

RESEARCH OF DETERIORATION OF SELECTED NON-METTALIC MATERIALS IN SLIDING ARRANGEMENTS OF THE VERTICAL FRAME SAW

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Abstract

The authors attempt to investigate and provide reasonable grounds for the application of selected non-metallic construction materials in linear slide bearing arrangement of the frame guidance of the vertical saw frame. In their experimental research, the authors verify the selected technical parameters of selected materials under laboratory and operating conditions.

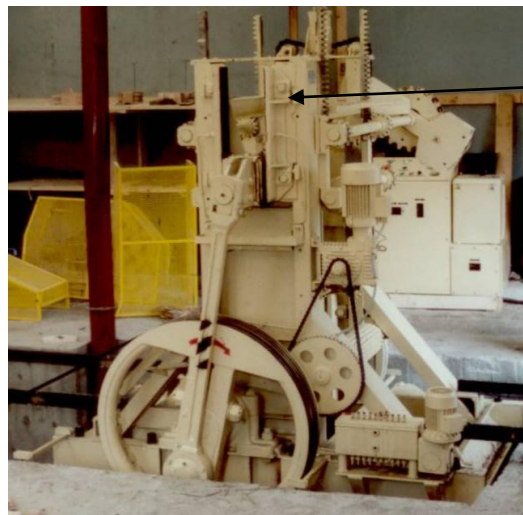
Keywords: Friction coefficient, sliding pair, wear, service life.

1 Subject matter of the research

Main parameters of the saw frame include frame lightness and stroke, number of strokes per minute or number of shaft revolutions per minute, type and size of the material feed. A vertical frame saw makes vertical straight-line reciprocating motion ensured by the crank mechanism (Fig. 1).

To assess the load of the crank mechanism sliding pair objectively, kinematic and dynamic analysis of the crank mechanism must be performed. Fig. 2 illustrates the crank mechanism of the vertical frame saw. The crank mechanism is made up of a connecting rod, crank and main crankshaft. The connecting rod connects the sash pivot and crank pin.

There are two handles on the shaft, which is located in two bearings on the base plate, one of which is the camshaft pulley and the other the flywheel. The camshaft pulley and flywheel are both firmly connected to the shaft. The linear movement axis of the frame is deflected from the crank rotation axis by the e value. To assess the load of the crank mechanism sliding pair objectively, kinematic and dynamic analysis of the crank mechanism must be carried out.



linear guidance of
the saw frame

Fig. 1 Uncovered electric frame saw

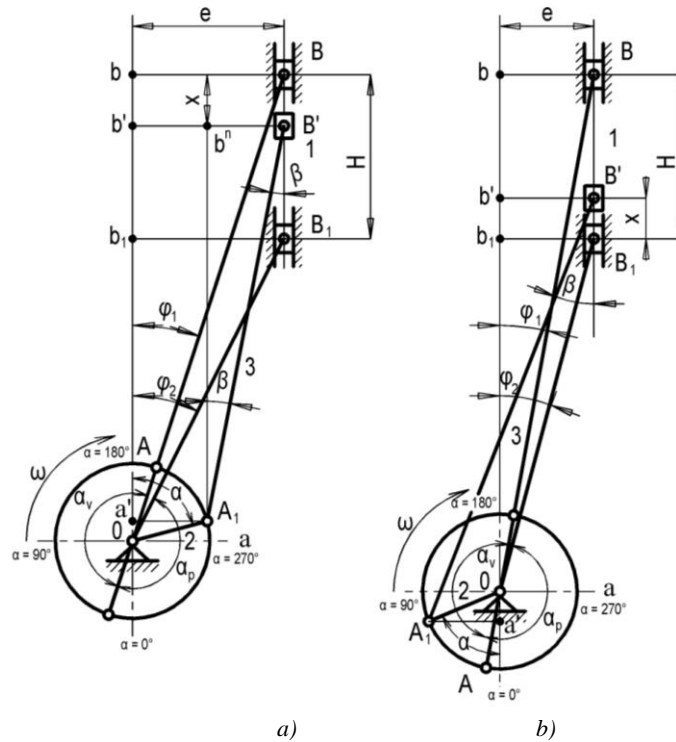


Fig. 2 Crank mechanism [2]

a) movement from the top to bottom dead center, b) movement from the bottom to the top dead center, 1 – base frame, 2 – crank, 3 – connecting rod, x – lift, e – deflection of the frame axis from the crank mechanism rotation axis

1.1 Kinematic analysis of the crank mechanism

$$x = \sqrt{(l+r)^2 - e^2} - l \cdot \cos \beta - r \cdot \cos \alpha \quad (1)$$

where: x – travel (m),
 e – deflection of the frame axis from the crank mechanism rotation axis (m),
 r – crank radius (m),
 l – length of the connecting rod (m).

