



ASSESSMENT OF THE SERVICE LIFE OF RAILWAY'S STEEL CONSTRUCTIONS BASED ON PROBABILITY APPROACH

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In the paper is presented process of transformation of stress-records trough probability approach. The process is based on statistical analysis of magnitudes, which have influence on service life of railway's constructions. Body of the article is concerned on determination of response of stresses from total traffic load with use Monte Carlo method.

Keywords: processing of stresses, probability approach, influences on service life, service life of constructions

Introduction

For assessment of the service life of a construction is necessary to come from knowledge of the total traffic stress. It is caused by power effects and other influences (temperature change, corrosion, material ageing, climatic influences) that evoke change of stress of the construction. In case of railway's steel constructions the tension has a character of complicated stochastic process. If the estimation of service life of the railway's steel construction should be credible, it must be performed on basis of stochastic approach. It is necessary to treat also the second essential basis, i.e. to material characteristics, for evaluation of the service life in the same way.

In connection with continuous tendencies of developed producers and operators of railway's steel constructions to improve their philosophy of evaluation of fatigue service life, it is necessary to search for new accesses to solution of these problems also in the Czech Republic. One of the possibilities might be a process indicated in other parts of this contribution.

If we come out from a hypothesis of cumulation of the fatigue damage, every time limitation causes load of partial damage of the construction. It is possible to characterise the sum of partial damages from given loads acting at the same time as a general partial damage, which it is possible to express by a relation:

$$D_C = D_P + D_T + D_S + D_V + D_O \quad (1)$$

where D_C is general partial damage

D_P	is partial damage from traffic load
D_T	is partial damage from load by the influence of temperature change
D_S	is partial damage in consequence of ageing of the construction
D_V	is partial damage from influence of outer climatic conditions
D_O	is partial damage from other loads.

In practice we generally have a possibility to measure only the immediate response from traffic load. However if we perform the measurement several times while keeping all the conditions of load except for one, we can determine (e.g. percentually) meaning of this condition. The conditions are e.g. temperature, driving velocity, climatic conditions. It is possible to determine so-called significant coefficients and probability of their appearance by the performed tests and subsequent statistical processing.

Significant coefficients

Response from traffic load is generally obtained by tensiometric measurements in form of time record of the stress at detail of the construction. Then we can determine the response of construction on this load in every time moment. Total stress in construction in a given time moment is then possible express by relation, in which are significant coefficients:

$$\sigma_{TOTAL} = k_T * k_S * k_V * k_O * \sigma_P \quad (2)$$

where	σ_{TOTAL}	is total stress in the construction in a given time moment
	k_T	is significant coefficient from the load by temperature
	k_S	is significant coefficient considering ageing of the construction
	k_V	is significant coefficient from the load of outer climatic conditions
	k_O	is significant coefficient from other loads
	σ_P	is stress in the construction in a given time moment from traffic load.

It means, that influence of different factors on general stress (temperature, ageing, outer climatic conditions, other loads) is expressed by the help of significant coefficients (2). To determine these coefficients, we have to first of all perform many measurements to find out the influence of these factors. Selection of particular factors is directly related to type of the construction and to the way of its straining in period of its technical life.

For calculation of service life is necessary that the significant coefficients are preferably constant while measuring the sample (representative) record of the strain.

If every degree of the load is assigned to a value of significant coefficient, we can determine the density probability of appearance of the significant coefficient. We come out from the determination, that values of significant coefficients are constant in period of measuring of the representative sample. Representative sample is determined by the measurement while operating, it must correspond to the load, that really takes effect on construction in period of its life. It must include with appropriate emphasis all traffic influences (e.g. big differences between quality of geometric position of the track at different railways as well as at tracks itself ČD). Representative sample is therefore more accurate; the bigger is the time period, in which it was recorded. However record length is limited by stability of outer conditions. If the conditions change, this fact must be expressed again by the help of significant coefficient.

Traffic load is significant for determination of time life of the construction; it is mostly a summary of more loads. To express the response from traffic load with the best possible accuracy, it is necessary to separate influences from other loads. This can be realised if supposing the influences of other loads are unchangeable with time. Therefore it is necessary to limit in time the record of the response from traffic load (e.g. measurement on steel construction of the bridge should be performed only in several week cycles). But on the other hand for calculation of the service life it is necessary to include these other influences into the calculation. Time record of the response from traffic load is considerably shorter than time change of significant coefficients from the other loads, it is necessary to

extrapolate the time record from traffic load, so there can be expressed changes in consequence of the changes of significant coefficients. This can be managed by the help of simulation of the response from application load by Monte Carlo method.

