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PROCESSING OF EXPERIMENTALLY ASCERTAINED STRESSES OF RAILWAY'S STEEL CONSTRUCTIONS BASED ON PROBABILITY APPROACH

ZPRACOVÁNÍ EXPERIMENTÁLNĚ ZJIŠTĚNÝCH NAPĚTÍ ŽELEZNIČNÍCH OCELOVÝCH KONSTRUKCÍ NA ZÁKLADĚ PRAVDĚPODOBNOSTNÍHO PŘÍSTUPU

Bohumil Culek jun., Bohumil Culek sen.

In this abstract there is indicated process of transformation of stress-records trough probability approach. The process is realized on the basis of statistical analysis of magnitudes, which have influence on service life of railway construction. Substance of the article is concerned on determination of response of stresses from total traffic load by the principle of method Monte Carlo.

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:

$$D_C = D_P + D_T + D_S + D_V + D_O \qquad \textbf{(1)}$$

where D_C is general partial damage

Ing Bohumil Culek ml.,Katedra dopravní infrastruktury, culek@upce.cz,
Prof. Ing. Bohumil Culek, CSc. st., Katedra dopravních prostředků, , bohumil.culek@upce.cz,
Univerzita Pardubice, Dopravní fakulta Jana Pernera, Studentská 95, 532 10 Pardubice.

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 tensiometeric 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:

$$\sigma_{TOTAL} = k_T * k_S * k_V * k_O * \sigma_P \tag{2}$$

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).

