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SYSTEMATIC STUDY OF TYRE WEARING IN TRAFFIC EXPLOITATION

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ABSTRACT
In the paper we are dealing with the utilization of digital sherography for non-destructive testing of tyres. Modern contactless testing method based on digital shearography is presented. Obtained shearograms clearly show material wearing of tyre caused by traffic exploitation in different conditions. Results are compared with those of planned experiment.
Keywords: tyre, shearography, non-destructive testing

1. INTRODUCTION
Holographic interferometry is one of the most sensitive methods for measuring dislocation and deformation [1, 2]. It has found its place also in diagnostics of influence of construction changes on tyre properties at their long-time traffic exploitation. It is an excellent experimental tool for analysis of fatigue of material as well.
The aim of this work is application of planned experiment and optimization of the process of tyre testing at long-term testing via holographic interferometry.

2. THEORETICAL ANALYSIS
One of the possibilities how to get maximum information at minimum costs is active factorial experiment
Creation of appropriate model for feedback description of corresponding parameter can be demonstrated for two-level experiment by scheme according to fig. 1.

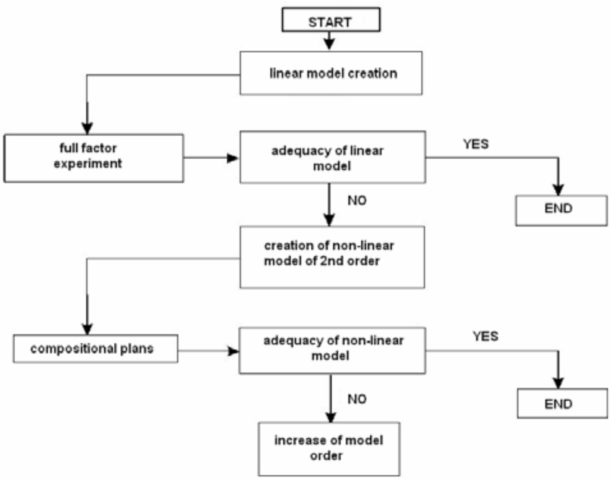

Figure 1. Creation of appropriate model

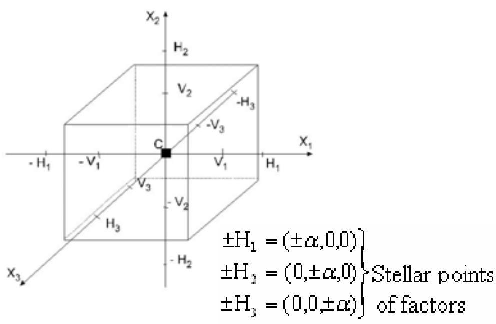

Figure 2. Scheme of central composition plan

Number of levels of particular factors varying in this plan is five, while it is good to choose distance of stellar point to the centre of plan so that factor levels are equally distant from the centre of plan. Rotary central plan of experiment is thus created.
Dispersion estimation of regression equation coefficients is calculated from several repeated measurings in the centre of plan. Constant α for rotary central plan is calculated according to the equation α = 2k/4. When k = 3 factors then α = 1.682 and total scheme of planning matrix for rotary central plan of II. type is in table No. 1.

Table No. 1

Exper. number	**FACTOR VALUES IN NON-DIMENSIONAL SYSTEM OF COORDINATES**									**Output value**
I	x1	x2	x3	x1 x2	x1 x3	x2 x3	x12	x22	x32	y
1	-1	-1	-1	1	1	1	1	1	1	y1
2	-1	-1	1	1	-1	-1	1	1	1	y2
3	-1	1	-1	-1	1	-1	1	1	1	y3
4	-1	1	1	-1	-1	1	1	1	1	y4
5	1	-1	-1	-1	-1	1	1	1	1	y5
6	1	-1	1	-1	1	-1	1	1	1	y6
7	1	1	-1	1	-1	-1	1	1	1	y7
8	1	1	1	1	1	1	1	1	1	y8
9	-1.682	0	0	0	0	0	2.82	0	0	y9
10	1.682	0	0	0	0	0	2.82	0	0	y10
11	0	-1.682	0	0	0	0	0	2.82	0	y11
12	0	1.682	0	0	0	0	0	2.82	0	y12
13	0	0	-1.682	0	0	0	0	0	2.82	y13
14	0	0	1.682	0	0	0	0	0	2.82	y14
15	0	0	0	0	0	0	0	0	0	y15
16	0	0	0	0	0	0	0	0	0	y16
17	0	0	0	0	0	0	0	0	0	y17
18	0	0	0	0	0	0	0	0	0	y18
19	0	0	0	0	0	0	0	0	0	y19
20	0	0	0	0	0	0	0	0	0	y20

