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A MEASUREMENT FACILITY FOR THE DETERMINATION OF COIL HELICAL SPRINGS RIGIDITY

Summary. This paper deals with a theoretical description of coil helical springs rigidity and with experimental spring determination on model. This experiment is instrumental in theoretical expectation verification.

Experimental measurement of spring rigidity has been performed.

STANOWISKO DO BADAŃ CHARAKTERYSTYK SZTYWNOŚCI SPRĘŻYN ŚRUBOWYCH

Streszczenie. Artykuł zawiera metodykę i opis stanowiska do badań własności sprężystych sprężyn śrubowych. Dla przykładu załączono wyniki badań sztywności wybranych wielkości sprężyn.

1. DEFORMATION OF SPRING

Deformation of spring v is the change of the initial height h_0 (fig. 1a). This deformation may be calculated using Castigliano´s theorem:

$$v = \frac{\partial U}{\partial F} \tag{1}$$

Castigliano´s theorem indicates, that a generalized shift in place of elastic body is defined by a partial directional derivative of deformation energy U [J] of the whole body in the direction of force F [N].

For a thin spring with little lead using formula (1) it follows that:

$$U = U_{Mk} = \frac{M_k^2 . l}{2 . G . J_p} \ [J] \tag{2}$$

where:
M_k [Nm] – torque of spring wire,
l [m] – length of spring active part $= \pi \cdot D \cdot i$ [m],
i [-] – number of active coils,
J_p [m^4] – quadratic polar moment of spring wire cross section,

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$$J_p = \frac{\pi . d^4}{32} \ [m^4] \tag{3}$$

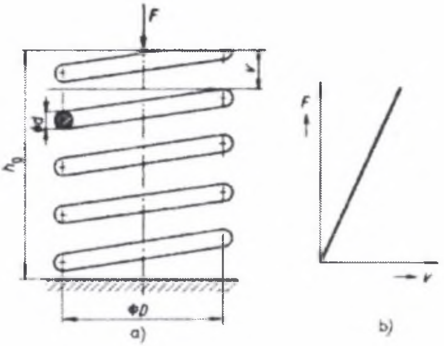

Fig. 1. Deformation of spring; a) scheme of spring diameters, b) rigidity diagram
Rys. 1. Deformacja sprężyny; a) schemat wraz z wymiarami, b) wykres sztywności

Having used formulas (1), (3) and (2), we state the following result:

$$U = \frac{M_k^2 . l}{2. G. J_p} = \frac{\left(\frac{F. D}{2}\right)^2 . (\pi . D. i)}{2. G. \frac{\pi . d^4}{32}} = \frac{4. F^2 . D^3 . i}{G. d^4} \ [J] \tag{4}$$

Deformation of spring follows from the Castigliano's theorem:

$$v = \frac{\partial U}{\partial F} = \frac{\partial}{\partial F}\left(\frac{4. F^2 . D^3 . i}{G. d^4}\right) = \frac{8. D^3 . i}{G. d^4} . F \ [m] \tag{5}$$

From formula (5) it is evident, that deformation of spring is linearly equal to force F [N] (fig. 1b). Note that *spring rigidity* and *constant of spring* are often used k [N.m^{-1}].

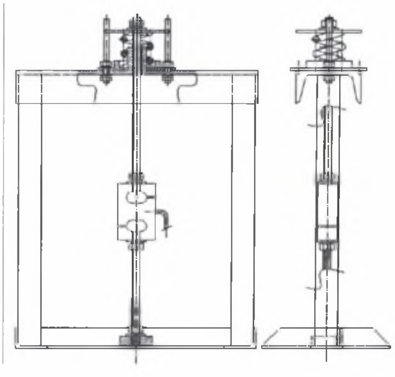

Fig. 2. Measurement equipment model springs rigidity determination
Rys. 2. Model urządzenia pomiarowego do badania sztywności sprężyn śrubowych

Deformation v [m] is expressed by formula:

$$v = \frac{F}{k} \ [m] \tag{6}$$

From formula (6) it follows that *spring rigidity* k [N.m^{-1}] and has dimension:

$$k = \frac{F}{v} = \bar{F} \ (v = 1 \ m) \ \ [N.m^{-1}] \tag{7}$$

2. MEASUREMENT EQUIPMENT FOR COIL SPRINGS RIGIDITY DETERMINATION

The measurement stand (fig. 2) for coil helical springs rigidity determination has been built in the R&D and Testing Department, Institute of Transport, Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava. The measurement facility consists of the rigid frame, a measured spring, a stretching device, a tensometric sensor of load and the PC with a built-in measurement adaptor.