Simulation of response of the stress from traffic load

Simulation of the stress consists in generation of values of the stress. It should stochastically correspond to structure of representative sample of the stress. It means, that frequency of particular amplitudes in the same time period, which responds to time period of recording the representative sample, is the same. To use this way, firstly we have to statistically evaluate the representative sample (fig. 1), it means that we determine the frequency of local extremes of the stress and process them by the help of histograms (fig. 2).

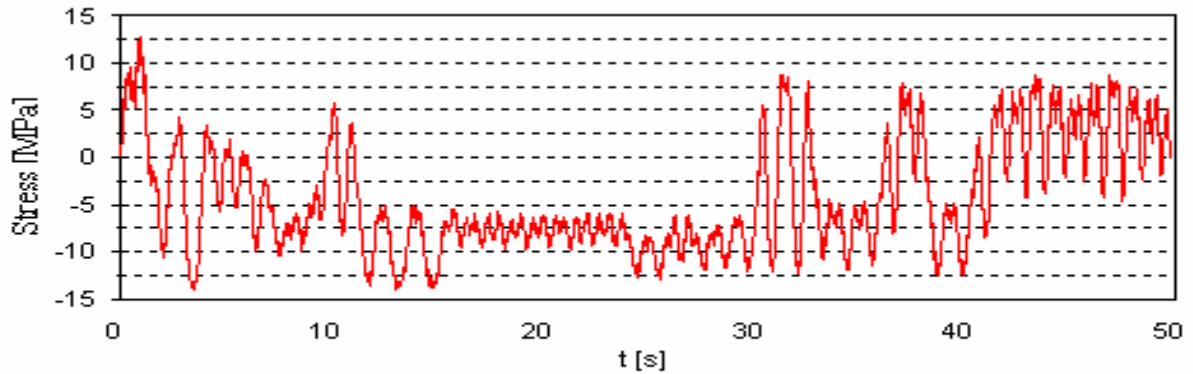


Fig.1 Representative record of the stresses

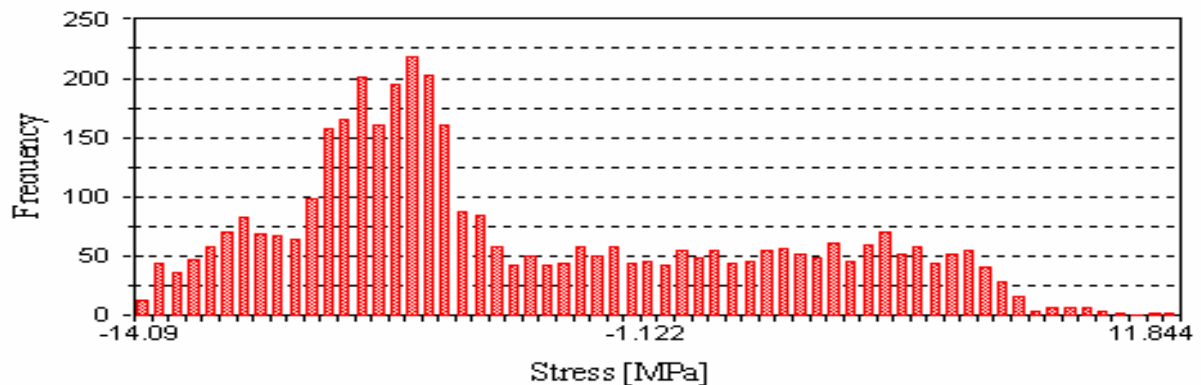


Fig.2 Frequency histogram of particular local extreme stresses

While sampling fine enough the histogram describes probability density of appearance of local extreme of the stresses. On basis of this density we can generate random values of local extremes of the stresses. Disadvantage of generation by this way is, that it does not respect mean values of particular stress ranges. More suitable way is to discredit the stochastic process by using Rain-flow method in two-parametric expression (fig.3), which respects mean value of the range. Then we get probability densities of appearance of the appropriate amplitude on particular levels of mean values of the stresses (fig. 4).