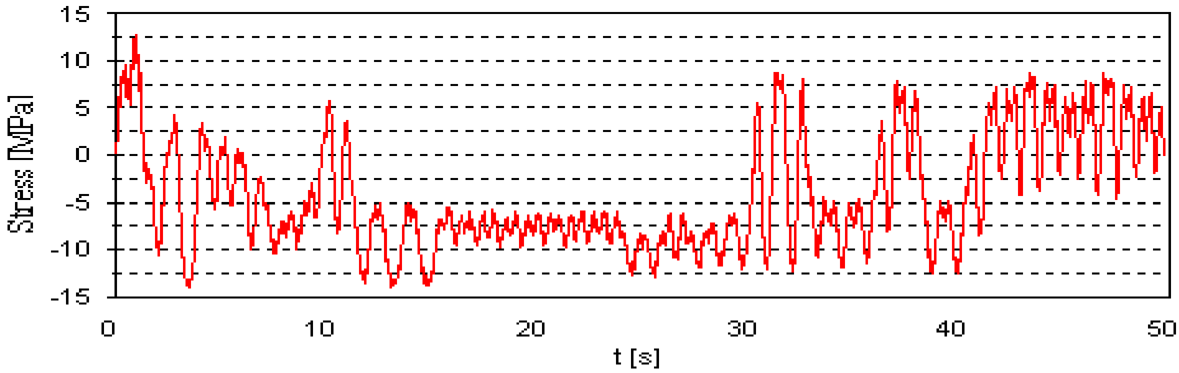

Fig.1 *Representative record of the stresses*

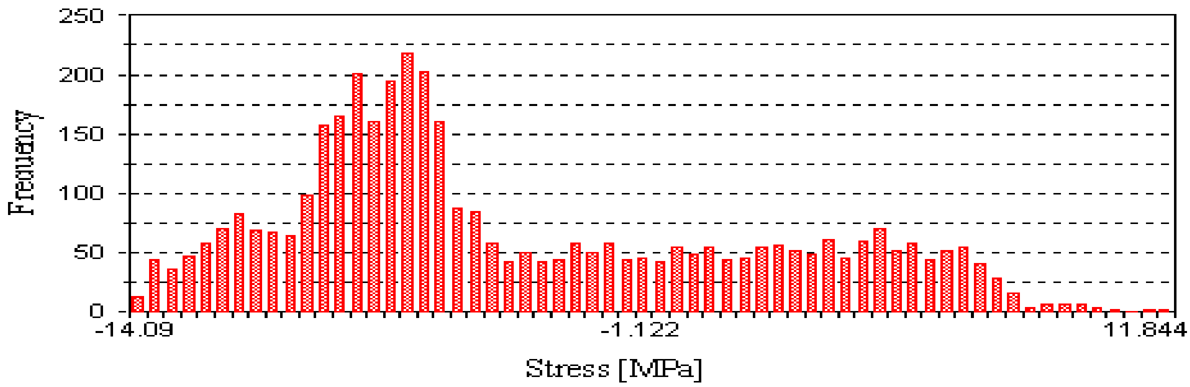

Fig.2 *Frequency histogram of particular local extreme stresses*

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

																																σ_a [MPa]
$-\sigma_m$ [MPa]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	18	10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	15	36	16	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	44	70	40	8	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	280	360	142	12	14	6	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	876	922	1143	106	104	14	24	2	6	2	2	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1134	2072	1822	372	209	80	60	17	18	7	3	2	5	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	1	1472	2787	1895	458	358	152	135	44	15	18	9	4	0	0	2	2	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0
	0	1460	3666	1464	667	388	280	101	76	30	18	18	14	3	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1396	3957	1795	751	529	275	225	88	82	24	29	4	12	1	1	0	0	2	0	0	4	0	0	0	0	1	0	0	0	0	0
	5	2459	5556	2640	951	863	525	424	165	146	53	44	23	19	4	2	0	6	0	8	0	0	0	0	0	1	0	0	0	1	0	0
0	1	5242	10359	9188	2683	3315	864	970	383	276	96	60	34	21	10	6	4	20	10	6	1	1	0	0	0	0	1	0	0	0	0	1
	0	6671	23275	12004	8372	4829	2875	1083	657	228	125	78	37	27	17	62	27	2	1	2	1	1	1	1	3	0	0	3	0	0	0	0
	0	2877	14473	3589	4496	983	1177	387	327	141	88	42	40	97	78	13	6	0	4	2	0	8	7	1	0	9	2	0	1	0	0	0
	0	972	4838	1393	1033	602	425	251	151	86	66	84	114	2	3	3	4	0	2	16	13	0	0	17	14	1	1	0	0	0	0	0
	0	479	2111	662	587	288	295	104	86	34	40	2	4	6	6	0	3	15	16	0	0	9	6	0	1	0	0	0	0	0	0	0
	1	206	1000	226	210	60	100	32	26	6	12	14	0	2	0	5	24	0	2	5	9	0	0	0	0	0	0	0	0	0	0	0
	0	50	376	58	54	16	10	4	2	2	4	0	0	4	5	2	2	2	5	0	1	0	0	0	0	0	0	0	0	0	0	0
	0	28	140	22	30	6	4	6	10	2	2	0	0	2	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	6	48	8	6	0	0	0	2	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	6	36	4	2	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	2	4	4	2	2	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$+\sigma_m$ [MPa]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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

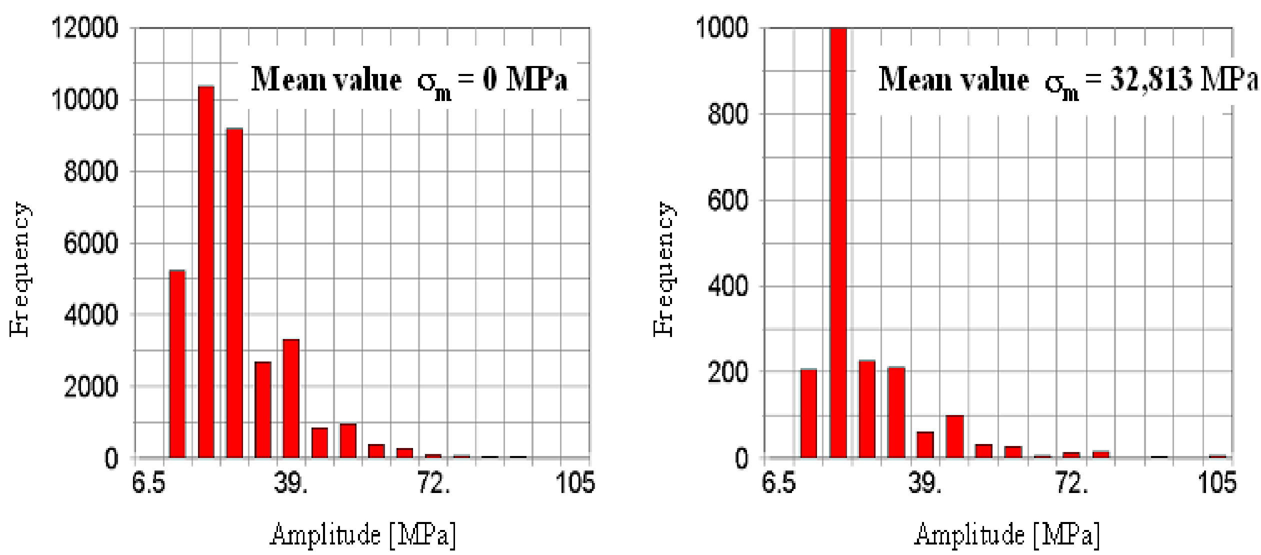

Fig.4 *Demonstrations of probability densities of appearance of the amplitudes on different mean values*

