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*train load monitoring,
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Otto PLASEK[1]
Milan VALENTA[2]

THE MONITORING OF TRAIN OPERATION LOAD

The monitoring of the train operation load was arranged in the railway station Vranovice along with measuring of the new type of turnout for high-speed tracks. The aim of paper is a description of the measuring and the results evaluation.

The railway station Vranovice was chosen as a station on the first Czech railway corridor between Brno - Wien. Tensors were installed on rail foots. Train passages were recorded in the measure and memory unit. The obtain records were evaluated by special software. The values of wheel loads were computed for every recorded axle. The important experience was obtained from measuring and evaluation, especially with electromagnetic fields caused by train control system.

Histograms were calculated for evaluated axle loads. Extreme impacts caused by imperfection on wheel running surfaces were assessed individually. Then the day, week and month summary was compiled. Summaries of axle loads were statistically evaluated. The overview of a typical axle load distribution in Czech corridor track was obtained.

MONITORING OBCIĄŻENIA EKSPLOATACYJNEGO POCIĄGÓW

Monitorowanie eksploatacyjnego obciążenia pociągów zostało przygotowane na stacji kolejowej Vranovice wraz z pomiarami nowego typu rozjazdu dla linii dużych prędkości. Celem referatu jest opis pomiarów i ocena wyników.

Stacja kolejowa Vranovice została wybrana jako stacja na pierwszym czeskim korytarzu kolejowym Brno – Wiedeń. Na stopach szyn zainstalowano czujniki. Przejazdy pociągów były rejestrowane w układzie pomiarowo-pamiętającym. Uzyskane zapisy zostały poddane ocenie za pomocą specjalnego oprogramowania. Wartości obciążeń kół zostały obliczone dla każdej zarejestrowanej osi. Z pomiarów i oceny wyciągnięto ważne wnioski doświadczalne, zwłaszcza w zakresie pól elektromagnetycznych spowodowanych przez system sterowania ruchem pociągów.

Dla wszystkich ocenionych obciążeń osi zostały przygotowane histogramy. Oddzielnie oceniono skrajne wpływy spowodowane niedoskonałościami na powierzchniach bieżnych koła. Następnie skompilowano podsumowanie dzienne, tygodniowe i miesięczne. Statystycznie oszacowano podsumowania obciążeń na osiach. Uzyskano przegląd typowego rozkładu obciążenia osi na czeskim szlaku przelotowym.

[1] Brno University of Technology, Faculty of Civil Engineering, Institute of Railway Structure and Constructions, Veveri 95, 662 37 Brno, Czech Republic, plasek.o@fce.vutbr.cz

[2] Institute of Applied Mechanics Brno, Ltd, Veveri 95, 611 00 Brno, Czech Republic, valentam.uam@telecom.cz

1. INTRODUCTION

Safety and reliability of a railway operation are the main factors at an application of new structure elements. The verifying of these elements includes the mathematic modelling, laboratory tests and field test during common train operation.

A new prototype of the turnout for high operation speed with a moveable nose of frog was installed to the main track in the railway station Vranovice. The railway station Vranovice was chosen as the station on the first Czech railway corridor between Brno - Wien. Many tests oriented to verifying properties of particular structure elements were done. One of these tests was the long-term monitoring of operation load caused on this turnout. This monitoring was realized in the cooperation of Institute of Railway Structure and Constructions of Faculty of Civil Engineering and Institute of Applied Mechanics Brno. The continuous monitoring was running for four months in the end of the year 2003.

2. MEASURING PRINCIPLE AND DESCRIPTION OF MEASURING APARATURE

2.1. MEASURING PRINCIPLE

The method of strain measuring was chosen to the monitoring of wheel loads. This method was verified during measuring of wheel and lateral forces during experimental train passages in the year 2002 in the same experimental track section. The distribution of bending stresses in the rail profile is very complicated and the shear stresses affects to relationship between stress and measured strain. The only part of the rail profile where the strain is corresponding to normal bending stress is the rail foot. The relative complicated situation in the loading of the rail is expressed on Fig. 1. It is necessary to use a pair of tensometers to reduce the influence of a wheel force eccentricity and horizontal lateral force.

