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Analysis of Stress and Stick-Slip Effect of the Test Stand

M. Petrů [1,*], L. Ševčík [1], P. Srb [1], R. Kovář [1]

[1] *Technical University in Liberec, Studentská 2, 461 17 Liberec, Czech Republic*
[*] *michal.petru@tul.cz*

Abstract: The paper describes the design of noise removal effect of the friction pair of trapezoidal screw in a special device call Stick-Slip effect. Article builds on previous measurements and testing sliding pairs. The pair worked in the special bath oil, its characteristics is that it does not support the mechanical lubrication. Measurements and calculations showed that it is necessary to enlarge the diameter for 32 kN load trapezoidal screw.

Keywords: Stick-Slip Effect; High Voltage Electrical Equipment; Bolt Connection; Trapezoidal Screw.

1 Introduction

The aim of the research was to define the cause and eliminate sound effect coming from the device. Sound effect derives a pair of highly loaded machinery parts - motion screw and nut. Loaded pair is used in non-standard environments of high voltage electrical equipment in electrical substations. The non-standard environment is seen in the movement of this pair immersed in transformer oil deeply below the surface. Transformer oil has no good mechanical lubricating properties because it does not contain Sulphur. Oil help to transformer perform to its design standards, an electrical insulating oil must maintain its characteristics over a wide range of operating temperatures. All electrical oils are designed to offer excellent heat transfer and dielectric properties, even at the lowest start-up operating temperatures. In addition, oils are formulated to offer excellent resistance to the effects of ageing, sludge formation and deposit build-up. Loaded pair cannot be lubricated, because there would be oil contamination and deterioration of its electro-insulating properties. The causes were sought in the structure of the machine, frame stiffness, mechanical strength machine and used materials.

2 New Design of Pair of Screw

The result of research from the viewpoint of the friction pair of stick-slip effect is a proposal to reduce the contact pressure. This was realized by increasing the diameter of bolt. Trapezoidal screws are produced in a wide range of diameters and pitches. Their calculation using standard empirical formula, which show only the average value.

Fig. 1: Trapezoidal screws TR 50 × 8 and TR80 × 10.

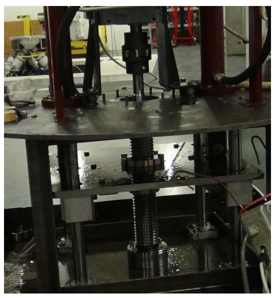

Fig. 2: Test equipment.

Calculations were chosen as sufficiently bearable 80 mm. Mechanical characteristics are in Tab. 1. It can be compared with the original solution of diameter 50 mm. In Fig. 1 are samples precision trapezoidal screws TR 50 × 8 and TR80 × 10, and tested on the test equipment Fig. 2.

Tab. 1: Comparison of the calculated mechanical parameters trapezoidal screws.

Parameters	TR 80		TR 50	
d	80	mm	50	mm
$d_{mid.}$	75	mm	46	mm
pitch	10	mm	8	mm
d_3	69	mm	41	mm
H_{teeth}	5	mm	4	mm
L1	120	mm	90	mm
f_{dyn}	0.13	lubricated 0.005-0.01	non lubricated 0.1-0.16	
gama	0.0425	rad	0.0553	rad
f'	0.1346			
p_v	400 speed factor			
p_{all}	5	MPa		
v_{all}	80	mm/min	80	
F	32000	N	32000	
Mk $_{gen.}$	260	Nm		
$Mk_{max.}$	413	Nm	Maximal gearbox moment	
$n_{gear.}$	10	rev/min	10	
v	0.1	mm/min	0.08	
$p_{cont.}$	3.0196	Contact press in MPa	6.5643	Contact press in MPa
Mk_{up}	214.66	Nm	141.47	Nm
Mk_{down}	110.88	Nm	58.45	Nm
Mkdif	103.78	Nm	83.03	Nm

3 Experimental Analysis

Measurement parameters:

- method of pin-on-disc, load of 180 N, tested pin material: steel class 11523, 14220, 17140 stainless, material counterpart: 3 kinds of bronze, CuSn8, CuSn12, CuSn7Zn4Pb7,
- pin diameter: about 3.8 mm linear speed: 0.033 mm/s, radius after which the pin moving body: 16 mm, length of slide track: 200 m,
- lubricating fluid - Shell Diala Oil D 75 ml, (submerged sample).

