

Performance Study of a Double Crossover for Facing and Trailing Directions

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ABSTRACT: This paper presented the performance study of two frogs in a double crossover in the railway network in the Netherlands. These frogs are located on the same track line. Each train passes through Frog 1 in the facing direction and Frog 2 in the trailing direction. Both frogs are monitored with ESAH-M crossing dynamic behaviour measurement tool and remote displacement measurement system Video Gauge.

Results indicate that Frog 1 experiences high wheel/rail contact force (acceleration) and wear in Frog 2 develops fast. Frog 2 suffers from lack support of ballast, while the potential damage in Frog 1 is mainly related to the rail part.

1 INTRODUCTION

A turnout lifetime typically encompasses several main phases: construction, usage, maintenance or replacement. During the lifetime, trainload, thermal gradients, corrosion, chemical attack, insects, etc. stress railway turnout. Dynamic trainload dominated in turnout condition development. Primary experimental and numerical researches indicate that train axle load [1], travelling directions [2], train-passing quality [3], crossing type (material, number, etc.) [4], wheel/crossing profile [4-6], sleeper/ballast stiffness [7-8], etc. all influence in crossing performance.

A crossover is a pair of crossings that connects two parallel rail tracks. The utility of a crossover is to provide skylight time for each line in busy track. This speciality involves wheel/crossing interaction mainly in straight direction. On the other hand, extra interruptions are brought into straight lines. The presented study is a part of the ongoing project Structural Health Monitoring System (SHMS) for railway turnouts (TU Delft). The objective is to evaluate the performance of these crossings, then further assess the structural degradation procedure and give advice on maintenance.

2 MEASUREMENT OVERVIEW

2.1 Field condition

The crossings are casted manganese steel frogs (1:9) in a double crossover in the railway network in the Netherlands. These frogs are located on the same track line. Trains pass through one frog (Frog 1) in the facing direction and another (Frog 2) in the trailing direction. Therefore, the wheel/rail impact position on Frog 1 is on the wing rail, while on Frog 2 is on the crossing nose. Regarding to the frog number, the train operating velocity on this line is relatively high – 140 km/h. The problems observed on these frogs mostly related to rail damage and geometry deterioration. By the start of monitoring, Frog 1 was in normal operation condition, Frog 2 was brand new.

Two measurement systems are introduced in the monitoring of both frogs. ESAH-M measures the dynamic 3-D accelerations, wheel/crossing impact positions and wheel passing quality [9-11]. Video Gauge System records the dynamic movements of rail/sleepers when a train passing through [11].

The main unit of each ESAH-M is located out of the track with extension cables connecting to all the sensors attached in the crossing. An accumulator supplies power for each ESAH-M, which guarantees ESAH-M to measure up to 500 passing trains continuously. Video Gauge is a system with extreme reliability on hard disk storage and power supply, continuous measurement is difficult to implement. Video Gauge measurements performed with intervals of 2-3 weeks. Waterproof targets were installed on the interested positions in advance. With all these preparation, measurements can be done without access to the track.



Figure 2.1 Instrumented frog with ESAH-M sensors and Video Gauge targets/camera

2.2 Measurement Arrangement

The storage of ESAH-M is 500 passing trains regardless of power supply. Based on the train density, the system will become full in around 3 days. In one ESAH-M measurement period, the track condition is assumed to be unchanged. In Frog 1, due to the high impact forces, the ESAH-M acceleration sensor felled off several times, all the unreliable data is removed from the database.

By the time of writing this paper, ESAH-M data is collected 6 times and Video Gauge measurements are performed 5 times. Measurement arrangement is precisely shown in the table below.