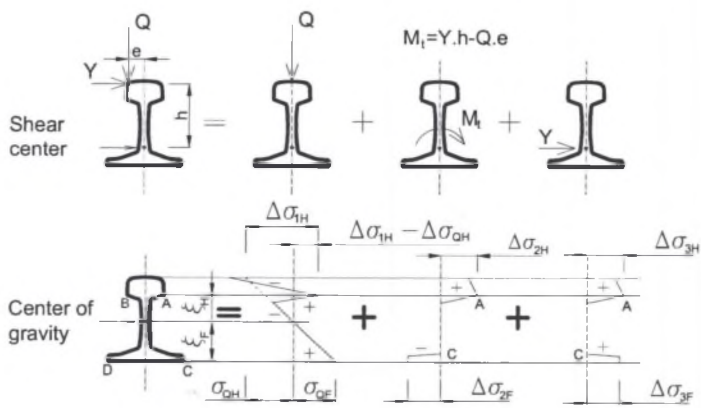

Fig.1. Load decomposition for measuring of rail stresses [1]

The tensometric sensors were placed in point C and D according Fig.1. The value of the wheel force caused in the vertical symmetry axis of rail profile was evaluated according to the next equations:

- the values of normal bending stresses were computed for every point according equation:

$$\sigma_{QF} = E.\varepsilon_{x,F} \tag{1}$$

in which σ_{QF} means normal bending stress, $\varepsilon_{x,F}$ elasticity strain, modulus of elasticity $E = 210$ GPa

- wheel load Q for point i was computed according to the equation:

$$Q_i = \frac{\sigma_{QF,C,i} + \sigma_{QF,D,i}}{2} \cdot k_{1,i} \tag{2}$$

in which $k_{1,i}$ means constant determined by measuring strains caused wheel force of the known value.

2.2. SENSORS

Tensometers were placed to cross-section three meters in front of the turnout. They were installed in both rails according Fig.2.

T1 on rail foot outside on right rail
T2 on rail foot inside on right rail
T3 on rail foot outside on left rail
T4 on rail foot inside on left rail

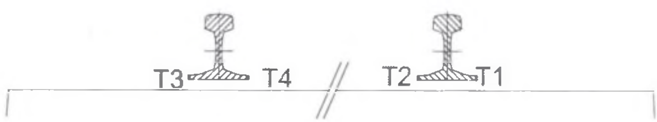

Fig.2. The position of tensometers for monitoring of operation load – view towards the prototype turnout

The tensometric sensors T1, T2 were used for measuring of the wheel force Q_1, the tensometric sensors T3, T4 were used for measuring of wheel force Q_2. Tensometric sensor T5 was placed on switch rail to identify switch position.

2.3. MEASURING DEVICE

The device of the type EMS DV803 was used for the monitoring. This device may be used for multi-channel measuring of quasistatic and dynamic quantities. The parameters of this central are:

- 48 channels, used only 5 channels
- sample frequency max 12,8 kHz, used 50 Hz
- processor 16-bit Motorola

- memory 1GB Compact flash
- Ethernet 10Mb/s
- operation temperature -20 až +65 °C

The technical difficulties during measuring and its preparation appeared. The next questions and problems had to be solved:

1. Location of measuring central
2. Protection of sensors and cables
3. Disturbance of measuring equipment by electromagnetic fields
4. Evaluation of signal records