Results of measurements:

- For stainless steel friction coefficient was high so that it had to be reduced and the load force so that the measurement was terminated.
- For best gliding properties amounted to a pair of pins 11523 and 14220 and the mating pair CuSn12 and CuSn8 oil Shell Diala D. Stainless steel bolt did not work.
- Plasma surface due to a high pressure early wear and acts as a base material.
- Adaptation of bearing surfaces is characterized by increased noise levels at the beginning of the measurement.

- Last measurement was performed on the same device other technical universities because of the high value of the tangential force, which led to the destruction of the sensor.

Results of measurements are shown below. Of the forces acting between the materials was calculated coefficient of friction see. Fig. 3. further, the recorded noise levels, see Fig. 4.The results in the figures are for different materials. The test device is shown in Figure with drawn from the oil bath. Since the production of these screws is expensive tests were done first material samples. Measurements were performed on tribological device Tribotester UMT-3 brand BRUKER see Fig. 5. From these tests was the optimal configuration of materials. It can be said that the best results are achieved in carbon steel in combination with CuSn. Have been tested special nanolayers deposited on the pins, see Fig. 5. These coatings, however, soon wear out and have friction pair of great importance. Measurements were made on the device see Fig. 6.

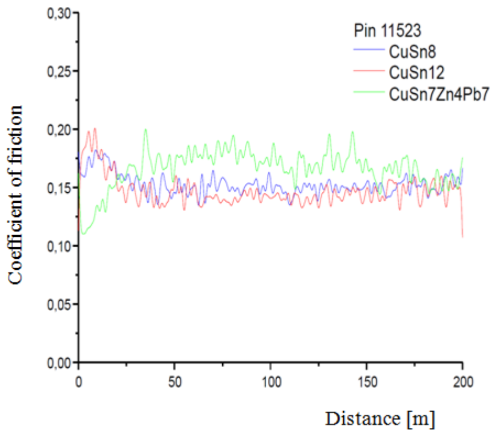

Fig. 3: Calculated coefficient of friction.

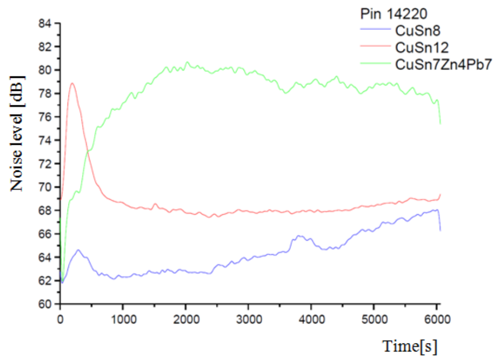

Fig. 4: Recorded noise levels.

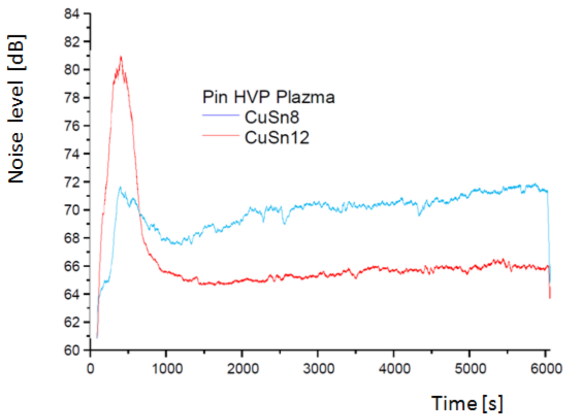

Fig. 5: Calculated coefficient of friction.

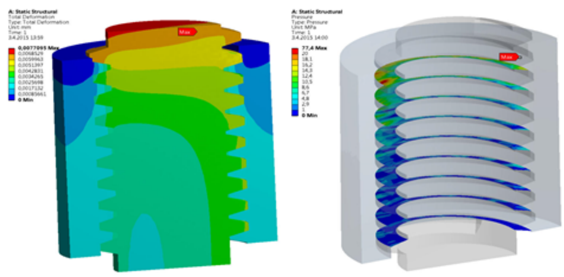

Fig. 6: Measure instrument.