The following holds true:

$$\frac{r}{l} = \lambda \quad \text{and} \quad \frac{e}{l} = \lambda_1 \quad (2)$$

The following holds true for the straight-line motion speed of the frame: [2]

$$v_B = r \cdot \omega \cdot \left(\sin \alpha - \lambda_1 \cdot \cos \alpha + \frac{\lambda}{2} \cdot \sin 2\alpha \right) \quad (3)$$

The following holds true for the acceleration of the frame straight-line motion: [3]

$$a_B = r \cdot \omega^2 \cdot (\cos \alpha - \lambda_1 \cdot \sin \alpha - \lambda \cdot \cos 2\alpha) \quad (4)$$

2 Determination of the loading force

Values of mechanical stresses in the frame connecting-rod at the bottom and top dead center and the value of the connecting-rod cross section were taken from the technical report titled Dynamic testing of ERP — 65 for the purpose of the investigation since repeating tensometric measurements under operation would be both time consuming and costly. The highest mechanical stress (pressure) is in the connecting-rod of the frame at the

bottom dead center under full cut and its value is $p = 32,6$ MPa. The stress corresponds to the force $F = 72\,536$ N where the connecting rod cross-section $S = 2,225 \cdot 10^{-3} \text{ m}^2$ [1]. Upon decomposition of the resulting loading force at the bottom dead center ($\alpha = 180^\circ$) into the x and y axes, we can determine its F_x and F_y components (calculation is provided in Table 1).

Mechanical stress reaches the value of $p = 11,7$ MPa [1] at the top dead center, connecting rod is under tensile stress and the F_x force is in the opposite direction, 26032,5 N. Upon decomposition of the resulting loading force at the top dead center ($\alpha = 0^\circ$) into x and y axes, we can determine its F_x and F_y components. The maximum specific pressure for the flat guided element of the sliding pair is $p_{\max} = 414\,665$ Pa.

Table 1 Constituents of the F loading force

Entered Values			Calculated values	
Angle α ($^\circ$)	Angle β ($^\circ$)	Stroke x (m)	$F_x = F \cdot \sin \beta$ (N)	$F_y = F \cdot \cos \beta$ (N)
0°	$6,895^\circ$	0,000	- 3125,2	- 25844,2
180°	$6,895^\circ$	0,400	8707,9	72011,4

For experimental testing under laboratory conditions, it is necessary to determine the loading force acting on samples while the specific pressure of functional parts of the sliding pair corresponds to operating conditions.

3 Characteristics of linear slide guides

Manufacturing machines guides must meet an array of requirements, including primarily the following:

- high-precision motion,
- high stiffness,
- wear resistance,
- possibility to specify allowance,
- simple and perfect design with a high quality surface,
- low passive resistances in the direction of movement,
- ability to absorb vibrations in horizontal and vertical movement.

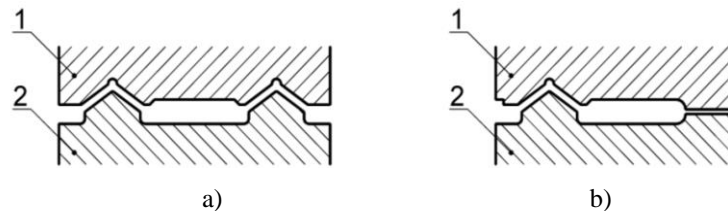


Fig. 3 Cross- sections of straight flat guides [4]
a) triangular guides, b) combined triangular and flat guides,
1 – movable guide component, 2 – fixed guide component

Our investigation addresses the issue of sliding guides due to the direct interaction between movable (1) and fixed (2) constituents (Fig. 3) on the respective guide surfaces.

The slide assembly operation in all areas of the sliding friction is characterized not only by the material, but also the friction coefficient value, wear value and other parameters of operation, in particular the type of lubricant used, value of sliding speed, type and value of the sliding knot load, structural layout, etc.

To analyze wear, it is necessary to determine the most critical factors under the conditions given: [4]

- type and properties of bodies touching each other (properties of surface layers),
- properties of the medium located between friction surfaces,
- characteristics of the mutual relative motion (direction and speed of movement),
- load (size of acting forces and their temporal change), and others.

