CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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CETRA[2018]
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

TITLE
Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

ISBN
978-953-8168-25-3

DOI
10.5592/CO/CETRA.2018

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
“Tiskara Zelina”, May 2018

COPIES
500

Zagreb, May 2018.

Proceedings of the
5th International Conference on Road and Rail Infrastructures – CETRA 2018
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EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

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EXPERIMENTAL VERIFICATION OF AN OPTIMISED HEATING SYSTEM FOR HOLLOW SLEEPERS CONTAINING POINTS POSITIONING SYSTEMS

Julian Heger[1], Franz Kurzweil[2], Markus Schladitz[1], Robert Adam[1], Steffen Großmann[1]
[1] *Technical University of Dresden, Institute of Electrical Power Systems and High Voltage Engineering, Germany*
[2] *ÖBB-Infrastruktur AG, SAE, Austria*

Abstract

Points allow trains to move uninterruptedly from one railway line to another. In winter, blowing snow and ice can freeze the points positioning and locking system contained in hollow sleepers to fail. Then trains can no longer passage between railway lines and are delayed or cancelled. Conventional heating systems with one flat heater cannot prevent from freezing. Therefore in 2013 an optimised design of a heating system was proposed by the means of the Thermal Network Method. Based on this proposed design, a heating system with two heating jackets and a flat heater with lower power consumption were manufactured and mounted into a hollow sleeper containing a positioning system at a high-speed railway line in Austria. With a field study, the temperature distributions and power consumptions of the optimised heating system and the conventional heating system of adjacent points were studied over two winter periods. Also endoscope cameras were mounted inside the hollow sleepers to record infiltrating snow and thawing processes. Previously with the thermal network computed temperature distribution and now measured temperature distribution of the optimised heating system correspond approximately. Compared to the conventional heating system, temperatures of the critical components of the positioning system are significantly higher but do not exceed admissible temperatures. Due to harsh environment conditions, the recorded pictures inside the hollow sleeper with the conventional heating system are inconclusive. But recorded pictures from inside the hollow sleeper with optimised heating system show steadily thawing of infiltrated blowing snow. Efficacy of the optimised heating system also improved. The power consumption is slightly lower compared to the conventional heating system.

Keywords: allocated heating elements, increased temperature-rise, high-speed railway line, blowing snow, points failure

1 Introduction

In winter, rails and positioning systems of points can be heated to prevent fails due to ice or snow. For hydraulically operated positioning systems flat heaters were subsequently fitted into hollow sleepers. However, blowing snow kept accumulating in the hollow sleeper and ice possibly blocked the hydraulic cylinder of the positioning system. Furthermore, retrofitted heaters may exceed admissible temperatures determined by the hydraulic system. In a previous work temperature distributions of a hydraulically operated positioning system contained in a hollow sleeper were studied for different heating configurations by the means of the Thermal Network Method (TNM), [1]. A heating system composed of allocated heating elements at the hydraulic cylinder and the hollow sleeper was identified as most effective. The authors

DOI: https://doi.org/10.5592/CO/CETRA.2018.721

suggested to test such a heating system under harsh outdoor conditions in order to approve the actual effectivity. This paper determines heating jackets and one flat heater with lower power as appropriate allocated heating elements. In orders to assess the optimised heating system under real operating conditions, a field study was conducted over two winter periods at points of a high-speed railway line in Austria. This paper presents results of the field study showing significantly increased effectivity of the optimised heating system compared to the conventional heating system. Furthermore with TNM computed temperature distributions correspond approximately with measured temperature distributions of the field study.

2 Optimised heating system

According to the results of the TNM, heat specifically fed into the hydraulic cylinder significantly increase temperatures of the positioning system and hence keep from freezing. In order to heat the actual hydraulic cylinder, heating jackets were selected. The benefits of heating jackets are a broad variety of manufacturable sizes, power stages and comparatively little space requirements. For the investigated positioning system heating jackets fitting tightly around the hydraulic cylinder barrels were manufactured and mounted (Fig. 1).