Plan of experiment is considered to be done for the following load regime:

- various experimental tyre speeds (60 km/h to 280 km/h) - factor x1
- various tyre load (4 kN to 13.2 kN) - factor x2
- various duration of experiment (1 h to 200 h.) - factor x3

Other factors will be kept at constant value, such as tyre inflation, tyre temperature etc.
Observed output value will be separation movement in dependence on the change of factors (x1), (x2) and (x3).
Regression equation for three-factors planned experiment of II. type with particular factors on three levels has general form.

$$y = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_2 x_3 \qquad (1)$$

3. EXPERIMENTAL PROCEDURE

Non-destructive analyzer for deformation observation ITT-1 produced by SDS Systemtechnik GmbH

It includes ITTMes and ITTView programs
Feeding device – with loading and unloading on one side
CCD camera and 4 laser diodes.

Figure 3. Non-destructive analyzer

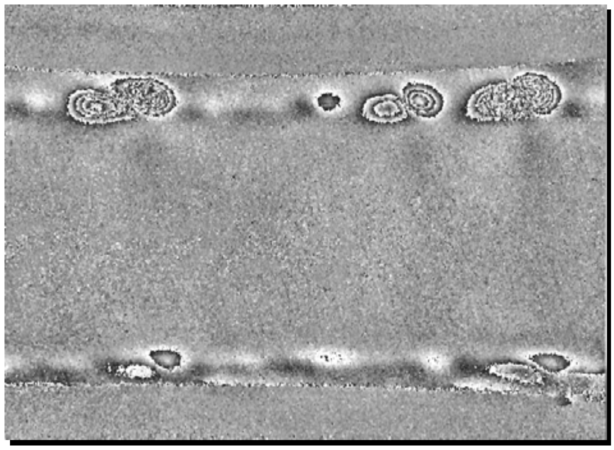

Figure 4. Displaying of separation on the screen

Non-destructive analyzer (Fig. 3) allows quick and simple detection of structural defects (closed separations). Tyre testing is done by inducing low external vacuum on tyre causing externally invisible material separations to protrude. These structural defects are monitored by means of interferometric measuring method, TV-shearography. Measuring principle is based on electronic phase interferometry. Interferogram is directly measured by means of CCD camera. That is the reason why tyre surface is illuminated by coherent light – laser and at the same time observed with adjustment shift. Two phases dislocate images – before and after ambient pressure decrease – they are superposed and pre-processed. To visualize typical abnormalities (separations), interferential image of tyre surface at normal pressure is stored into computer memory. Second image, acquired in deformed state at low pressure, is subtracted from the first stored image. Difference of these two images is displayed on computer monitor. Typical abnormalities (separations) are shown as dots on computer monitor - see fig. 4. Phase and video image is at disposal for each sector.

System software provided with SDS tyre testing system includes besides ITTMes program for management and recording of measured values also the system for data browsing - ITTView allowing evaluation and archiving of measured results independent on test process [3], [4, 5].

4. RESULTS AND DISCUSSION

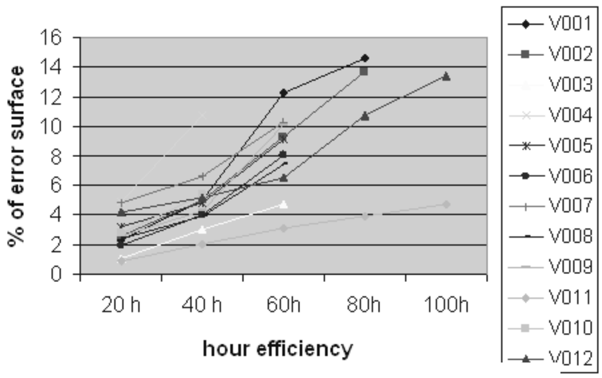

Figure 5. Variants comparison

Introduced graphs show that:

- tyre no. 10, variant no. 11 had the smallest area of defects after 40 hours in the area of shoulder
- tyre no. 12, variant no. 12 had the smallest area of defects after 40 hours in the area of bead
- tyre no. 10, variant no. 11 had the smallest area of defects after 40 hours in overall tyre

Tyres no. 10 and 12 had the best performance and tyre no. 10, variant V011 also showed best results regarding percentage of defects. This tyre was recommended to developers as the best one out of all tested variants and was put into practice. Bead area of tyre no. 12 was recommended because of the best percentage ratio of defects in this area.

5. REFERENCES

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