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MULTI-AXES FORCE TRANSDUCER USING THE SYSTEM FOR ACTING PRESSURE IMAGE VISUALISATION

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Abstract – The special compact transducer has been developed – to be better known the force's and pressure's effects by transporting the loose materials. The projects of these transporting devices often demand to know not only the normal force's effect, but the effect of the lateral forces "the shearing or slip forces", too. The transducer creates two parts. First one is calibrated as Vector signal analyser – to be caught the elementary forces F_x, F_y, F_z (Cartesian system). The strain gauges are used on the special deformation "S–shape" element. Worth seeing - the second part of transducer - what is the small visualisation system. As the sensor - the conductive elastomer is used in matrix arrangement with the 286 sensing elements, to be caught the acting media pressure distribution. The signals digitising allows the onboard Image Preparation. The developed SW enables the PC–visualisation in real time; or the Digital Image Acquisition. By synchronising both parts, the other advances can be realised as: to record the elementary forces waveforms by dynamic mode, to analyse the pressure distribution up to 30 Hz (snaps/s), histogram 3D, auto-calibration, image correction etc.

Keywords: force transducer, visualisation system, lateral force

1. BASIC INFORMATION

The advanced multi-axes force transducer is realised for the industry necessities of the transport devices as: the pipe-lines and ducts for the loose material transport, their profiles, bending, coating, covers; and for the construction of the drives elements especially – the paddles of the wheel–stirrers or the turbine vanes, too. To be better understood the force's acting and the pressure's distribution, the special compact transducer has been developed – to be improved, the measurement techniques, to get any more precise data - for the projects and construction the above mentioned elements of the transport devices. The construction's development usually demands - to get more information, either the interaction of the moving parts vs. surroundings (i.e. turbine vanes, wheel-stirrers etc.), and either the information about the instantaneous running of any technological operations. A pressure contact scanning belongs to the important features of the mutual activity among the systems or theirs parts. Not only normal forces are usually interesting, but lateral forces - which are caused by the circumfluence of the loose or liquid material, too – known as "the shearing or slip forces"**.** To help, these ones to be caught and analysed - for what, this transducer is developed.

The transducer offers the others measuring possibilities - can be used as the probe to help the better determination:

- the mapping of the streamlines distribution, especially for the granulates and the rough-seeds materials – as can be seen in Fig. 1.
- the consistencies setting of the loose mixtures (similar as the dry concrete mixtures)
- the friction factor determination between the various materials
- believed – transducer can be used for liquid materials, too – (don't be tested to this time).

Fig. 1. Streamlines granulate distribution mapping

2. TRANSDUCER PERFORMANCE

The compact portable transducer (introduced in Fig. 2.) consists from two sensors, which are activated only through the frontal site of transducer, what enables to be caught – either the elementary forces, and either the pressure distribution in the followed area.

As pressure sensor, the untraditional conductive elastomer - type CS57-7RSC – has been used, for the original transducer design. For this high quality elastomer, the producer [3] - guaranteed practically no change in the mechanical qualities and in conductivity, too - during 10^6 loading cycles. The experiments number has been started to be known the properties and behaviour of this pressure

Fig. 2. Transducer performance in loose material

sensing material (thickness 0,5 mm). The fundamental static and dynamic tests have been done, as (sensitivity; reproducibility; hysteresis; zero-stability, long time-stability, etc.); the other special problems have been solved, too – as (transducer cover; calibration).

The experiments results generated the pressure sensor design. The elastomer sheet is situated between 2 electrodes. The flexibility of the superficial electrode (FPC – flat printed circuits technology - used on Cuflex material, th. 0,05 mm) enables to be attacked the sensing elements. These ones are situated overall the front-site area (55x25 mm) – see Fig. 3. The perpendicular electrodes arrangement allows to be realised 286 sensing elements (1x1 mm - each). By this way - "the frontal sensor" is done. The used principle – by acting pressure (force) - the elastomer´s conductivity is changed, what is caught as electrical signal for the further processing.

