MODELING AND MEASURING MECHANICAL DAMAGE FOR ADJUSTABLE LUMINAIRE

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Abstract

The article describes one of the tests that were performed on the street light fittings. Simultaneously with the test a mathematical model was developed with the parameters of the test part – angularly positional flange and the modelling result was compared with the results of the experiment. On the basis of the data obtained, a new model of the tested component of the luminaire with optimized toothing was created in order to simplify the production of the aluminium casting of the luminaire.

Key words: *adjustable luminaries, optimization, toothed couplings, flange, FEM model*

INTRODUCTION

Part of the public lighting luminaires being tested is a flange that can be adjusted to allow for an illumination angle from -30 to + 90 °; The flange can be seen in Fig.1. The flange principally comes from the front toothed coupling, also known as the Hirt's coupling (*Pešík, Části strojů, 2015, Budynas, Shigley's mechanical engineering design,2011*). The teeth in the form of an equilateral triangle are located at the periphery of the coupling faces. Working surfaces of the teeth are subjected to the pressure and bending. The coupling is preferably used where the small dimensions are required. Easy to assemble and disassemble. Its disadvantage is very precise production.

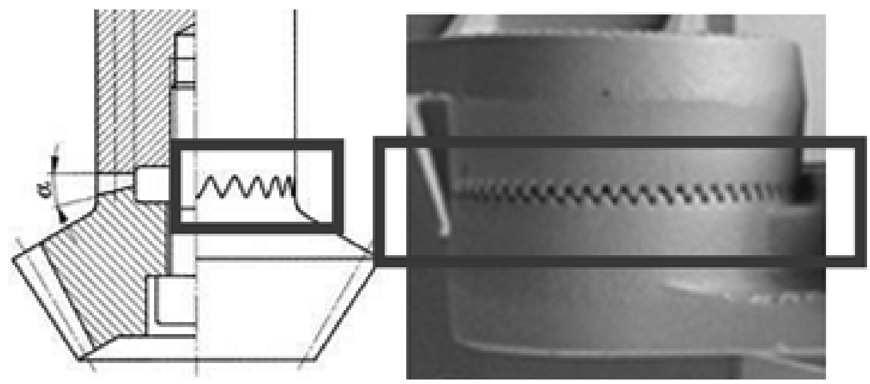

Fig.1 a) Coupling with front teeth, b) Positional flange

MATERIALS AND METHODS

Luminaire with an integrated adjustable flange which is mounted on a mast or boom, was the object of the testing . The luminaire body is adjustable in the range of -30° to + 90° thanks to the toothed joint (flange). The flange is in Fig.2. The luminaire can be divided into two parts; body of luminaire - an aluminum casting and an electrical part that provides primary lighting function. The luminaire including the flange was loaded with force acting in one direction at a distance of 0,33m from the center of the flange in the first phase of the test. The test was performed using a hydraulic motor, and the rod (Fig.3). The force was captured using a force cell GTM with a range of up to 50kN. The aim of the test was to identify the weakest spot on the luminaire, the load value and the condition and mode of damage (Fig.4).

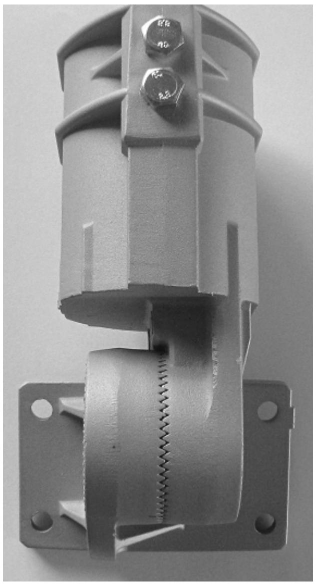
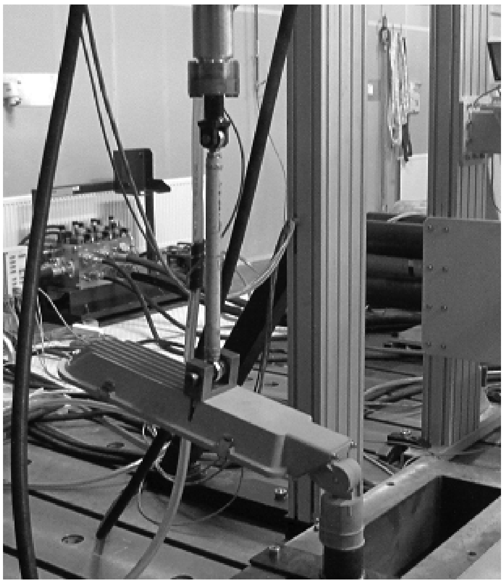
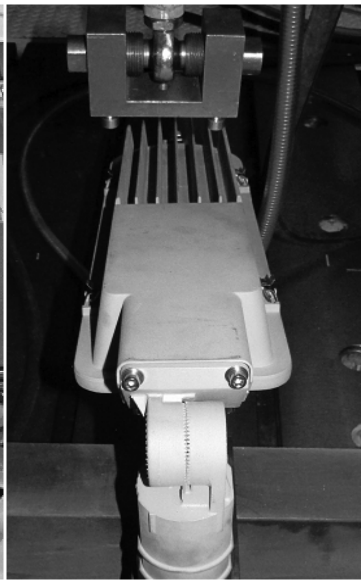