The rigid frame is composed of U and L welded rolled profiles (fig. 3)

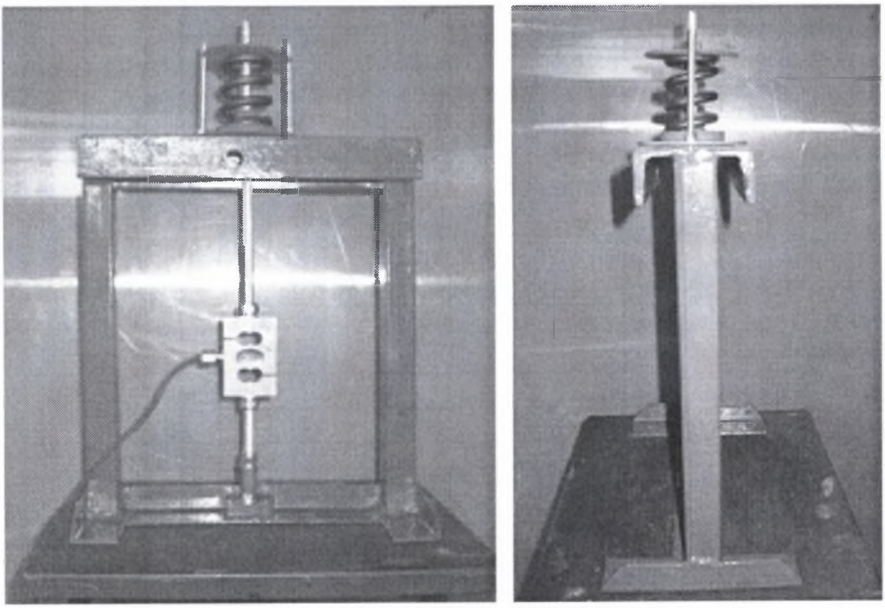

Fig. 3. Model springs rigidity determination
Rys. 3. Urządzenie pomiarowe do badania sztywności sprężyn śrubowych

Adequate accuracy of deformation v [m] (deflection) of spring with nut M12 is realized. This nut generates thrust F [N] to the measured spring (fig. 4).

Deformation power is scanned by a tensometric sensor of load (Hottinger Baldwin Messtechnik sensor type RSC A) fig. 4. Measurement equipment consists of PC with a built-in measurement adaptor Advantech.

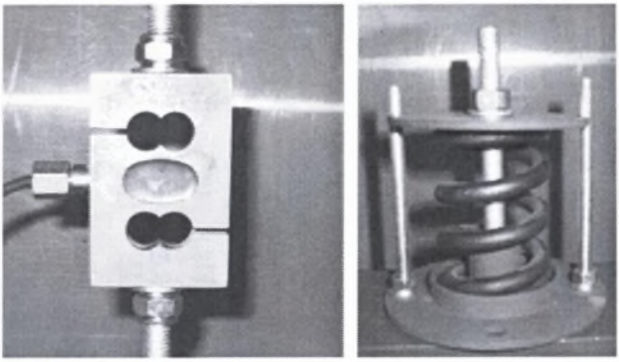

Fig. 4. Model springs rigidity determination
Rys. 4. Urządzenie pomiarowe do badania sztywności sprężyn śrubowych

3. MEASUREMENT PROCESS

a) We know basic parameters of measured spring (basic height h_0 [m], effective diameter D [m], diameter of wire d [m], number of active coils i [-]).
b) Between lower and upper thrust rings the measured spring is clamped.
c) Deformation of spring by the nut rotation is realized.
d) Height h [m] of the spring is measured at a suitable moment.
e) Values of repeated measuring are tabulated. From these tabulated values spring rigidity is subsequently calculated.

4. RESULTS OF MEASUREMENT

The process of deforming force F [N], depending on deformation of spring with thread diameter D = 50 mm, wire cross section d = 5 mm, initial height of spring h_0 = 128 mm, is described in fig. 5.

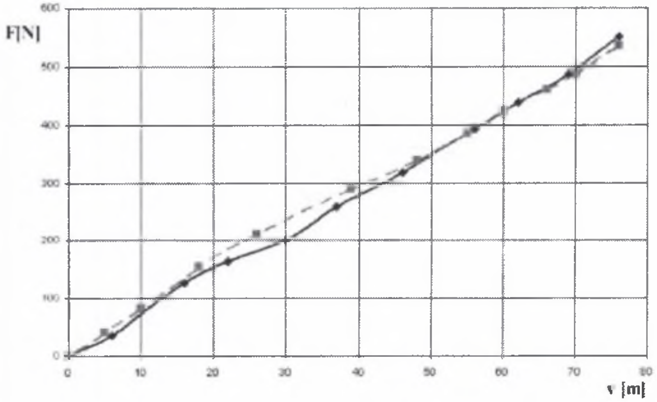

Fig. 5. The process of deforming force F [N], depending on deformation of spring with thread diameter D = 50 mm
Rys. 5. Wykres siły powodującej deformację sprężyny o średnicy drutu D = 50 mm

The process of deformation force F [N], depending on deformation of spring with thread diameter D = 50,5 mm, wire cross section d = 9,5 mm, initial height of spring h_0 = 90 mm, is described in fig. 6.