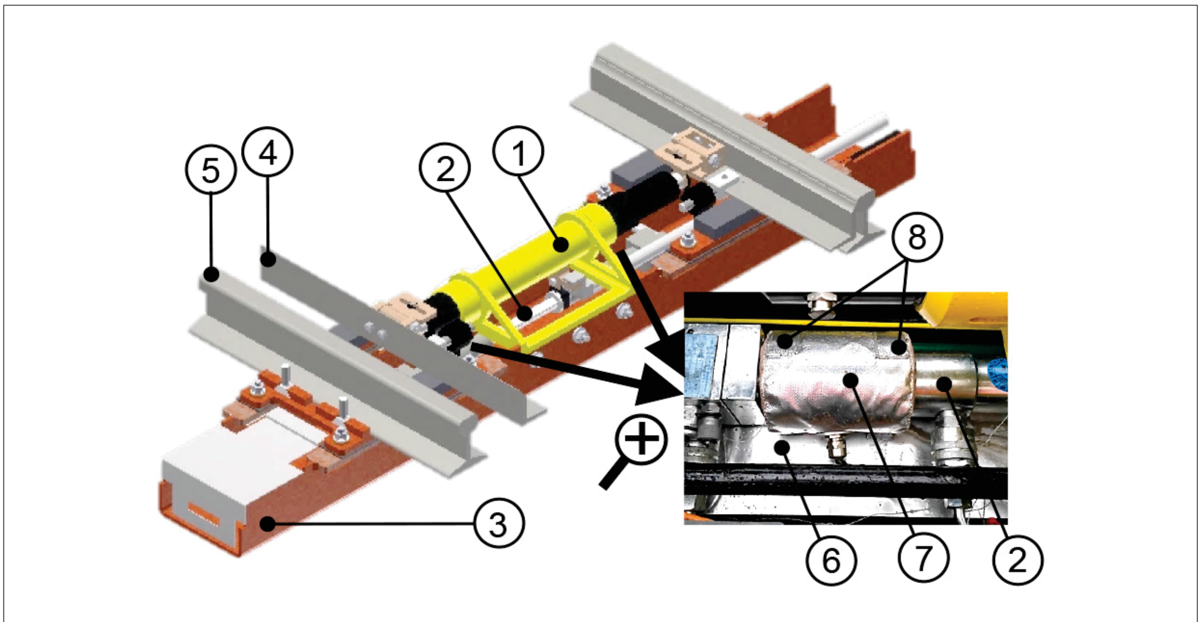

Figure 1 Optimised heating system with two heating jackets and a flat heater

Build-in touch fasteners guarantee easy assembling inside the hollow sleeper. An additional thermal insulation around the heating jackets increases efficiency since less heat is transferred to the environment. In order to thaw infiltrated blowing snow, the existing flat heater is reused but together with the heating jackets connected to an adjustable transformer. The adjustable transformer reduces output voltages and therefore lowers the power of the flat heater to about 60 % of its rated power P_r. The power must be reduced so admissible temperatures will not be exceeded.

3 Experimental set-up

In order to verify the increased effectivity of the optimised heating system, a field study was conducted during the winter periods 2014/2015 and 2015/2016. Therefore, two opposite points of a high-speed railway line were selected (Fig. 2). One points positioning system and hollow sleeper were fitted with the optimised heating system. The opposite points positioning system and hollow sleeper were fitted with the conventional heating system. The temperatures of the positioning system and the heating elements were measured with thermocouples (type K) at both points (Fig. 3) and recorded. Also power consumption of all heating elements were measured and recorded. Endoscope cameras with build-in illumination were mounted inside the hollow sleepers and recorded pictures from the inside. Because of the harsh conditions by overpassing trains with high-speed, two out of six endoscope cameras failed in the first winter period. Also the lens of the remaining endoscope camera inside the hollow sleeper of the reference system polluted quickly. Therefore, pictures from the inside of the hollow sleeper of the conventional heating system are mostly blurry and inconclusive. Infiltrating or thawing snow could not be recorded. However, pictures from inside the hollow sleeper of the optimised system are mostly clear. The overall weather condition at the rail track was recorded with a surveillance camera. Nearby ambient air temperature was measured and recorded. Also, the control signal for heating and detected precipitation at the tracks were recorded. The recorded data were stored by a PC placed in a nearby technical station. A wireless USB modem connected the PC to the cellular network so all data were also remotely accessible. Remote access was found to be very convenient when checking the status of the systems.