Fig. 3. The transducer - Front-site sensing area

The elementary forces measurement is realised by means the second one sensor, tightly fixed the first one, with. The six-axis deformation is measured by using the special deformation element ("S-shape" Fig. 4.) – equipped with the strain gauges. This sensor measures the lateral forces in two axes, and the normal force – to be set the total pressure at the front-site area of the transducer, at the same time. Due to this fact, the correction and the auto calibration can be done for the first one sensor, too.

The demand - the enough rigidity, and to be damaging-proof for the industry environment using – is rather difficult to insure, especially what concerns the frontal sensor cover-layer. For any no-sharp granulates, the silicon rubber seems to be quite well. The others transducer cover layers depend from the loading character, what determines the total thickness of this layer (about 0,7 mm – to this time). Except the frontal sensor, the transducer as a whole is situated in the stainless steel box, including the electronics for the frontal sensor.

Fig. 4. Detail of strain gauges "S-sensor"

3. RESULTS

The PC-processing is preferred for the output signals of the multi-axes force transducer which supports the acting pressure Image Visualisation. The other demand, no complicated cabling has been respected, too – either from the view-point of user, and either from the view-point the interferences possibilities.

3.1. Force sensor output

The elementary forces to be evaluated – the 6 channels measuring unit is used. This one enables the standard signal processing for the strain gauges bridge-connection (as signal conditioning, amplification, A/D-converting etc.) – and therefore, the other details won't be given here. As an available unit can be used - e.g.: HBM-Spider 8; or similar. The elementary forces records (by the dynamic test) are introduced in Fig. 5. – as the "S-sensor" results : the Output voltage vs. Time dependence U = f(t).

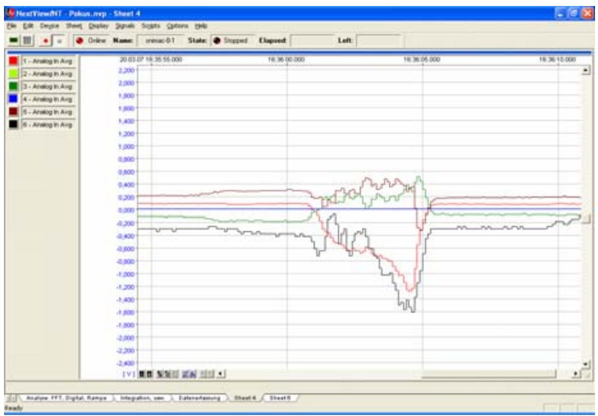

Fig. 5. Six channels - elementary forces wave forms
Output voltage vs. Time dependence U = f(t)

The example of "S-sensor" calibration – by the sensitivity matrix determination (for 4 channels - only). The orientation of Cartesian system can be seen in Fig. 6.

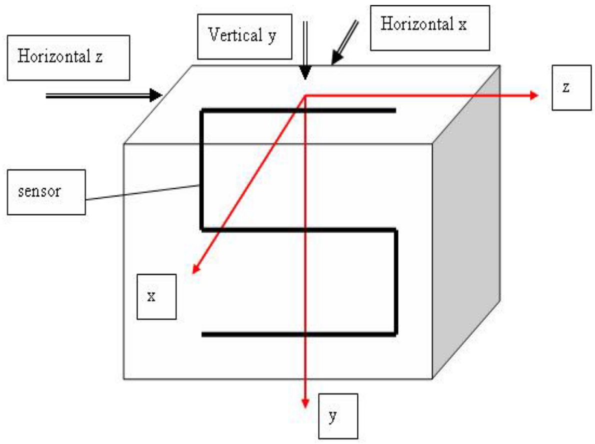

Fig. 6. The orientation of Cartesian system for "S-sensor" - diagrammatically

Measurement results - for 4 channels $U=(k_1, k_2, k_3, k_4)$ are given as product of elementary forces $F=(F_x, F_y, F_z)$ vector and sensitivity matrix A(4x3 form) – unit [mV/N], expressed , as (1) and (2) :

$$\begin{bmatrix} k_1 \\ k_2 \\ k_3 \\ k_4 \end{bmatrix} = \begin{bmatrix} +0{,}0037 & -0{,}058 & -0{,}179 \\ +0{,}0053 & -0{,}0168 & +0{,}136 \\ -0{,}00695 & -0{,}0377 & +0{,}175 \\ +0{,}1536 & -0{,}0064 & +0{,}002 \end{bmatrix} \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} \qquad (1)$$