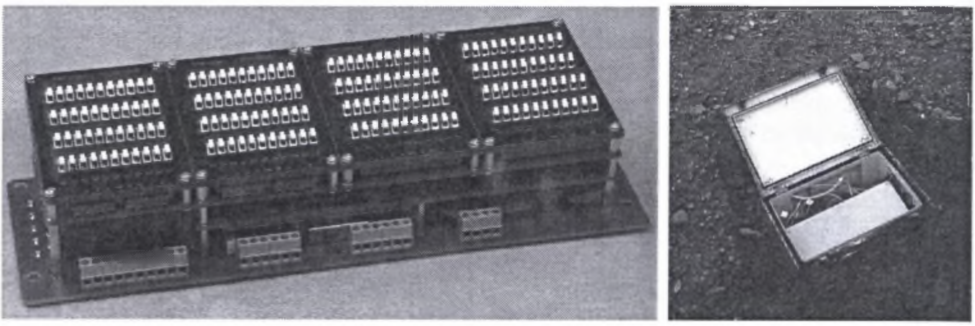

Fig.3. The measuring central EMS DV 803

The location of the measuring central was very difficult because it was necessary to protect this device against weather conditions and vandalism. Some variants were estimated and it was decided to dig it into formation outside of ballast bed in a special case.

Tensometers were influenced by very hard weather conditions. They must be protected against possibility of mechanical damage by a grain of ballast material, against undesirable manipulation and against electrical effects. The sensors were covered by three protect layers – protect varnish, special putty layer and thick aluminium foil. The shielded twisted cables were used. The cables were protected against mechanical damage by putting into plastic pipes and covered by fined grained stone.

Although all precautions were made the complete protection of the measuring central against disturbing influences during train passage was impossible. Many faults were found in signal records at the beginning of measuring. The main reasons of the disturbance were:

- stray earth currents due the electrified track by an alternating voltage system
- electromagnetic field caused by train control system
- electromagnetic field caused by power cables

These disturbing influences were removed by relocation of measuring central to distance 6 m from the track. The disturbance by alternating current was suppressed by using the sample frequency 50 Hz.

The most difficult problem was securing a suitable source of electrical power. The serious changes of voltage were caused by train passages. Using a toriod element on electrical power cables solved the problem.

Undisturbed monitoring of the operation load for the duration of 82 days was the result of all the correction arrangements.

3. SIGNAL RECORDS EVALUATION

The duration time of the signal records was 24 hours. These records were evaluated separately. An example of the signal record is on the Fig.4. The record for a particular train is deformed on this figure to vertical local deviation so we can see record for many trains passages. A long-term variation of stresses in unloaded rails during a day caused by temperature changes and corresponding rail profile displacements may be analysed from signals.

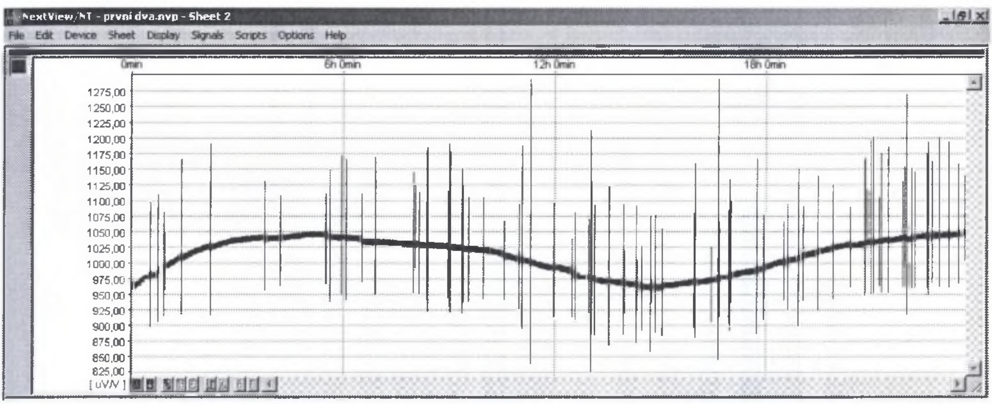

Fig.4. The signal records for 24 hours, the sensor T1

It was impossible to evaluate manually signal records because the high amount of wheelsets during 24 hours. The special software Peak Detector was developed for evaluation of these records. This software detect strain deviation of every train and then for every particular wheelset. Values of local strain extremes are used for computation wheel forces according equations (1,2). The result table summary contains the data:

- number of train passages in 24 hours
- number of wheelsest in 24 hours
- histogram of wheel forces
- cumulative histogram of wheel forces.