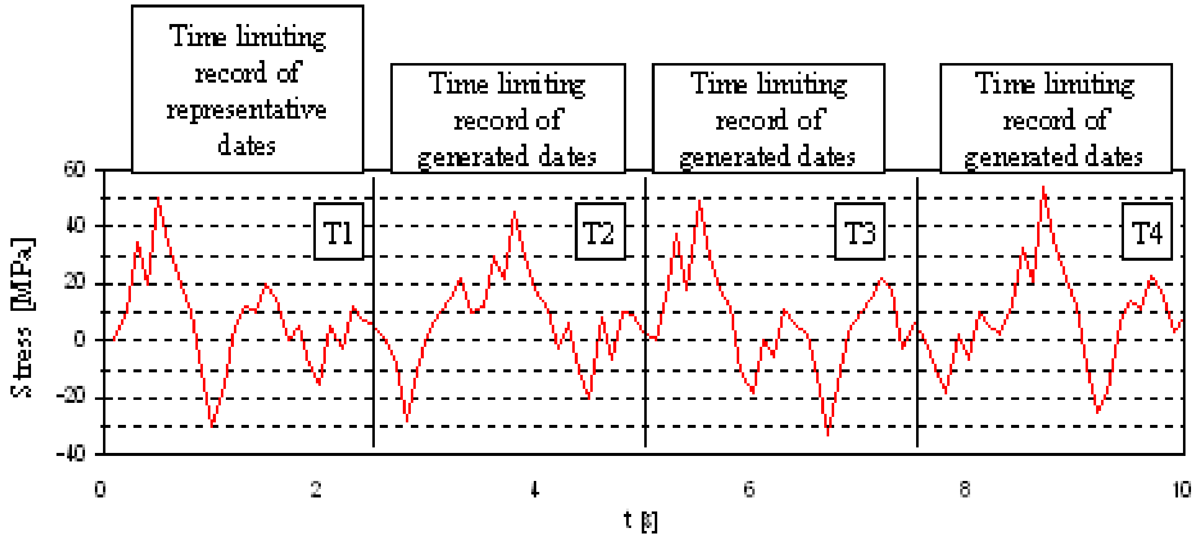

Fig.5 *Simulation of stress response*

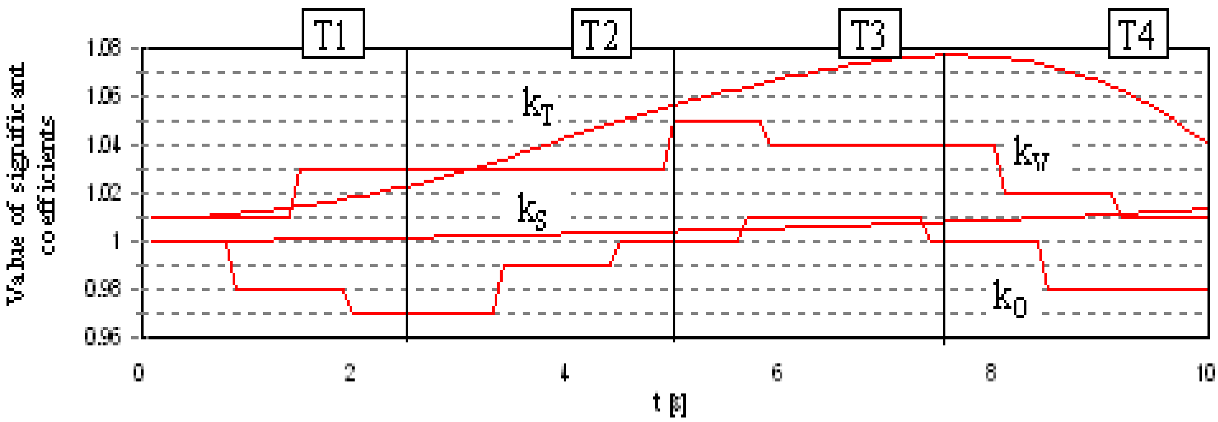

Fig.6 *Time change of significant coefficients*

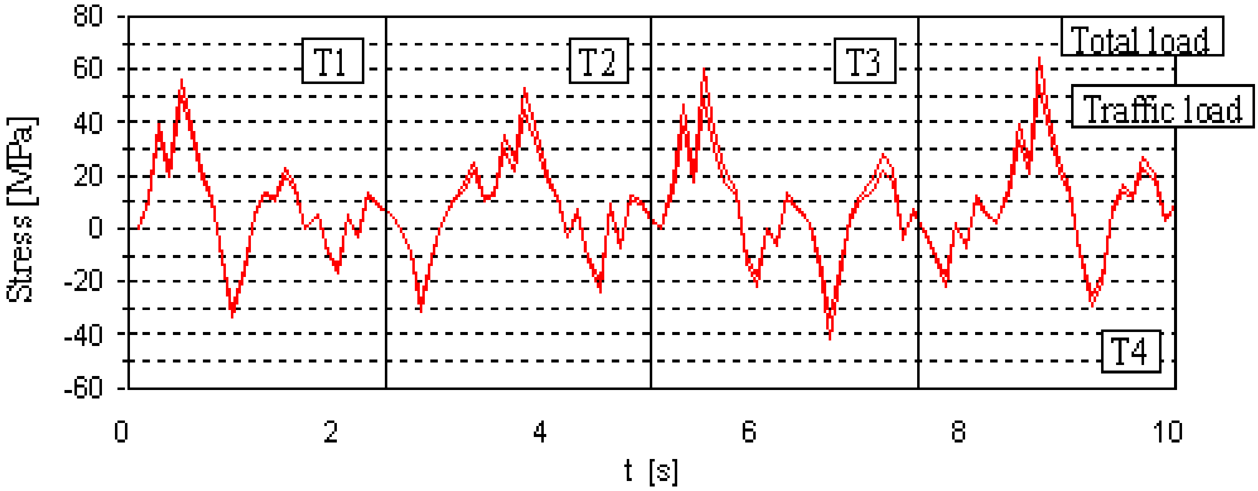

Fig.7 *Process of the total and traffic load*