$$\Rightarrow \quad U = A \, . \, F \qquad (2)$$

By calculation of inversion matrix $\mathbf{A_i}$ we can calculate real forces F_x, F_y and F_z (in Newton) for axes x, y and z – what can be set, as (3):

$$F = A_i \, . \, U \qquad (3)$$

Inversion matrix A_i has been set in form (4) – unit [mV/N] :

$$A_i = \begin{pmatrix} -0.417 & 0.119 & -0.593 & 6.49 \\ -11.742 & -3.934 & -8.953 & 0.013 \\ -2.181 & 1.686 & 2.172 & 0.093 \end{pmatrix} \qquad (4)$$

3.2. Pressure sensor output

To be seen the acting pressure distribution on the frontal sensor – the simple interactive SW is developed. This one allows enough quite well Image Visualisation, by the results processing – as: 2D-model (Fig. 7.), 3D-MM (mountain model), 256 grey-scale levels or colour-palette, histogram, amplification, zoom. Simple statistics is implemented, too – as: min, max, mean.

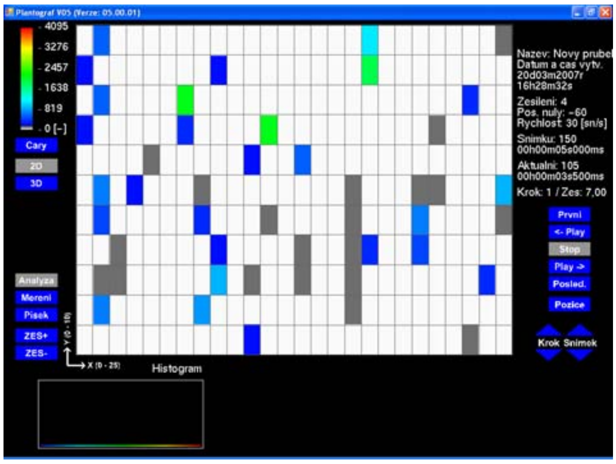

Fig. 7. Front-site sensing area - Sensitivity test

3.3. Transducer main features

Front-site measuring area	25x55 mm
Number of sensors on front-site area	286 pcs
Sensors array	11 x 26
Dimension of sensors	1x1 mm
Grid resolution	2 mm
Max. normal force at front-site measuring area	300 N
Max. normal force at one sensor	6 N
Max. shearing force	100 N
Number of digital levels	256
Scanning frequency	30 Hz (snaps/s)
Overall transducer dimensions	30x60x160 mm

4. CONCLUSION

The main advantage of the qualitatively new Transducer is - to be caught and analysed the elementary forces, if only the frontal transducer-site is pressure-attacked. In the same time, the Image Visualisation of the pressure distribution in this pressurised area can be roughly introduced, too – what enables the special developed SW; and the comfort of the PC-data processing; then datalogging etc.

The application possibilities are concentrated mainly for the loose materials. Especially, the lateral forces – as "shearing and slip forces" are the object of interest; beside that – their relation to the normal force (including the pressure distribution in the followed area) can be set, too. Transducer is designed to be caught the conditions for the force distribution in the limited spaces, for example - on the paddles of the wheel-stirrers; or for the transporting pipe-lines profiles. Further, for the study-possibilities of the force distribution, which is generated during the movements of the loose or liquid materials. The advantage – (to be known the lateral forces) – can be used by judging such physical qualities, as: adhesion, viscosity, glueyness, and similar.

The main disadvantage seems to be the shape and size of this transducer, which causes the harmful effects e.g.: by the stream-lines mapping; on the contrary, this one is "rather small" – to be caught the right pressure distribution in a huge transport-duct. The other mentioned problem above is the vulnerable cover layer - especially what concerns the sharp rough-materials. The PTF-foil (Teflon) cover-layers tests – don't get quite well results to this time. The "waterproof" protection hasn't been realised to this time; nor the liquid-materials tests, too. The noise and interference problem is solved by using the short cabling (shielded) – length up to 3m; and the snaps frequency is used to 30 Hz (full snaps/s), only – by the dynamic tests.

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