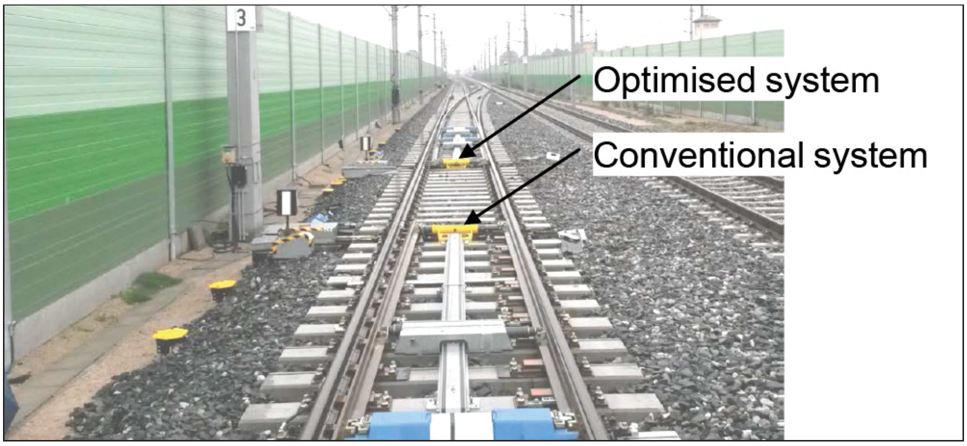

Figure 2 Selected points at a high-speed railway line in order to study the efficiency of the optimised and conventional heating systems for positioning systems contained in hollow sleepers