Table 2.1 Measurement arrangement

Date	Applied measurement devices	
	Frog 1	Frog 2
2015.03.09	Video Gauge	ESAH-M, Video Gauge
2015.03.27	Video Gauge	ESAH-M, Video Gauge
2015.04.02	-	ESAH-M
2015.04.08	ESAH-M	-
2015.04.17	Video Gauge	ESAH-M, Video Gauge
2015.04.23	ESAH-M	-
2015.05.01	ESAH-M, Video Gauge	ESAH-M, Video Gauge
2015.05.19	ESAH-M	ESAH-M
2015.07.02	Video Gauge	Video Gauge

3 RESULTS AND DISCUSSION

3.1 Wheel/rail interaction

ESAH-M records the frog acceleration signal with a sampling frequency of 10 kHz, automatically calculates maximum accelerations of each passing wheel. Based on the time point of maximum vertical acceleration of each passing wheel, the wheel/rail impact positions are collected to detect the fatigue area on the frog. The wheel passing condition according to the wheel/rail contact angle is also detected [9-11].



Figure 3.1 Fatigue area (Left) and wheel passing condition (Right) definition

In Frog 1, trains pass through it in trailing direction. The datum point of contact position is crossing nose, fatigue area on the wing rail. In Frog 2, fatigue area on the crossing nose, same as given in Figure 3.1. The figures below are contact position development in both frogs.