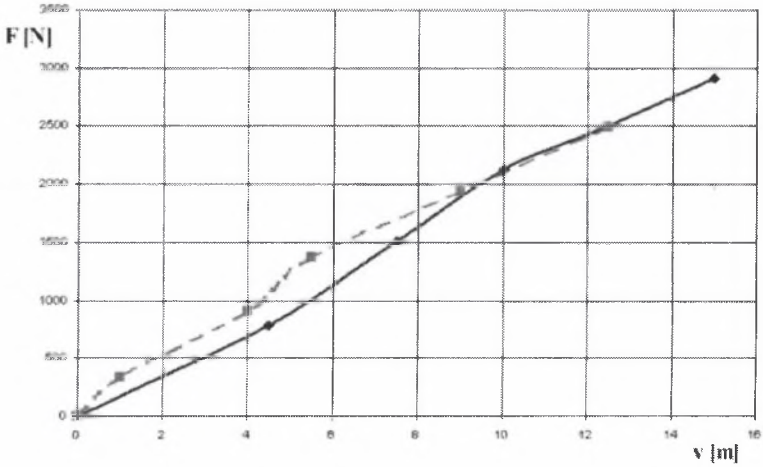

Fig. 6. The process of deformation force F [N], depending on deformation of spring with thread diameter D = 50,5 mm

Rys. 6. Wykres siły powodującej deformację sprężyny o średnicy drutu D = 50,5 mm

The curves have been obtained from repeated measurement of spring rigidity. A linear regression straight line has been inserted to smooth the curves (dashed line) fig. 7 and fig. 8.

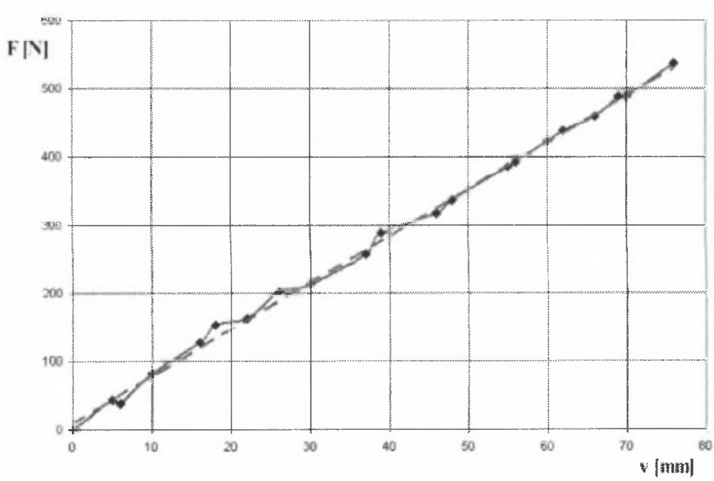

Fig. 7. Linear regression straight line of first spring (fig. 5)

Rys. 7. Liniowa funkcja regresji sprężyny wg rys. 5

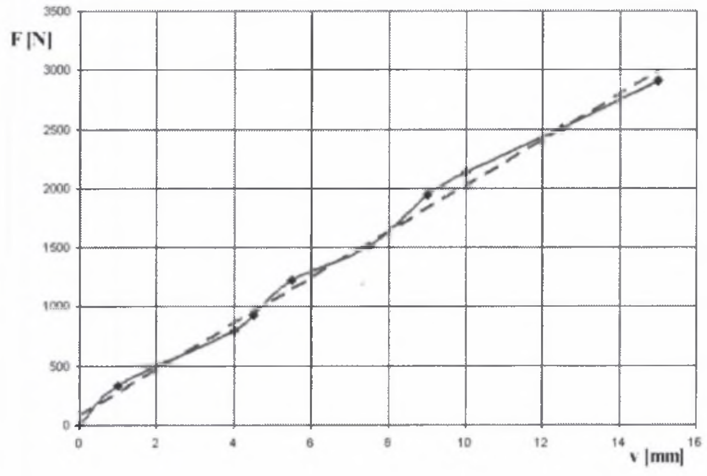

Fig. 8. Linear regression straight line of second spring (fig. 6)
Rys. 8. Liniowa funkcja regresji sprężyny wg rys. 6

5. CONCLUSION

Measurements carried out by utilizing the measurement facility for the determination of coil helical spring rigidity with a sufficient level of accuracy, describes the dependence of deformation on deforming force. The model facility enables to verify theoretical findings, which are described in literature [2].

Literature

1. Hájek E., Reif P., Valenta F.: Pružnost a pevnost I, SNTL/ALFA 1988, 307 p.
2. Hrabovský L.: Měřící pracoviště stanovení tuhosti vinutých válcových pružin. VŠB-TU Ostrava 2004.

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