The summary was compared with the daily records in the railway station. The daily summary contains a sum of wheel forces separately for both rails and a total sum of operation load. The overall summary for monitoring period is in the Table 1; the chart is on the Fig.5. It was detect 6,859 passages of trains during the monitoring period, corresponding operation load was 4,462,677 t, only 174 trains run threw branch line of the turnout.

Table 1

The overall summary of the operation load

Week	37	38	39	40	41	42
Number of trains	377	429	397	380	447	502
Operation load [t]	259,888	295,735	273,676	261,957	274,492	314,733
Week	43	44	45	46	47	48
Number of trains	477	427	485	450	434	446
Operation load [t]	312,576	299,372	319,170	287,258	280,412	302,358
Week	49	50	51	52		
Number of trains	462	445	450	251		
Operation load [t]	288,876	288,674	287,567	119,935		

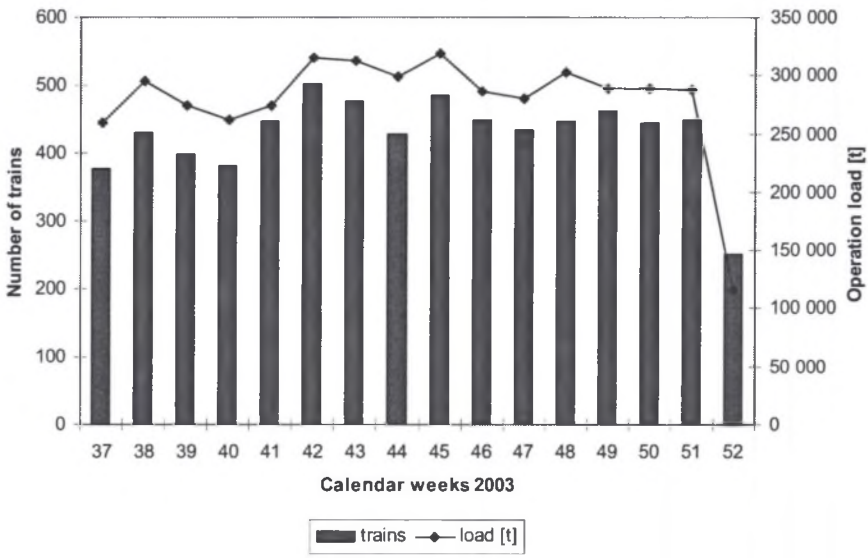

Fig.5. The overall summary of operation load for calendar weeks in the year 2003

4. STATISTICAL EVALUATION

The daily summaries were statistically evaluated. The histograms of wheelset forces were work up for every day for both rails separately and together. There were overall recorded 253.892 wheelset in the monitoring period. The histogram of the wheelset forces for the monitoring period is on the Fig.6; the force interval was used 20 kN (corresponding wheel force 10 kN).

The values of axle forces were statistically evaluated. The reduced random sample was tested for homogeneity and normality. The method of the computation of lower and upper barrier for testing homogeneity was used. The value of upper barrier 400 kN was lower than significant amount of axle forces because the sample statistical distribution is skewed to higher values. It is necessary to notice that extreme high values of wheel forces had to be removed from the evaluation because the wheels cause them due to imperfections on running surfaces. These impacts were multiple higher (above 30 kN) and they correspond to dynamic effects evidently.

Jarque-Berra statistical normality test [2] for the testing of the axle forces random sample was used. The Box-Cox exponential transformation was used for computation of basic statistic parameters of the sample distribution because the normality presumption was refused with $\alpha = 5$ %. The mean value and the standard deviation were computed for the transform data and results were transformed back to the origin random sample.