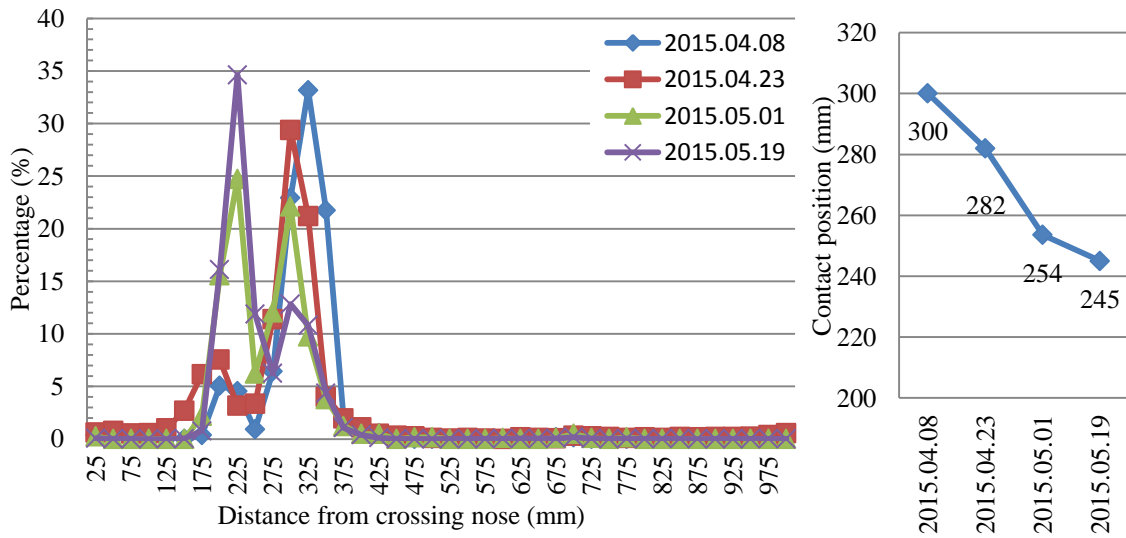


Figure 3.2 Wheel/wing rail contact position in Frog 1

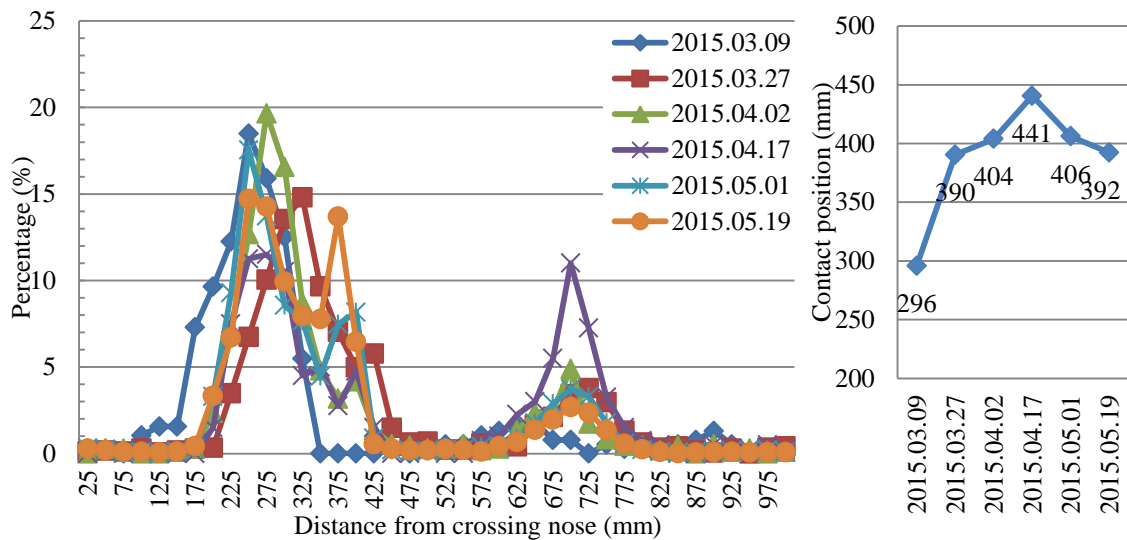


Figure 3.3 Wheel/crossing nose contact position in Frog 2

Figure 3.2 manifests two contact bands on the wing rail, one around 225mm and another around 325mm from the crossing nose. In the monitoring period, the main band shifted from 325mm to 225mm, and the average contact position decreased from 300mm to 245mm. Frog fatigue area centralized in 150-400mm.

In the initial operation period of Frog 2, wheel/rail impact area mainly distributes between 150mm and 350mm with an average value of 296mm. After 2 weeks, wheel/rail contact area gradually separates into two parts: main band in 200-450mm and minor band around 700mm. On 2015.04.17, wheel/rail contact in the minor band accounted for around 30%, and the average contact position is 441mm. In the other measurements, the average contact positions are around 400mm and minor band accounted for around 15% (Figure 3.3).

Dynamic acceleration of the frog reflects the wheel/rail contact force. Specifically, vertical acceleration mainly represents the impact when a wheel jumping from guide rail to the crossing nose, and vice versa. Lateral acceleration reflects the fierce degree of wheel flange contact. When the lateral acceleration dominated in total acceleration, the wheel/rail contact will be recognized as irregular contact (Figure 3.1), wheel-passing condition is inferior. Figure 3.4 – Figure 3.7 are the measured vertical acceleration distribution in both frogs.