On every level of mean value of the stress we can generate the required amplitude spectrum on basis of these probability densities of stress amplitudes appearance. After generation of the spectra on particular levels of mean values of the stress we can randomly sort these spectra (fig. 5), respecting principle of sequence of the stress amplitudes.

We get the stress signal by this way, which stochastically corresponds to representative signal. We get the total stress by using significant coefficients, that are subjected to the change in time (fig. 6). Course of the total stress is then different from the stress induced by traffic load, but stochastically

responds to that (fig. 7). Significant coefficients can be determined experimentally directly while operating, or in laboratory conditions. For example at significant coefficients of temperature influence must be checked influence size of the temperature, influence of quasistatic temperature change and influence of velocity of the temperature change. Then we determine the significant coefficient of the temperature as a product of partial components of this coefficient (fig. 8).

Two-parametric Rain Flow method
Matrix 32x32, gauge 210 MPa
Undercarriage frame Y-25, date 15.-16.6 1993
Tensiometer n. 131
Tracks of Czech Railways, sum of measurements 217 - 276

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Fig.3 Demonstration of evaluation of the stress signal by the two-parametric Rain-Flow method.

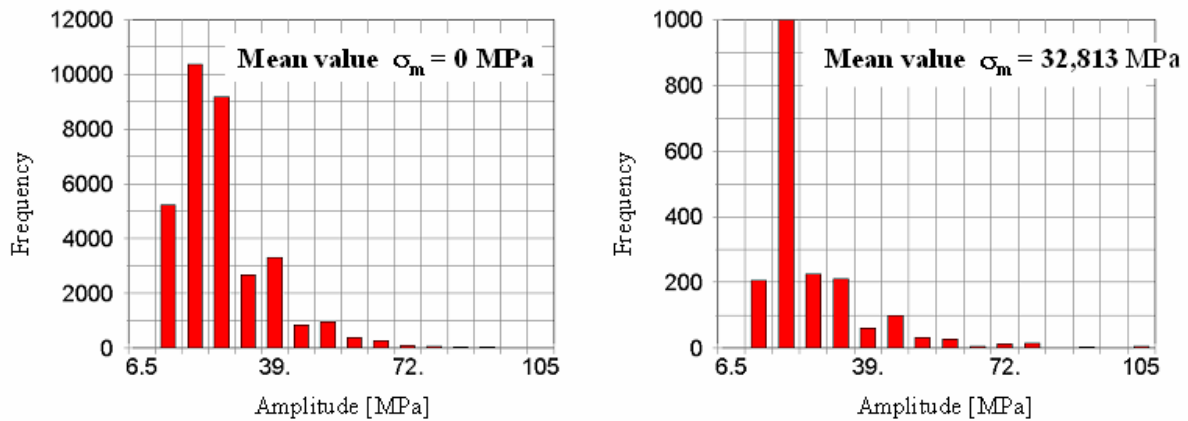


Fig.4 Demonstrations of probability densities of appearance of the amplitudes on different mean values