4 Numerical Analysis

To determine amount of strain and the size of the contact pressure between the screw and nut were compiled numerical analysis using the finite element method. The measured coefficient of friction was used in the FEM contact settings. In the program Ansys Workbench 14.5 contacts with friction were selected [2]. Ansys uses implicit algorithm for calculations [3], where individual states of the analyzed compression are updated gradually in time t to time $t + \Delta t$ according to Eq. (1).

$$\delta u_{i+1} = u_{i+1}^{t+\Delta t} - u_i^{t+\Delta t}, \tag{1}$$

where $u_i^{t+\Delta t}$is vector of nodal displacements for i$^{\text{th}}$ iteration in the time $t + \Delta t$.

Setting the size of the contact force tester was verified FEM calculations. In Fig. 7 values are calculated deformation and pressure screw TR 50 × 8 and Fig. 8 for screw TR80 × 10. The pressure on the larger bolt decreases by more than half.

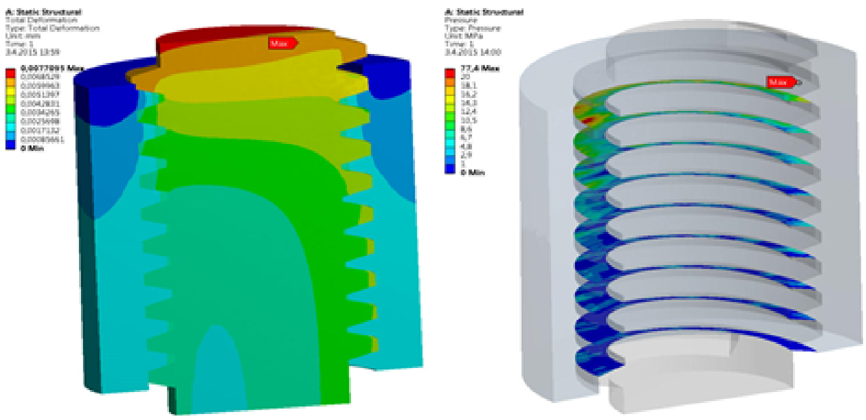

Fig. 7: Deformation and pressure screw TR50 × 8.

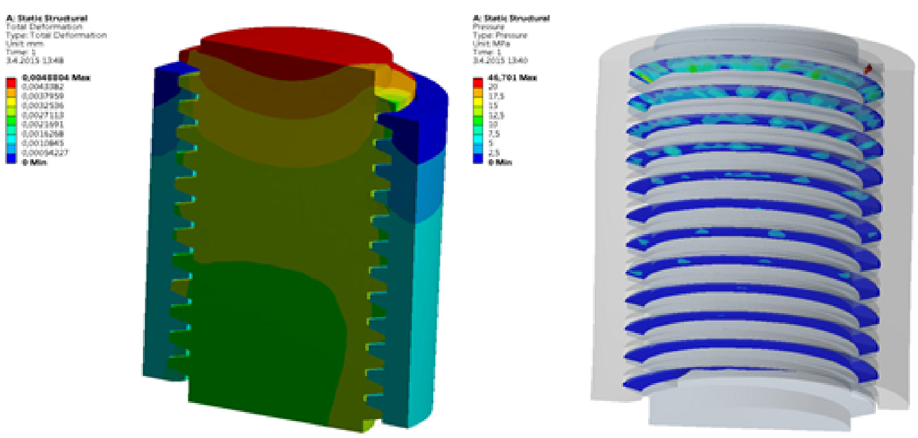

Fig. 8: Deformation and pressure screw TR80 × 10.

5 Conclusion

Measurements and calculations showed that it is necessary to enlarge the diameter of 32 kN load trapezoidal screw. This will reduce the contact pressure, which leads to polish the contact surfaces. You then slip together better and are not as easily stick slip effect.

Acknowledgement

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References

[1] F. Zypman, J. Ferrante, M. Jansen, K. Scanlon, P. Abel, Evidence of self-organized criticality in dry sliding friction, J. Phys. Cond. Matt. Lett. 15, 191 (2003).

[2] F. Heslot, T. Baumberger, B. Perrin, B. Caroli, and C. Caroli, Phys. Rev. E 49, 4973 (1994) Sliding Friction: Physical Principles and Applications – J. of Research 88. B12 (1983): 10359-10.

[3] M. Petrů, L. Ševčík: Analysis of Stress and Vibration on the test Stand. In. 52nd International Conference Experimental Stress Analysis (EAN 52), June 2 – 5, 2014. Mariánské Lázně, Czech Republic, 2014, ISBN 978-80-231-0377-6.