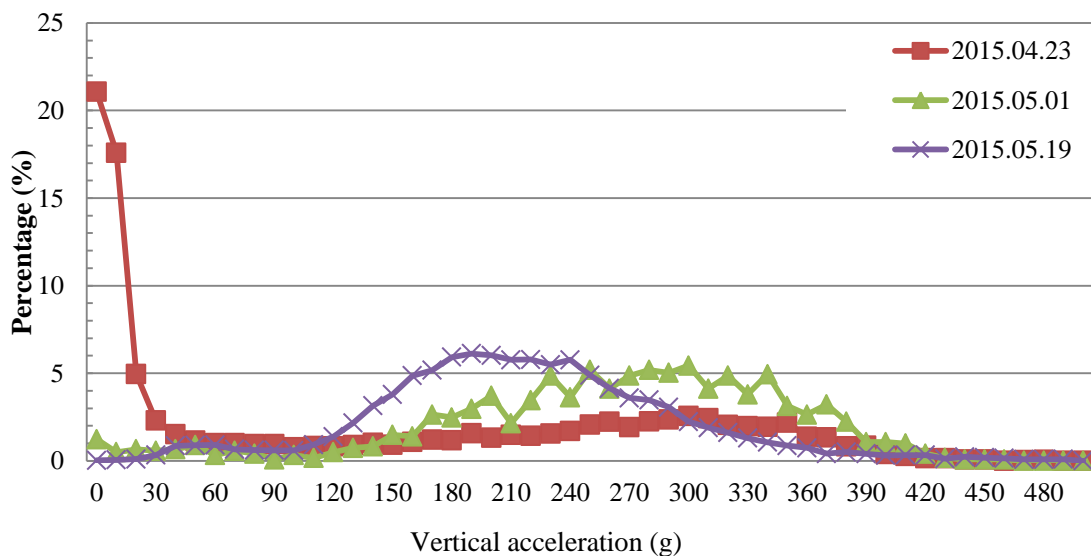


Figure 3.4 Vertical acceleration distribution of all passing wheels in Frog 1

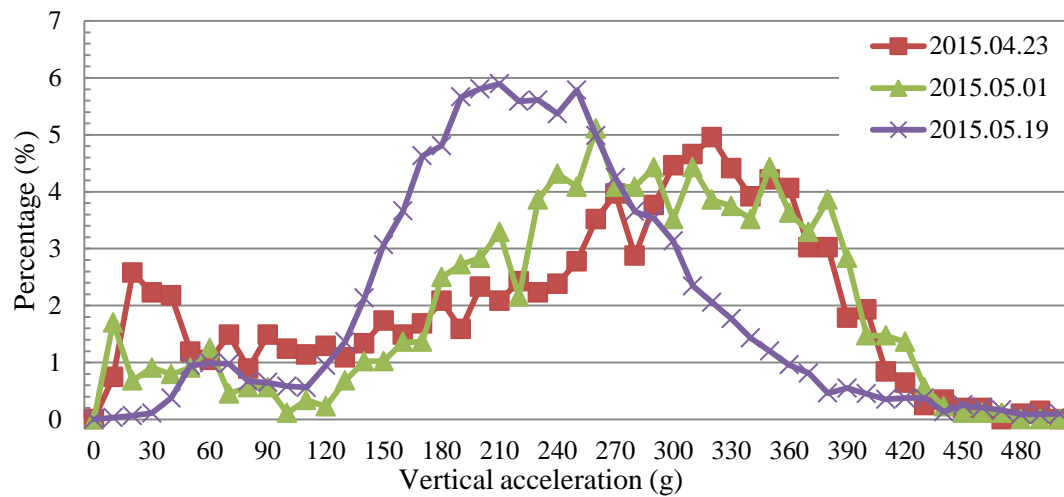


Figure 3.5 Vertical acceleration distribution of normal passing wheels in Frog 1

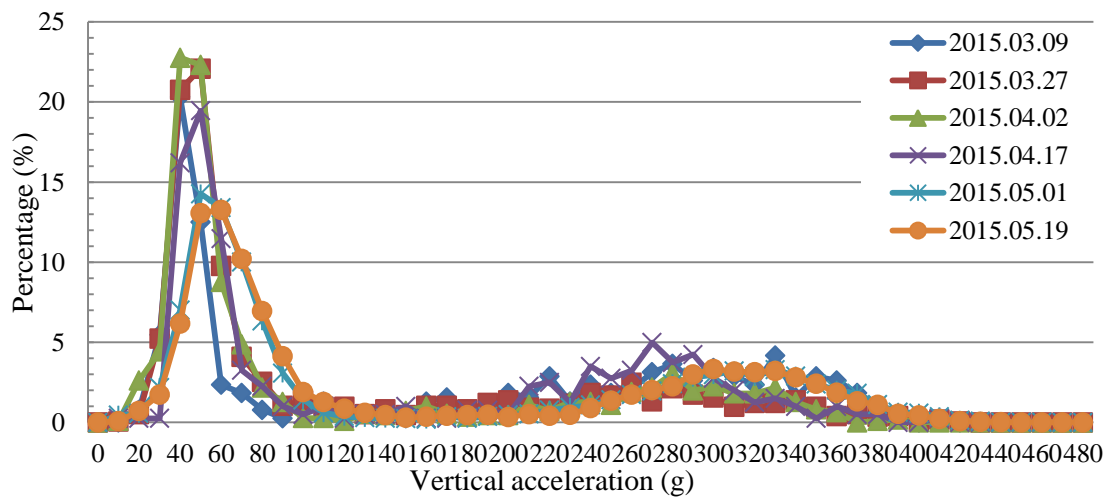


Figure 3.6 Vertical acceleration distribution of all passing wheels in Frog 2

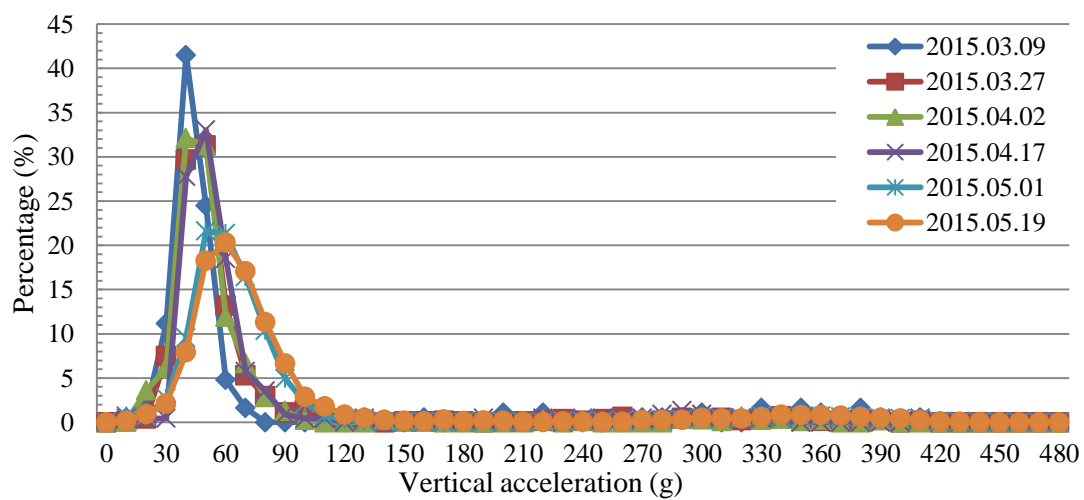


Figure 3.7 Vertical acceleration distribution of normal passing wheels in Frog 2

On the first record day in Frog 1, the majority passing wheels with rail vertical accelerations below 50g generated higher lateral accelerations. In normal passing condition, the vertical acceleration distributed mainly between 120g and 420g. During the monitoring period, the overall distribution shifted from around 300g to around 200g.

In Frog 2 measurement, the responses of regular passing wheels are mainly in the range of 20g to 100g. Irregular passing wheels generate high impact in lateral direction as well as in vertical direction.

Average acceleration values (α) describe the level of wheel/rail contact, and standard deviations (σ) are the reflection of distributions.