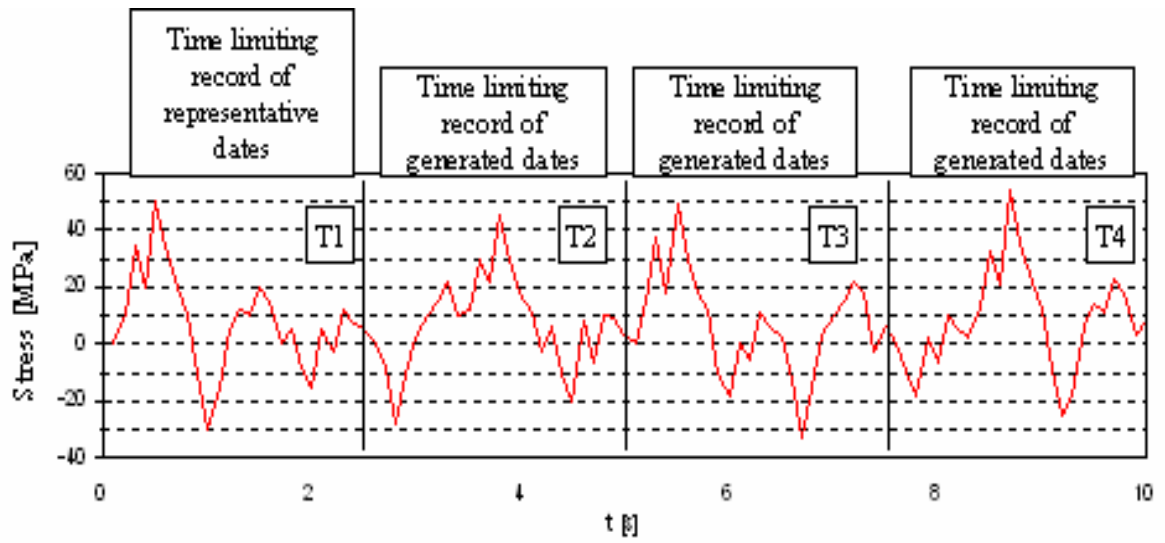


Fig.5 Simulation of stress response

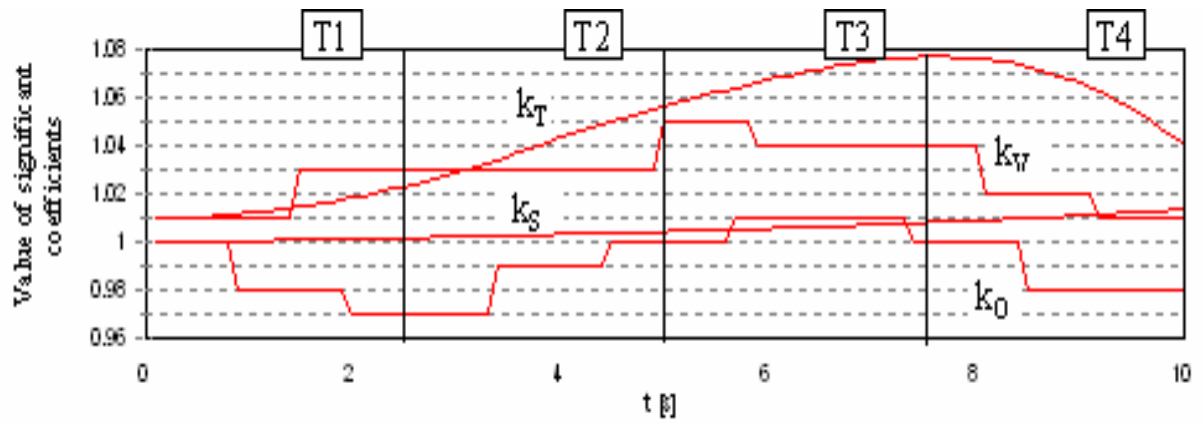


Fig.6 Time change of significant coefficients

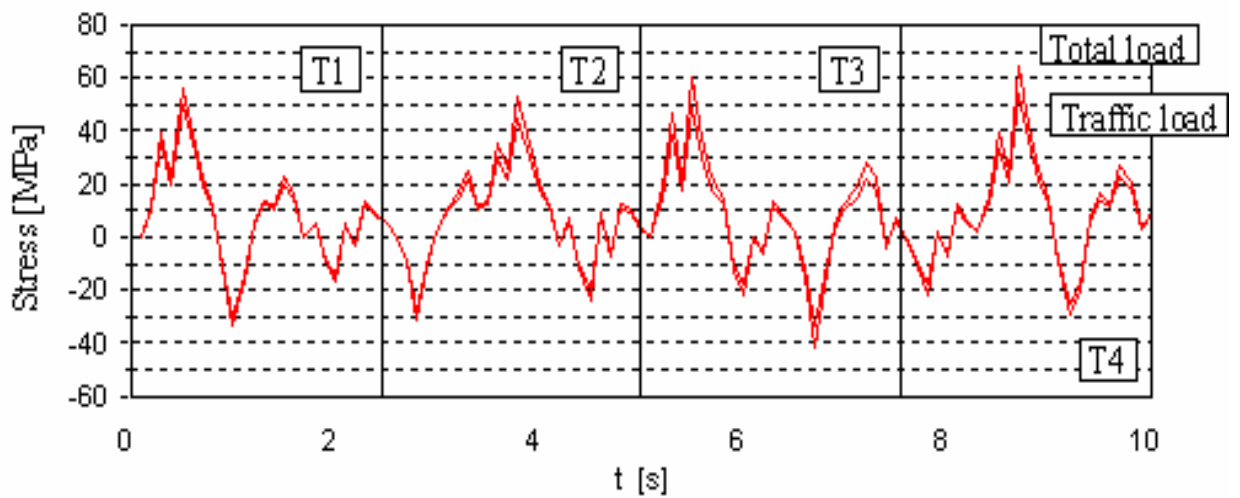


Fig.7 Process of the total and traffic load

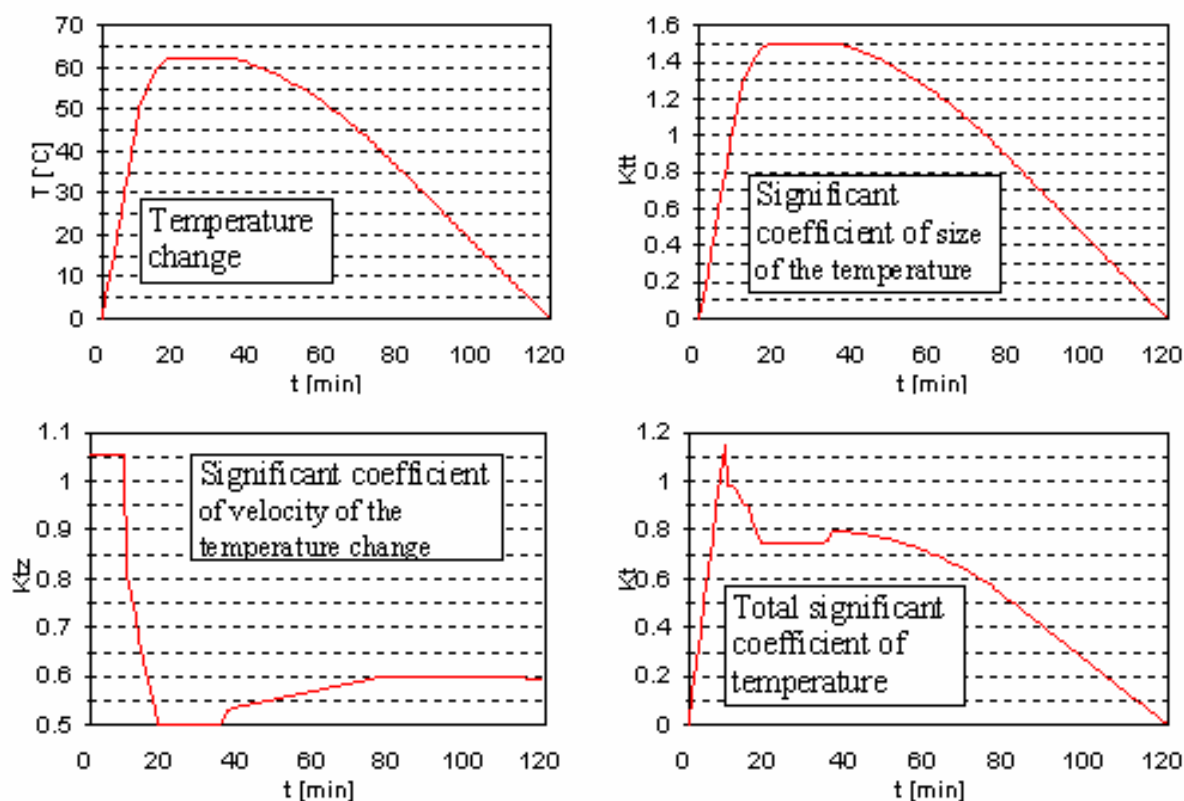


Fig.8 Determination of significant coefficient of the temperature

Conclusion

In the article there is indicated a principle of processing of experimentally determined stresses on basis of simulation of the response of construction stress at application the Monte Carlo method. It is possible to process also the data of material characteristics of objective construction by a similar progress. Both bases processed by this way then make a possibility of stochastic principle of estimation of the service life of railway's steel construction. Suggested progress of determination of estimation of the fatigue service life of railway's steel constructions on basis of stochastic approach comes from solving the grant work GA ČR No. 101/01/0242.

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