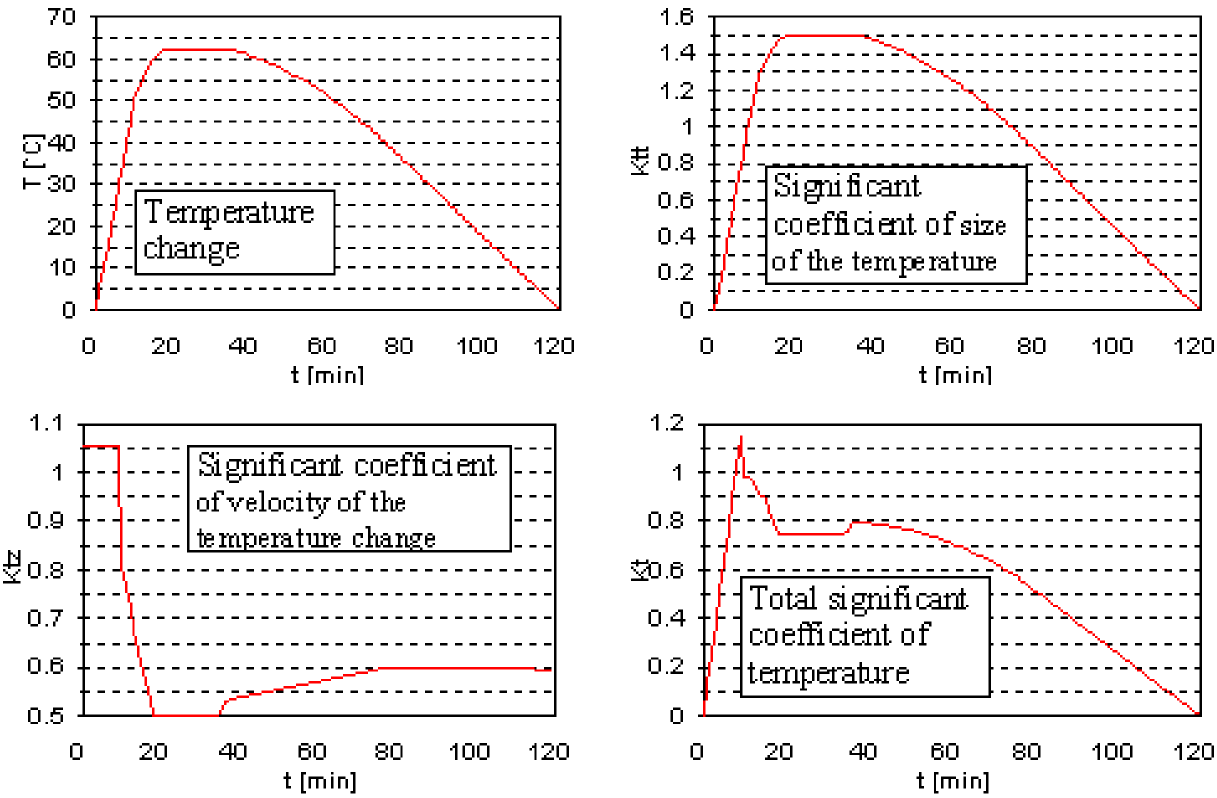

Fig.8 *Determination of significant coefficient of the temperature*

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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