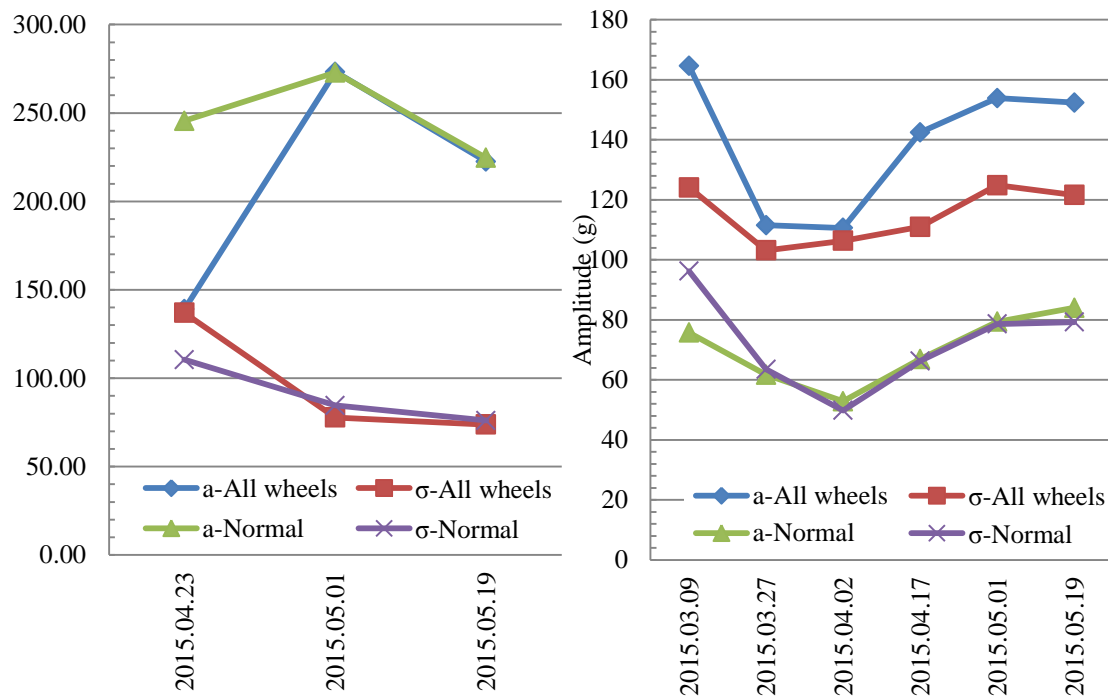


Figure 3.8 Average value and standard deviations of vertical acceleration in Frog1 and Frog 2

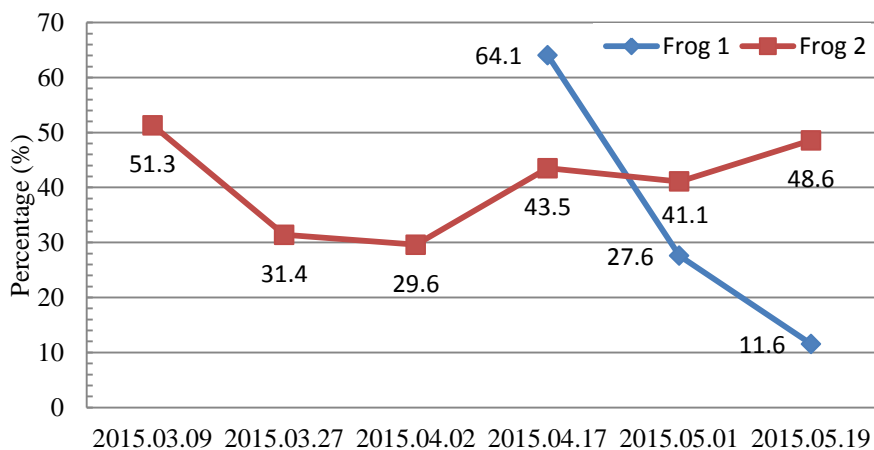


Figure 3.9 The development of the proportion of irregular passing wheels

Figure 3.8 and Figure 3.9 indicate that in the first record day of Frog 1, 2/3 of the wheels pass through the frog irregularly. In the following two record days, the proportion of irregular passing wheels dramatically decreased.

In the initial operation stage of Frog 2, half of the wheels pass through the frog irregularly. This ratio decreased in the next two record days and then increased again. In Frog 2, the average vertical acceleration value, standard deviation and the ratio of irregular passing wheels have positive correlation.

3.2 Ballast stiffness analysis

Video Gauge System mainly records the vertical displacements with a sampling frequency up to 117 Hz. Rail/sleeper displacement contains two main parts: low frequency (up to 10 Hz) and high frequency (30-50 Hz) responses. Low frequency response reflects the void between sleeper and ballast. High frequency response, on the other hand, describes vibration in the measurement system [11]. These two parts are separated by Chebyshev II Filter in MATLAB. The following figure is an example of filtering effect.

