slip on rails very slightly.

To verify the above-mentioned mechanism of rail corrugations, it is desirable that the roll slip phenomenon of wheel is directly confirmed from the variation of wheel rotation. However, the measuring the variation of wheel revolution precisely enough to identify the phenomenon of about 70Hz excited by the rail corrugations.

On the other hand, fortunately there is a mountain tunnel in which no rail corrugations are formed in almost the same ascending slope and driving wheel conditions in San-yo Shinkansen line as those in the tunnel under the sea. If the kinetic COF of rail can be compared between the mountain tunnel and the under-sea tunnel, the possibility of rail corrugations may be found out to understand such a roll slip phenomenon.

4. INFLUENTIAL FACTORS OF THE MAXIMUM TRACTION COEFFICIENT AND CONCLUSION

Investigating the possibility of the roll slip, the kinetic COF of rail was measured focusing on rust on the surface of rail due to the atmosphere in the tunnel under the sea to check the appropriately low COF which may induce roll slip phenomenon. However, it was not easy to measure the kinetic COF with a tribometer which is always adopted to measure the kinetic COF on the surface of rail because of too large moving resistance of steel bearing balls caused by very thick rust on the surface of rails. In fact, the kinetic COF cannot be properly evaluated by the rail tribometer.

Then the rust and/or surface materials generated on the surface of rails under the atmosphere both in the under-sea tunnel and in the mountain tunnel was analyzed to investigate the cause of low COF and roll slip phenomenon by infrared spectral analysis and X-ray diffraction analysis. The investigated and analyzed results of rust and surface materials of the both tunnels are as follows:

Fig.3 shows X-ray diffraction pattern analyzed for the surface materials of rail samples rested for a half year in the vicinity of track not installed in track in the under-sea tunnel and the mountain tunnel. In this figure, ß-FeOOH was found out only from the surface of rail samples in the under-sea tunnel. ß-FeOOH is generated by the atmosphere related to salty environment and can be the cause of low COF[3]. Considering the environment of the under-sea tunnel, ß-FeOOH should be generated and roll slip phenomenon takes place due to slightly low COF. On the other hand, roll slip phenomenon should not take place in the mountain tunnel because of no ß-FeOOH.

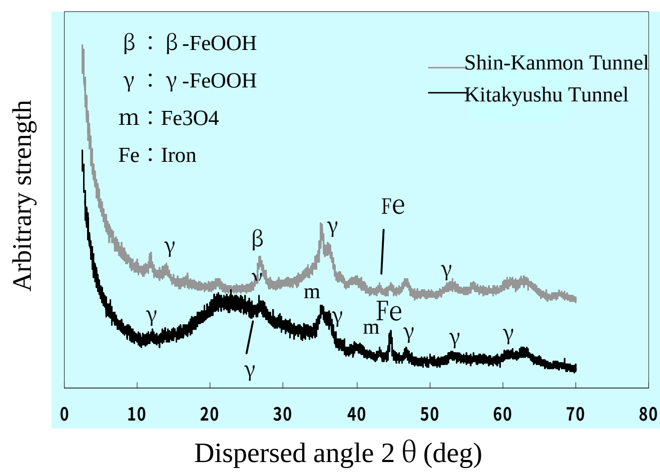

Fig.3 X-ray diffraction pattern of surface materials

5. CONCLUSION

ß-FeOOH was found out as one of causes to reduce COF on the rail installed in the salty and humid atmosphere, which should have given rise to roll slip between wheel and rail. Further study will be expected to understand how ß-FeOOH is produced and how to avoid producing it.

Reference

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