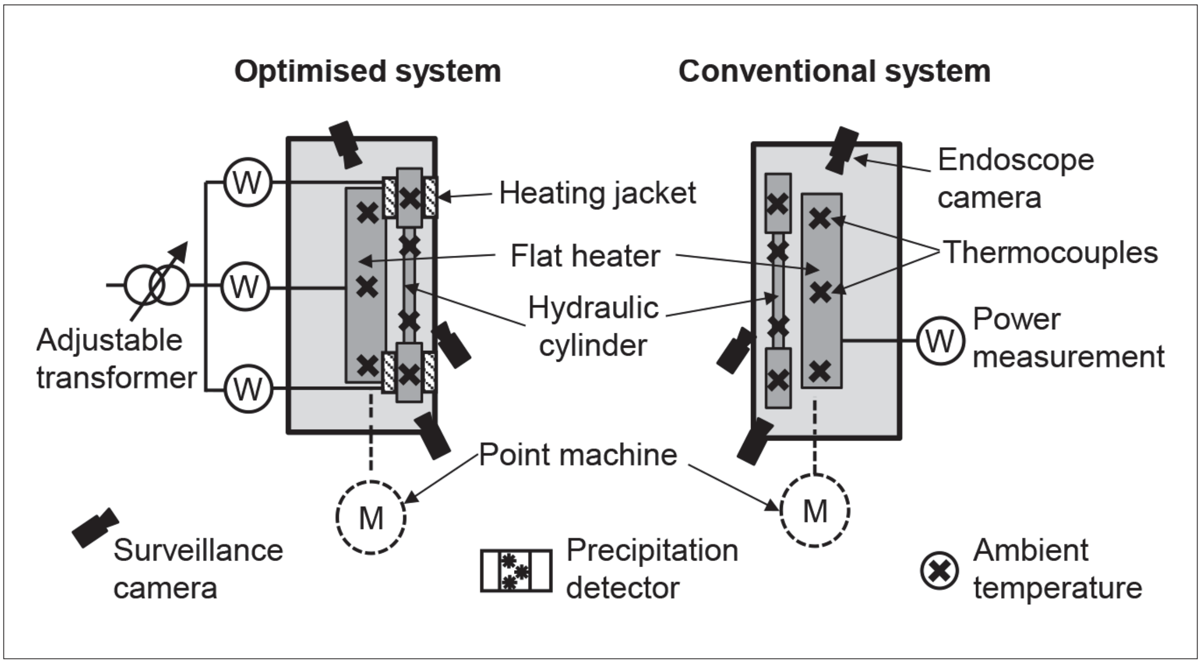

Figure 3 Experimental set-up of the optimised system and the conventional sys. at the high-speed railway line

4 Results

In this chapter selected data of the temperature distributions, the power consumption and recorded pictures of a thawing process are presented and discussed. Also with TNM previously computed steady-state temperature rises are compared to the measured steady-state temperature-rises of the field study.

4.1 Temperature distributions

Criteria were defined to assess the effectivity of the heating systems. Due to the hydraulic system temperatures of the positioning system and the hollow sleeper may not exceed the admissible temperature of ϑ_{max} = 70 °C. Also the hydraulic cylinder may not freeze and snow must be thawed up to ambient temperatures as low as ϑ_0 = 20 °C. Hence minimal temperature rise of the hydraulic cylinder and the flat heater must be Θ › 20 K (Eq. (1)).

$$\Theta = \vartheta - \vartheta_0 \quad (1)$$

Where ϑ is the temperature of the hydraulic cylinder and the flat heater. A representative sequence of measured temperature profiles, heating status and precipitation for 96 hours starting at 12.00 a.m. on the 5th January 2016 is shown (Fig. 4). The ambient air temperature varies between - 6.5 °C and + 9.5 °C. For all heating periods, the temperature rises of the hydraulic cylinder of the conventional system are always below 20 K. However, the minimum steady-state temperature rise of the hydraulic cylinder of the optimised system is Θ_{min} = 30 K and the maximum steady-state temperature rise is Θ_{max} = 62 K. Compared to the conventional system, these temperature rises determine the heating jackets significantly increase temperatures of the hydraulic cylinder of the optimised system and therefore decisively reduce risk of freezing. While heating is on, the flat heater of the conventional system reaches a minimum steady-state temperature rise of Θ_{min} = 51 K and a maximum steady-state temperature rise of Θ_{max} = 60 K. Due to the reduced power of the optimised systems the flat heater, its minimum steady-state temperature rise is Θ_{min} = 40 K and its maximum steady-state temperature rise is Θ_{max} = 49 K. Both systems exceed the required minimal temperature rise of Θ = 20 K and therefore risk of accumulating blowing snow inside the hollow sleepers is low. At t = 82 h the ambient temperature increases to ϑ_0 = + 5 °C while the systems are still heating. However, both points positioning systems do not exceed the admissible temperature. The conventional system reaches its maximum temperature of ϑ = 63.4 °C at the flat heater and the optimised system reaches its maximum temperature of ϑ = 61.5 °C at one of the heating jackets (Eq. (2)).

$$\vartheta = \Theta + \vartheta_0 \quad (2)$$

Because ambient temperature rises further, the signal for heating switches off at t = 84 h and after a delay time both systems suspend heating.