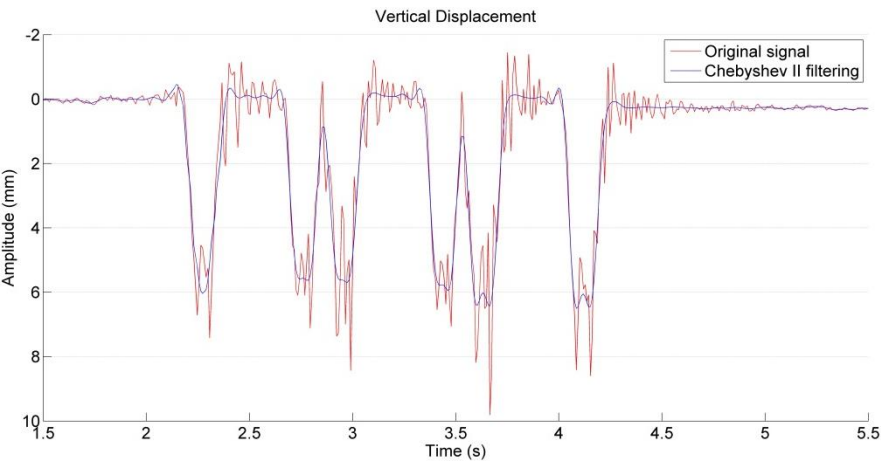


Figure 3.10 Chebyshev II filtering effect

Figure 3.10 indicates that Chebyshev II Filter effectively eliminates the structural vibration. The rest part is mainly the vertical movement of sleeper with the impact of passing train, which reflects the void under the sleeper. The measurements comparisons describe the void development in both frogs in the monitoring period.