Reliable operation of slide assemblies working under various operating conditions can be achieved primarily by selecting suitable materials for the sliding pair. From the systemic point of view, slide assemblies should not

be worn excessively or not be worn at all. Thus, the sliding pair should be designed so that the cheaper material constituent gets worn.

4 Experiment under laboratory conditions

Bearing in mind technological aspects, economic efficiency and manufacturing cost optimization, plastics and composites have recently been extensively used and have replaced metallic materials in constructing slide assemblies. [5]

Based on previous findings and data, the following materials were designed to be used in the experiment:

1. trade name Ertalon LFX,
2. trade name Oilamid,
3. trade name Lubramid 600T,
4. trade name Textit H (original material – standard reference material).

Table 2 Properties of materials [6]

MATERIAL		ERTALON LFX	OILAMID	LUBRAMID 600T
Properties	Measurement unit	Value		
Specific weight	(g.cm ⁻³)	1,135	1.14	1.14
Yield strength	(MPa)	70	70	80
Ductility	(%)	25	40	> 40
Young's modulus – tensile force	(MPa)	3 000	3 000	3 300
Impact strength – Charpy	([kJ.m ⁻²)	≥ 50	no refraction	no refraction
Notched Impact strength – Charpy	(kJ.m ⁻²)	4	5 - 6	4
Brinell hardness	(N.mm ⁻²)	145	140	160
Allowed mean pressure in deformation 1/2/5%	(MPa)	22/43/79	22/43/79	22/43/79
Service temperature - short-term - long-term	(°C)	165 -20 up to +105	-40 up to +160 -40 up to +105	160 -40 up to +105
Absorption capacity under standard conditions	(%)	2	1.8	2,2
Water absorption capacity	(%)	6,3	6.0	not specified

The results of the experiment are the basis for the selection of the most appropriate material for the guided constituent of the proposed sliding pair of the ERP-65 linear guide saw.

Samples for experimental testing of wear

Dimensions of the sample: width \check{s} = 15 mm, length l = 120 mm, thickness h = 4 mm.

Testing procedure:

- Before testing, shaft bearings under testing must be lubricated,
- After tightening samples to the loading arms of the testing equipment, the selected compressive force value is set,
- Constant revolutions are adjusted to the value of the peripheral speed of the testing enclosure surface ($v = 1,015$ m.s-1),
- Temperatures of both sliding pair constituents are registered,
- Wear value is monitored after a specified number of hours given in the table.

The following loading forces were used in the wear test:

$F_{N1} = 57,22$ N (corresponds to operating conditions),

$F_{N2} = 105$ N (exceeds operating conditions).

Decreasing dimensions were measured with a dial indicator in the test samples under all constant loads.

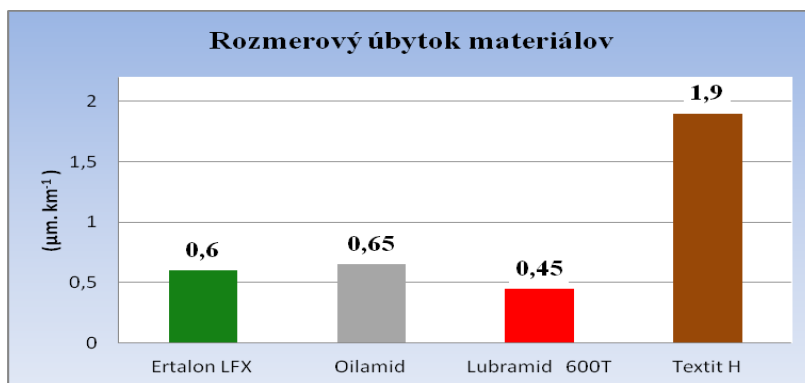


Fig. 4 Comparison of decreasing dimensions in test samples under constant load F_{N1} , Textit H – original sample (etalon)

Assessment of the experiment under F_{N1} load

In testing material wear under dry friction and constant load $F_{N1} = 57, 22$ N, the lowest wear values were obtained in Lubramid 600T and Ertalon LFX. Friction came with counterpart surfaces, namely cast iron housings and material samples getting warmer. The Ertalon LFX sample was heated at the minimum and Textit H sample at the maximum. However, it should be noted that testing was carried out without using lubricants.