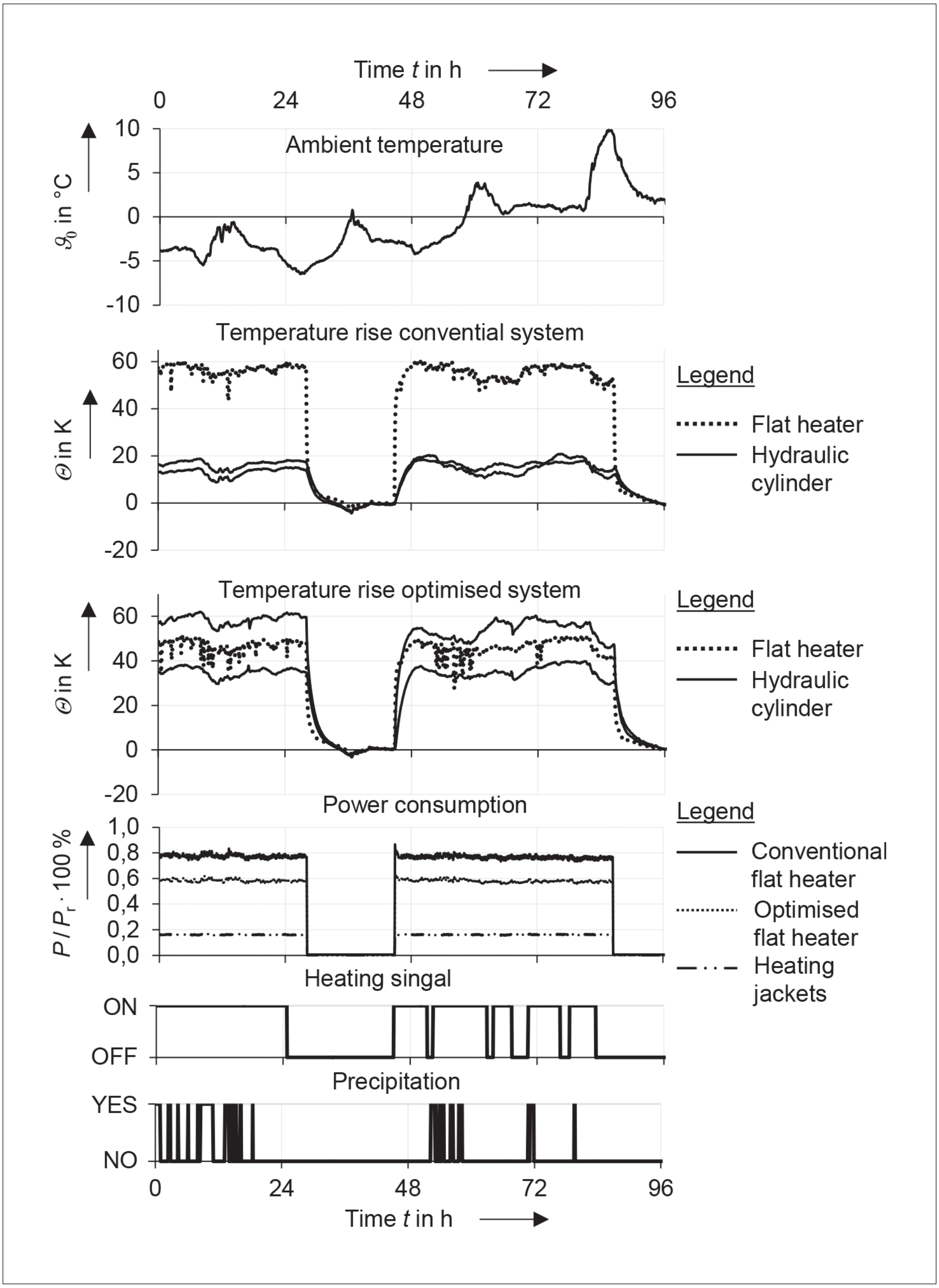

Figure 4 Recorded sequences of ambient temperature, critical temperature rises and power consumption of the conventional system and optimised system, heating status and precipitation, starting at 12.00 a.m. on 5th January 2016

4.2 Power consumption

Power consumption for both systems were recorded. Surprisingly, the power consumption of the conventional flat heater was always significantly lower than its rated value P_r. Maximum power consumption was recorded with 86 % of P_r and mean power consumption amounts to only 77 % of P_r. Two reasons were found to be accountable for deviation of power consumption and rated power. First, resistance of the flat heater is temperature dependent. When the temperature rises, the resistance also increases. Because the voltage supply U is constant, the current I drops with increasing resistance (Eq. (3)).