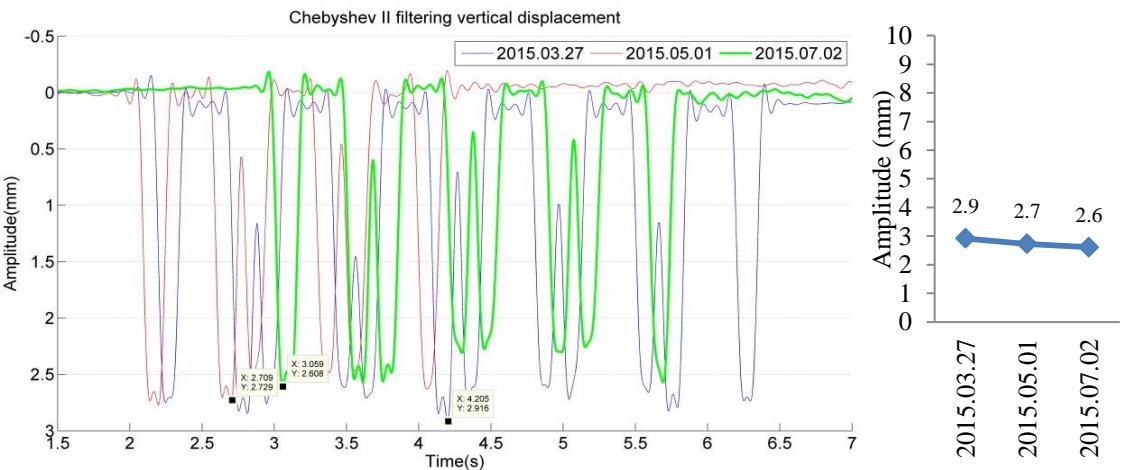


Figure 3.11 Vertical displacement development in Frog 1

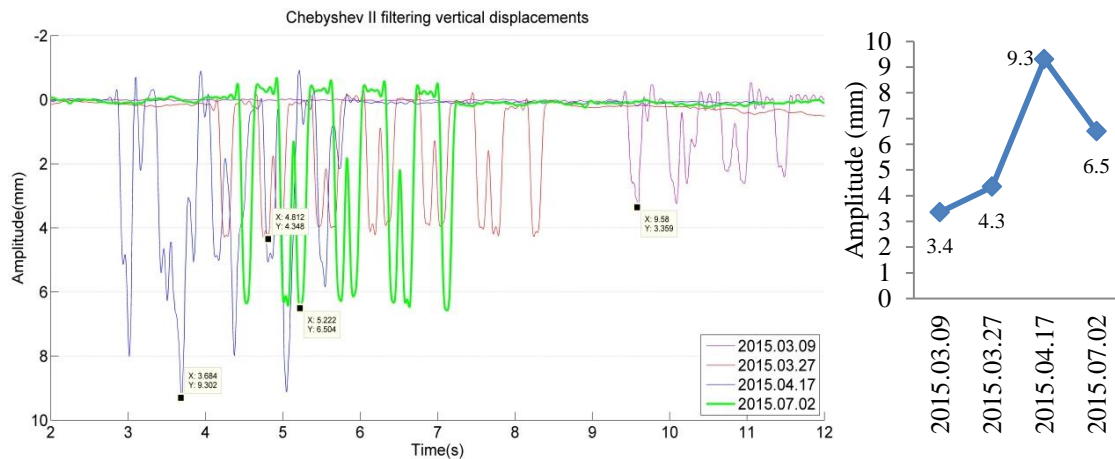


Figure 3.12 Vertical displacement development in Frog 2

In the monitoring period, filtered sleeper displacements in Frog 1 is constant, ballast condition is stable, approximately 2.7mm. In Frog 2, from 2015.03.09 to 2015.04.17, sleeper displacement increased from 3.4mm to 9.3mm. In the very last measurement, the amplitude decreased to 6.5mm.

3.3 Discussion

According to previous study, the average vertical acceleration of a normal 1:15 crossing in worn condition in the railway network in the Netherlands is around 65g, good condition 45g [12]. In this section, the average vertical acceleration of Frog 1 is over 200g, In Frog 2, this value reached up to 80g with only normal passing wheels. The damage risk is relatively high in both frogs.

3mm vertical displacement in Frog 1 is acceptable [11], which means problems mainly appears in the rail part. The high stiffness of casted manganese steel frog also contributes to the structural vibration.

In Netherlands, the average service period for a crossing is around 20 years. With the fast growing damage in these frogs, life length is shortening markedly.

4 CONCLUSION AND FUTURE WORK

Two casted manganese steel frogs (1:9) in the railway network in the Netherlands have been monitored with ESAH-M and Video Gauge System. Both systems are improved to operate out of the track, which guaranteed safety work and continuous measurement with ESAH-M. The monitoring results indicate that the wheel/rail contact forces (accelerations) in Frog 1 are extremely high. Combined with relatively stable ballast support, the potential of rail defect is remarkable. Frog 2 is monitored from initial operation. After a short period (around 1 month) of wheel/rail adjustment, wheel/rail impact responses increase at express speed. With the strong structural vibration generated by passing trains, wear on Frog 2 develops fast.

Due to the high impact forces of passing wheels, the accelerometer attached on Frog 1 falls down several times. The fierce structural vibration in Frog 2 leads to the loss of targets during Video Gauge measurement on 2015.05.01.

The structural instability increased the difficulty of monitoring, also reflects the shortcomings of the experimental devices. In Figure 3.12, the measurement results on 2015.04.17 illustrate short frequency coverage of Video Gauge System. System updating is necessary for better field performance.

This is an on-going project as part of Structural Health Monitoring System for Railway Turnouts developed in TU Delft. Three months monitoring describes some features of the frogs

and shows some condition develop tendency. For thoroughly understand the condition degradation of this section, longer period of monitoring is necessary.

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