Forecasting Change of the Roller Screw Mechanism Efficiency on the Basis of a Comparative Analysis of Coated Surfaces

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Abstract. The paper presents the results of the influence of materials, lubricants and the type of coatings in friction roller screw mechanism on the values of the coefficient of friction and the coefficient of efficiency required to predict the efficiency of the drives. Theoretical studies were carried out for different types of roller screw mechanism coatings. The results can be used to predict the functional characteristics of the mechanisms during their design.

1. Introduction

During the computer-aided design of a roller screw mechanism it is necessary to predict its functional characteristics [1]. In some cases, especially for friction roller screw mechanism [2] (figure 1), a preliminary estimation of their efficiency is necessary if they are made of different materials, with different coatings and lubricants.

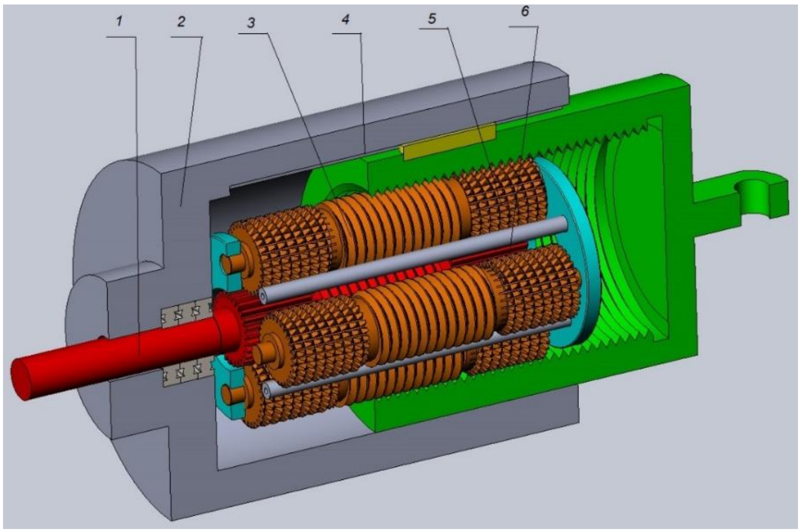

Figure 1. CAD–drawing of friction type roller screw mechanism:
1 - screw, 2 - housing, 3 - roller, 4 - nut, 5 - annular gear, 6 - bearing base.

In this paper, the influence degree of the material, the type of lubricant and the type of coating on the coefficient of friction and efficiency has been theoretically established.

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2. Materials and methods

The friction coefficients for uncoated surfaces has been determined from the reference data. Materials and steels were taken from [3-5] depending on the roller screw mechanism. Those are steel 40Kh, ShKh15, U8, 08Kh17T and coatings MoS_2, (AlSiCr)C:H, AlN, TiN. At the first stage, the friction coefficients for uncoated steels were found during the dry interaction of the parts. The efficiency of the roller screw mechanism [3] was found by using the dependencies:

$$\eta_{\text{пх}} \approx \frac{1}{1 + \text{А}_{\text{тр.с.}}/(\text{А}_{\text{п}} + \text{А}_{\text{тр.к.}})/(\text{А}_{\text{п}} + \text{А}_{\text{тр.о.}})/\text{А}_{\text{п}}}$$

where $\text{А}_{\text{п}}$ – the effective work per one revolution of the screw $\text{А}_{\text{п}} = FS$;

$\text{А}_{\text{тр.с.}}$ – the work of the sliding friction forces beyond the pole connection of the threads per one screw revolution at a half profile angle of $\alpha=\pi/4$.

$$\frac{\text{А}_{\text{тр.с.}}}{\text{А}_{\text{п}}} = \frac{2f}{1-f}$$

where f – the coefficient of sliding friction;

$\text{А}_{\text{тр.к.}}$ – the loss due to the rolling friction of the connected threads in the transmission:

$$\frac{\text{А}_{\text{тр.к.}}}{\text{А}_{\text{п}}} = \mu \frac{2\pi}{s}(k+1)tg\alpha,,$$

where μ – the coefficient of rolling friction (shoulder of the rolling friction torque);

$\text{А}_{\text{тр.о.}}$ – the losses due to the rolling friction in the transmission supports.

3. Results

The obtained values of the efficiency of steels during dry friction are listed in table 1.

Table 1. Coefficients of friction *(f)* and efficiencies of the uncoated roller screw mechanism under dry friction and lubricated friction.