Fig.2 Detail of flange **Fig.3** Loading of the luminaire **Fig.4 F**lange after test

During the experiment, a maximum force F = 1700N was measured; the graph in Fig. 5 indicates the value by a dashed line. With this force, the teeth of the flange were damaged, as can be seen in Fig.6.

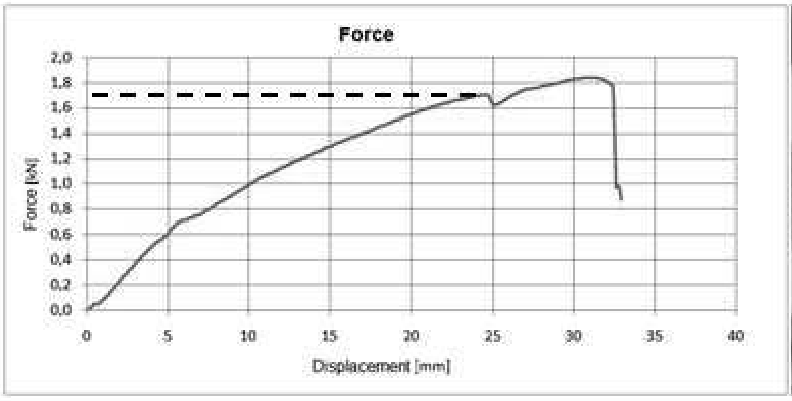

Fig.5 Result of measurement **Fig.6** Teeth damage of flange

Moment of force M [Nm] was calculated according to formula (1) at 561Nm at the point of force action. Force F[N] and radius r [mm] was measured.

$$M_K = F \cdot r \qquad (1)$$

Samples were taken from the body of the luminaire for image analysis and a determination of the weight of impurities in the aluminium alloy from which the luminaire is made. A mathematical model was also created and a simulation of the experiment was performed.Based on the measurement of the maximum force that damaged the flange, an attempt was made change the flange tooth geometry. The formula (2), (3) and (4) were used for the calculation.

$$M_k = F \cdot r = F_1 \cdot r \cdot z \qquad (2)$$

z – number of teeth, F1 – force acting of one tooth, r – radius of flange

$$\sigma_O \geq \frac{a \cdot F_1}{W_O} \qquad W_o = \frac{b \cdot h^3}{12} \qquad (3)$$

a, b, h – parameters of one tooth, σ_o – bending stress

$$\tau_s \geq \frac{F_1}{S} \quad (4)$$

S – working tooth content, τ_s – shear stress

The results of the calculations are summarized in Table 1. The results were used to model the new teeth of the adjustable flange so as to make it easier to produce while maintaining the same load characteristics.

Tab. 1 Parameters of toothed couplings

	z	F1 [N]	σ_o [MPa]	τ_s [MPa]
real flange	62	292,2	52,2	27,2
optimized model	36	500,9	22,4	23,3

NUMERICAL MODEL

Numerical model for the description and study of the mechanical properties of the samples of aluminium is based on analytical models. For homogeneous isotropic materials simple relations exist between elastic constants Young's modulus E, shear modulus G, bulk modulus K, and Poisson's ratio ν that allow calculating them all as long as two are known (5 – 8):

$$E = 2G(1+v) = 3K(1-2v) \quad (5)$$

$$G = \frac{E}{2(1+v)} \quad (6)$$

$$K = \frac{E}{3(1-2r)} \quad (7)$$

$$v = -\frac{d\varepsilon_{trans}}{d\varepsilon_{axial}} = -\frac{d\varepsilon_y}{d\varepsilon_x} = -\frac{d\varepsilon_z}{d\varepsilon_x} \quad (8)$$

Where: $d\varepsilon_{trans}$ is transverse strain (negative for axial tension (stretching), positive for axial compression);
$d\varepsilon_{axial}$ is axial strain (positive for axial tension, negative for axial compression).