$$I = U/R \tag{3}$$

Since the current I accounts to the power of two in the equation for power, the power decreases with increasing temperatures (Eq. (4)).

$$P = I^2 R \tag{4}$$

Secondly, the voltage at the connection point of the flat heater was always moderately below the rated voltage. Since voltage also accounts to the power of two in the equation for power, the power consumption also drops (Eq. (5)).

$$P = U^2/R \tag{5}$$

Because temperature rise Θ is approximately linearly dependent on the heating power, it is likely that the conventional heating system exceeds the admissible temperature when operated in the range of its rated power, e.g. at t = 82 h temperature rise would reach Θ = 78 K (Eq. (6), Fig. 4).

$$\Theta = \Theta_1 P_r / P_1 \tag{6}$$

Where Θ_1 is the measured temperature rise of the conventional flat heater with P_1 and P_1 the measured mean power consumption. Due to the adjustable transformer, power for the optimised system was approximately set to the planned rated power. Therefore, likelihood of exceeding admissible temperatures with the optimised system is significantly lower. For the optimised heating system the mean power consumption for the flat heater amounts to 58 % of P_r and for the heating jackets to 16 % of P_r. In total, the mean power consumption of the optimised heating system is about 74 % of P_r which is 3 % lower than the power consumption of the conventional heating system.

4.3 Thawing process of blowing snow

Endoscope cameras recorded pictures of thawing processes from inside the hollow sleeper of the optimised system (Fig. 5). On the set of pictures, infiltrating snow can be observed at 5.47 a.m. with camera 1 and camera 3. More snow keeps infiltrating until 7.07 a.m. while heating triggers the thawing process. At 8.17 a.m. almost all snow is thawed. With camera 2 water droplets can be seen on several parts of the positioning system but do not freeze. The recorded pictures determine the optimised heating system is operative. The system thaws snow reliably and keeps the positioning system from freezing.

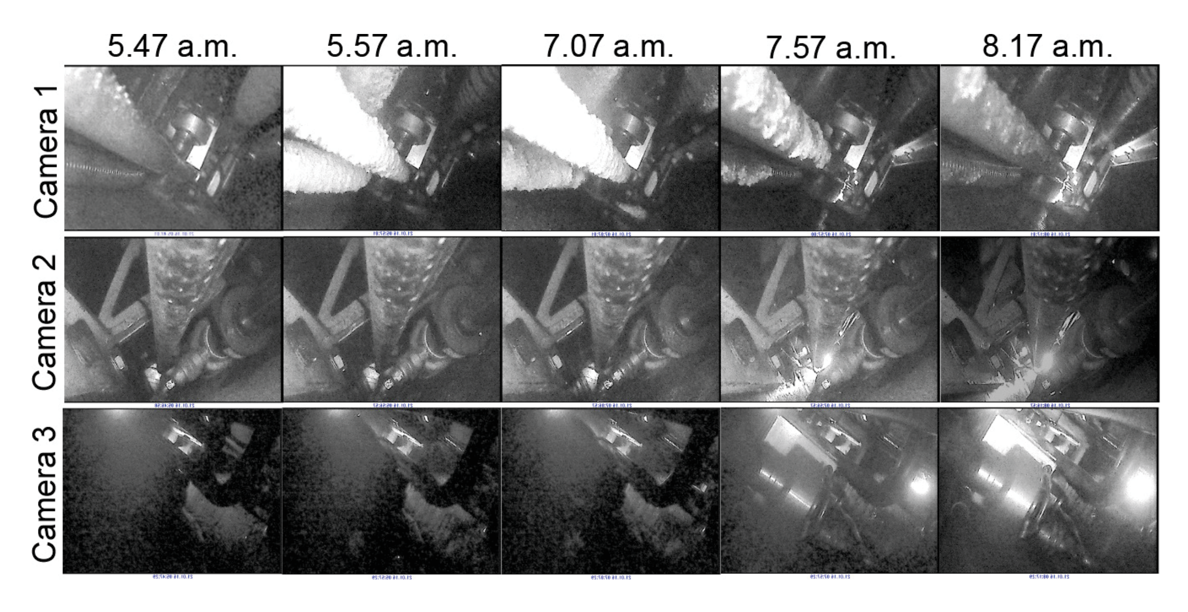

Figure 5 Infiltrating and thawing blowing snow, recorded with endoscope cameras inside the hollow sleeper of the optimised heating system on 21st January 2016