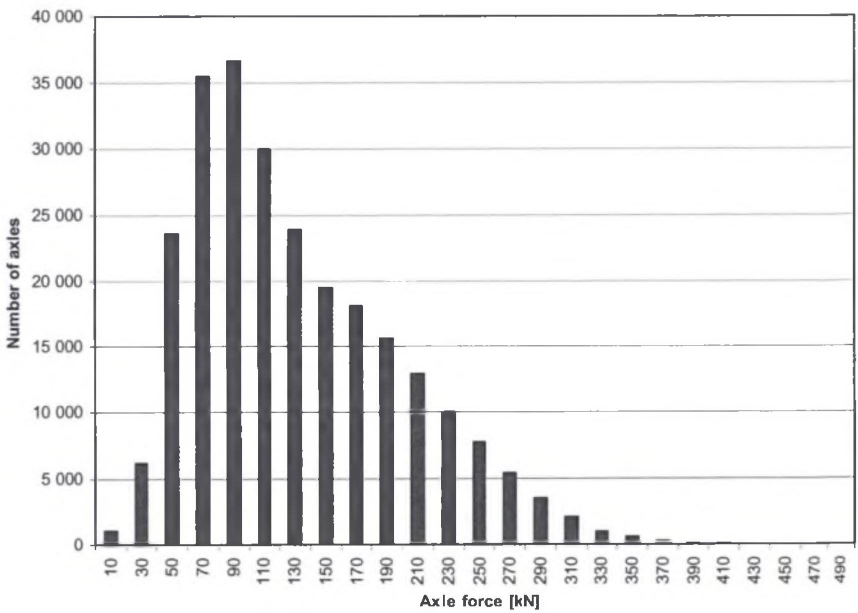

Fig.6. The histogram of axle forces for the monitoring period

The mean value of axle loads amounts 131 kN, the standard deviation amounts 71 kN. The presented values of axle forces include all dynamic effects of course. The relative high number of goods trains with empty wagons influenced relatively low mean value of axle forces. Whereas the normality presumption for the random sample was refused, the most suitable type of statistical distribution was searching by the help of quantil- quantil charts by means of the value of correlation coefficients. The lognormal, Gumbell and Weibull statistical distribution was compared. Weibull distribution shows as the most suitable for substitution of sample distribution. The comparison of probability density functions for chosen distribution types is on the Fig.7.

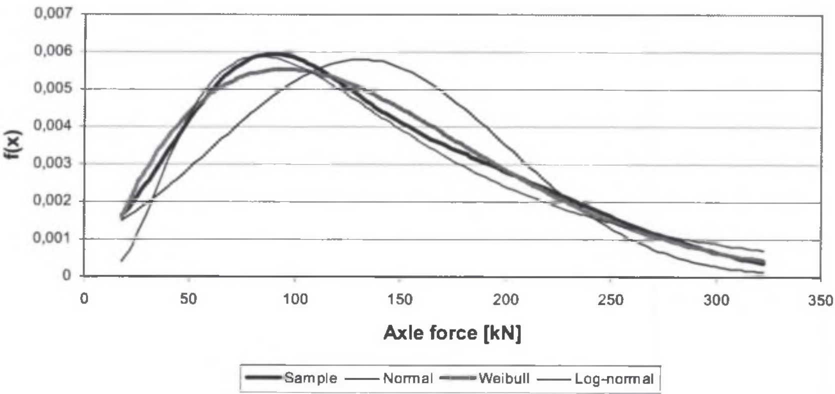

Fig.7. The sample probability density functions

5. CONCLUSIONS

The long-term monitoring of the operation load in conditions of common train traffic showed as extremely difficult due technical problems. The amounts of very important information had to be obtained from Czech Railways for useful solving of these problems. The cooperation with the manufacturer of the monitoring equipment was necessary. The special software and procedures had to be developed for evaluation of signal records. This kind of the monitoring was realized in Czech railways for the first time so the experiences from this monitoring will simplify similar future experiments.

The monitoring results are profitable for designers, manufacturers, building contractors and supervision organizations. The results give the basic information for design and evaluation of the new elements of railway structures. Also the results express technical state of railway vehicles and their influence on the railway structure.

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Reviewer: Prof. Zbigniew Ginalski