Steel name	Dry friction		Lubricated friction	
	f	Efficiency	*f*	Efficiency
40Kh	0.20	0.66	0.14	0.74
ShKh15	0.17	0.71	0.12	0.79
U8	0.15	0.74	0.10	0.81
08Kh17T	0.25	0.58	0.17	0.65

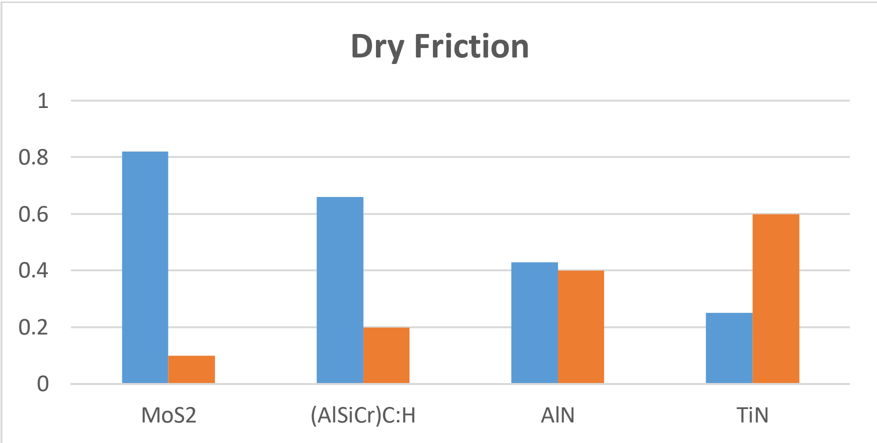
For roller screw mechanism with lubrication, the efficiency is 10.3...24.2% higher than for non-lubricated transmissionss, however, it still remains low for those types of friction mechanisms.

At the next stage, the coefficients of friction and efficiency were determined for roller screw mechanism with coatings. Type of coating: PVD; installation: UniCoat 600 SL+; thickness: up to 3 microns; type of coating: multilayer. The friction for the coating was obtained independently of the steels for each material. The measurement results are listed in table 2.

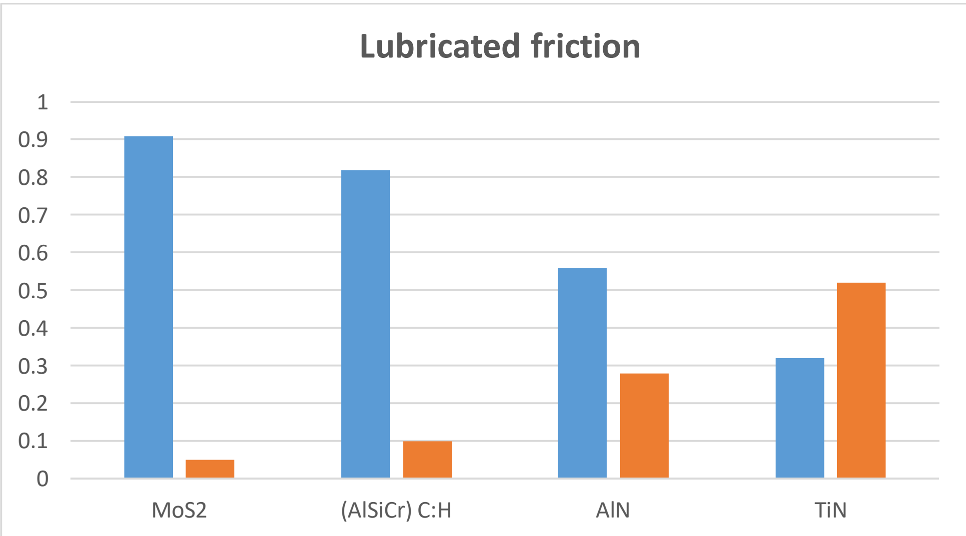
The analysis of the tables shows that during the use of coatings, the coefficient of efficiency can both increase and decrease. The coatings with MoS_2 and (AlSiCr) C:H structures have shown positive dynamics. During the use of traditional AlN and TiN coatings, the coefficient of efficiency can be reduced. This result applies only to the friction mechanisms of the roller screw mechanism and requires additional experimental confirmations.

Table 2. Coefficients of frictions *(f)* and efficiencies under dry friction and lubricated friction for surfaces with coatings.

	Dry friction		Lubricated friction	
Coating	*f*	Efficiency	*f*	Efficiency
MoS_2	0.1	0.82	0.05	0.91
(AlSiCr)C:H	0.2	0.66	0.10	0.82
AlN	0.4	0.43	0.28	0.56
TiN	0.6	0.25	0.52	0.32



(a)



(b)

Figure 2. Comparison of the coefficient of efficiency (■) and the coefficient of friction (■) in coated RSM under dry friction conditions (a) and with lubrication (b).

At the third stage, the values of the coefficient of friction and efficiency have been compared for the friction-type roller screw mechanism with deposited coatings under dry friction conditions and with grease as the most common operation alternative (see figure 2).

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4. Conclusions

The use of grease slightly increases the coefficient of efficiency by 10...13% in coated mechanisms. The use of grease can lead to a negative effect on the efficiency, which, obviously, also requires experimental verification.

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