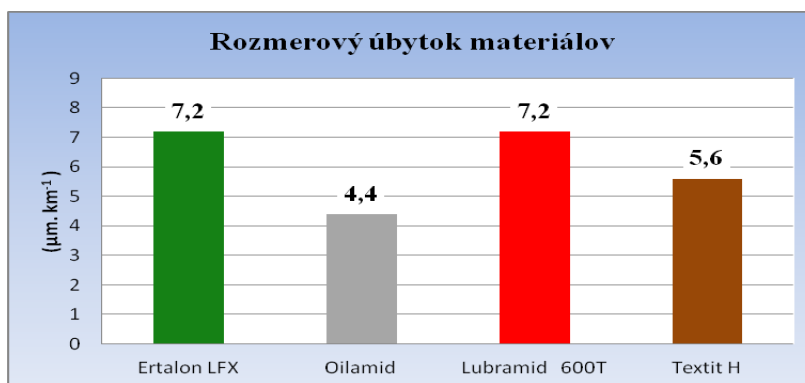


Fig. 5 Comparison of decreasing dimensions in test samples under constant load F_{N2} without using lubricants (Textit H – original sample (etalon))

Assessment of the experiment under F_{N2} load without using lubricants and with using lubricants

We have also conducted material wear testing under a constant load of $F_{N2} = 105$ N and applied plastic lubricant in order the look at possible changes in material behaviour when exposed to extreme loads. Wear testing was performed in quiet and easy modes of operation of sliding pairs. Achieved surface temperature values of cast iron housings were considerably lower than those achieved under dry friction conditions which confirms the fact that the correct type of lubrication can extend life of sliding arrangements in a significant manner. The lowest values of wear were obtained in Oilamid and Textit H materials although mutual differences of values compared are minimal.

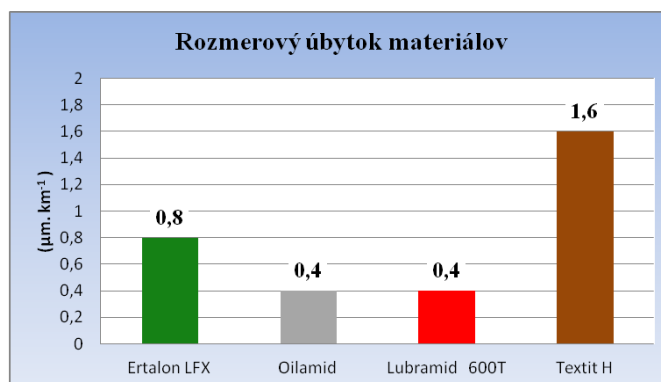


Fig. 6 Comparison of decreasing dimensions in test samples under constant load F_{N2} using lubricants, Textit H – original sample (etalon)

5 Conclusion

Material selection for sliding pairs is basically a compromise between ideal mechanical properties and wear resistance. It is absolutely essential to analyze thoroughly working conditions, conditions of environmental protection, information on accuracy allowances, expected production volumes, etc. The present paper addresses the selection of suitable materials following the outcomes of experimental testing of wear. Moreover, testing results of material sliding properties under the same conditions in the laboratory are presented.

It should, however, be noted that absolutely accurate results could only be gained after long-term testing and after adapting laboratory conditions to a feasible extent to operating conditions (e.g. taking into account the work of a sliding arrangement in different seasons of the year - extremely high and low temperatures).

References

- [1] Návod na obsluhu a údržbu ERP – 65 s výkresovou dokumentáciou
- [2] SVOREŇ, J.: *Drevárske stroje*. Časť I. FEVT Technická univerzita vo Zvolene, 2002. ISBN 80-228-1188-2
- [3] BANSKÝ, M., MICHNA, S.: *Kinematická analýza excentrického kľukového mechanizmu*. s. 5 – 12. Zborník AFT. Technická univerzita Zvolen, 2001. 169 s. ISBN 80-228-1133-5
- [4] BARYSZ, I.; ČILLÍK, L.; ŽIAČIK, A.; PFLIEGEL, M.: *Klzné uloženie - konštrukčné a teoretické riešenia*. Vysoká škola dopravy a spojov v Žiline, ŽILINA 1995. ISBN 80-7100-282-8 (1.vydanie)
- [5] KOPECKÝ, I., PILKOVÁ, M.: *Prístup k dimenzovaniu konštrukčných prvkov z vybraných nekovových materiálov*. In: [Transfer 2009 \[elektronický zdroj\]](#) : Využívanie nových poznatkov v strojárskkej praxi. - Trenčín: TNUAD, FŠT, 2009. - 1 elektronický optický disk. - ISBN 978-80-8075-414-3. - [6 s].
- [6] FURBACHER, I., MACEK, K., STEIDE, J.: *Lexikón technických materiálov*. Verlag Dashofer. CES EduPack 2006, GRANTA DESIGN, Cambridge, UK.

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