4.4 Comparison with previously computed results

In a previous work [1], steady-state temperature-rises were computed with TNM only for natural convection but no wind and all heat were directly fed into the positioning system. However, the computed temperature rises and now measured temperature rises for critical components correspond approximately. Maximum temperature rise of the hydraulic cylinder are almost the same. Likely due to wind, heat of fusion and evaporation of condensed water, measured minimum temperature rise is about 10 K lower than computed. Computed and measured temperature rises for the flat heater differ from 10 K for maximum temperature rise to 14 K for minimum temperature rise where measured temperatures are always lower. Amongst others the heat conductivity of the rail track ballast significantly determines these temperatures but can vary in a wide range [2]. Since the actual heat conductivity is not known, computed temperature-rises can differ from measurement. Basically, the comparison of computed and measured steady-state temperature rises shows that TNM is an appropriate method for optimising the heating system of hollow sleepers containing points positioning systems.

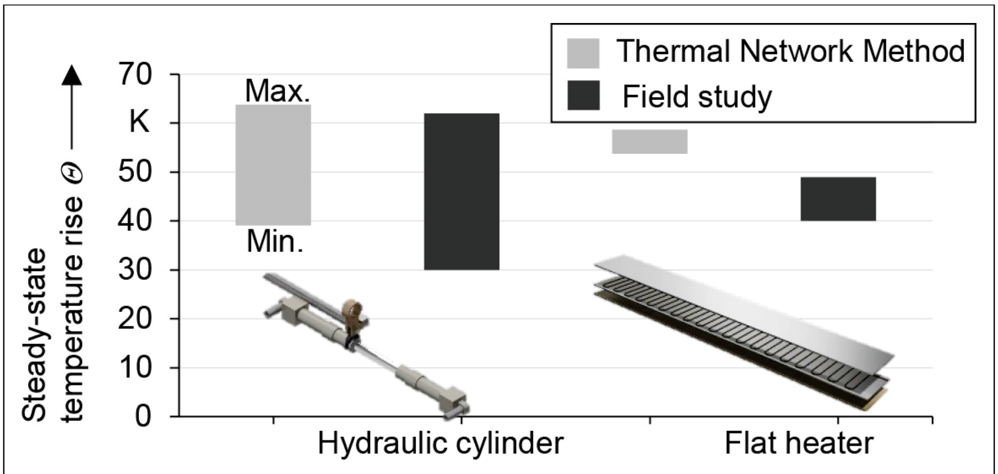

Figure 6 Maximum and minimum steady-state temperature rise of critical components previously computed with Thermal Network Method [1] and now measured during field study

5 Conclusion

With the results of a previously conducted investigation an optimised design of a heating system with heating jackets and a flat heater was proposed. In order to assess the effectivity a field study was conducted on points of a high speed route. The Field study experimentally determined that the optimised design reduces risk of freezing of the positioning system and thaws blowing snow inside the hollow sleeper reliably. Also the optimised heating system decreases the likelihood of exceeding admissible temperatures. With the previous work computed steady-state temperature rises of critical components correspond approximately with measured temperature rises of the field study. Hence TNM is an appropriate tool in order to optimise such a heating system.

References

[1] Kaufmann, B., Kurzweil, F., Heger, J., Adam, R., Großmann, S.: Development of a heating system for hollow sleepers containing points positioning systems, 3rd International Conference on Road and Rail Infrastructure – CETRA 2014, pp. 51-57, Split Dalmatia, Croatia, 28-30 April 2014.

[2] VDI e.V. (Hrsg.): VDI-Wärmeatlas (german), 11. Ausgabe, Springer-Verlag, Berlin, Heidelberg, 2013.