Simplified lamp lighting models were created in Solidworks software. One model was designed with original tooth dimensions. The optimized model has twice teeth dimensions. Lamp models were imported into the Ansys program, where the topology of the model was modified. The aluminium alloy parameters were inserted into the model. Friction contacts with a friction coefficient of 0.3 were inserted between the parts of the teeth. Fixed boundary condition was inserted into the bottom of the model, the model was deprived of all movements and rotation. As a second boundary condition, a vertical force of 1700 [N] is applied to the upper part of the model (Fig.7). The output of the simulation was the maximum von-Mieses tension between the teeth.

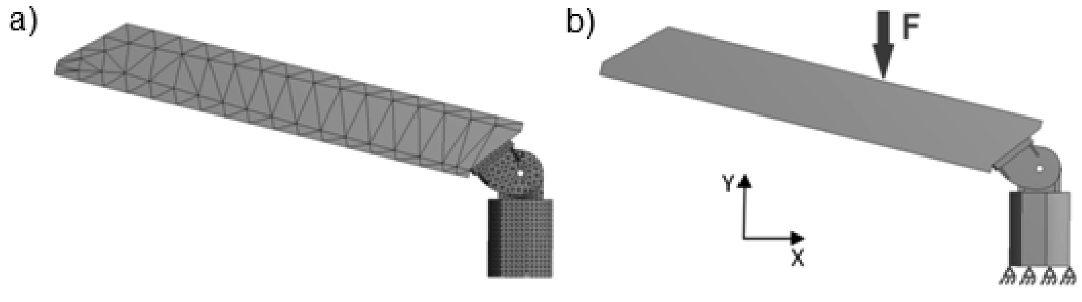

Fig.7 a) Mash of model, b) Inserting boundary conditions into the model.

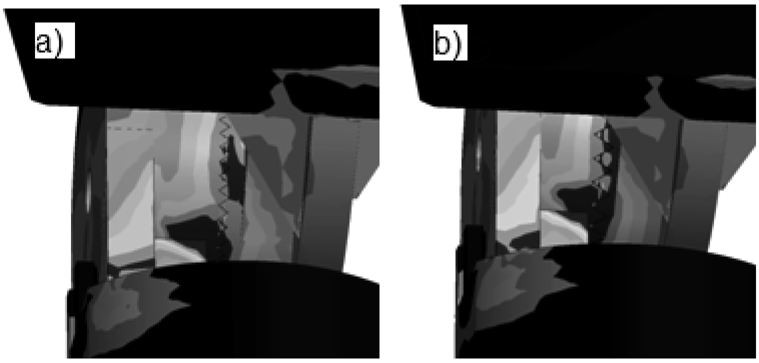

Fig.8 Detail of the von-Mises maximum tension a) for the flange, b) for the optimized model

RESULTS AND DISCUSSION

Calculations according to formulas 1-4 showed that a change in the geometry of the teeth did not significantly change the mechanical parameters of the flange. The safety of the adjustable flange when using a public light bulb under real conditions is not significantly affected.

The value of stress 316.8 [MPa] was measured when simulating real conditions. During optimization, a maximum stress of 286.5 [MPa] was measured. Changing the teeth geometry has affected the mechanical properties of the flange positively.

CONCLUSIONS

The measurement showed a high degree of security of the adjustable flange. Using the calculation and the proposed mathematical simulation, we pointed out the following possibilities: Tooth enlargement will simplify the production of aluminum casting, the positioning will be maintained at 10 ° and the safety of the light is not significantly affected.

ACKNOWLEDGEMENT

The results of this project LO1201 were obtained with co-funding from the Ministry of Education, Youth and Sports as part of targeted support from the "Národní program udržitelnosti I" program.

REFERENCES

1. Budynas, R.G., Nisbett, J.K., (2011). Shigley’s mechanical engineering design, McGraw-Hil, New York, ISBN 978-0-07-352928-8
2. Michna, Š., Lukáč, I., Louda, P., Očenášek, V., Schneider, H., Drápala, J., Kořený, R., Miškufová, A., et al, (2007). Aluminium materials and technologies from A to Z. Adin s.r.o., Prešov, ISBN 978-80-89244-18-8.
3. Pešík, L. (2015). TechnickáUniverzita v Liberci. Částistrojů, pp.39, ISBN 978_80- 7494-184-9
4. Wang, H.R., Wang, W., Gao, J.O.,(2010). Materials Letters 64, pp. 219-221.
5. ČSN EN 60598-1 ed.5, (2009). Svítidla – Část 1: Všeobecnépožadavky a zkoušky; Úřad pro technickounormalizaci, metrologii a státnízkušebnictví.
6. Katalogový list svítidla, dostupnýna: http://www.modus.cz/productoo/getfile.php?fileID=Mjk0MA%3D%3D&forceDownload=false

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