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CONSIDERATIONS ABOUT THE INFLUENCE OF CRYOGENIC TEMPERATURES UPON FRICTION FORCES

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ABSTRACT
All materials have a different behavior in cryogenic conditions compared to room temperature. Physical properties as well as mechanical and technological characteristics for materials are changed. In the paper there is presented the methodology of determining friction forces for sliding specimen, under cryogenic conditions. The equipment is presented and particularities of measurements under cryogenic conditions are specified.
Keywords: cryogenic temperatures, friction coefficient, cryostat.

1. INTRODUCTION
Cryogenic temperatures influence the physical properties as well as mechanical and technological characteristics for materials. Knowing their behavior at cryogenic temperatures gives the possibility to use those characteristics that change considerably at temperatures lower than 120K, which is considered to be the superior limit for these temperatures. Generally all materials increase their strength and decrease their plasticity in cryogenic conditions [1].
It is known that in cryogenic conditions, for a cutting process, working life of the tools increase significantly while the cutting forces required are lower [1]. This can be explained theoretically by considering cryogenic fluid as a cutting fluid, but it is not entirely right. Cryogenic fluid is evaporating immediately when the contact with the cutting part takes place so it must be something else.
Diminishing the friction between parts for devices that work in cryogenic conditions is an advantage if we speak only about the reduction of energy consumption.
In industrial conditions shortly after being manufactured a surface is covered (because of the environment) with layers of oxides or lubricants (mineral or vegetal). In this case a boundary friction takes place and the results are in favor of diminishing the friction coefficient.
Taking into account all presented before, a technical dry friction will be considered and not a pure one which can be obtained only in laboratory conditions.

2. EQUIPMENT AND TESTING CONDITIONS
Tests are performed on a material used for cutting device OSC 10 STAS 1700-86. Cylindrical test bars with spherical head (3mm. radius) are used for tests at room temperature and in cryogenic condition. Cryogenic cooler is liquid nitrogen with a 77K temperature of liquefying. The friction force measuring device used for experiments is presented in figure 1 and the cryostat in figure 2. A cryogenic agent pressurization installation was used.
The friction force measuring device consists of the following elements:
-the rotational disc (1) which supports the cylindrical ball head test bars (3),

-the cryostat (4) which is an enclosure with double walls and isolation inside,
-the handle (7) that press on the string (9) where two tensometric transducers (8) are fastened,
-an electronic tensometer that measures the force,
-the electric driving motor (12) that transmits the motion to the cryostat.

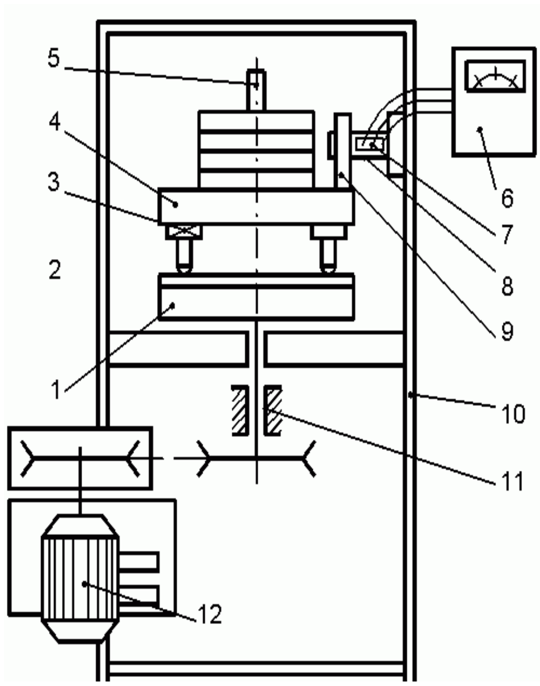

Figure 1 Friction force measuring device

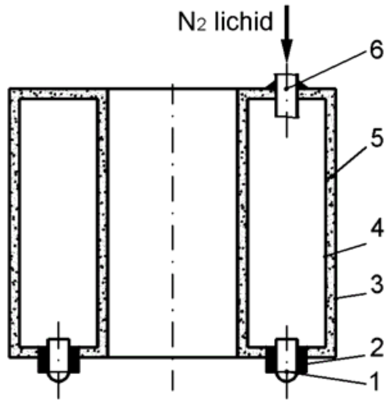

Figure 2 Cryostat

The cryostat (figure 2) has an interior wall (5) and an exterior one (3) both made of stainless steel and there is a thermo isolation with “santocel” powder (4), between it. Through bush (6) the cryogenic cooler is introduced in order to cool the test bars (1) fastened in a bush (2).
The nitrogen liquid is transferred through isolated pipes, from a Dewar vessel using a pressurization system with electrical resistance.
Cylindrical test bars with 3mm. radius made of OSC 10 are mounted in the fastening device and placed on the rotational disk. From the calibration diagram the countering force of string Fs is established. The testing time is 5 sec. The friction coupling is loaded with 9 normal loads (Fn1…Fn9). After each experiment the rotation disk is softly grinded with abrasive paper, cleaned of impurities and degreased. For each Fn load and both temperatures, 7 tests were performed.

3. EXPERIMENTAL RESULTS

The minimum and maximum values are removed and a medium value is introduced in table 1.
Friction force is calculated with the equation:

$$F_f = \frac{F_s \cdot R_s}{3R} \text{ [N]} \tag{1}$$

where:
-R_s is the distance between the handle that press on the string to the rotational axes; R_s=95mm.
-R is the medium distance between rotational axes and test bars; R = 54,33 mm
The friction cofficient is calculated as follows:

$$\mu = 3\frac{F_f}{F_n} \tag{2}$$

Results are presented in table 1 and diagrams are shown in figure 3.

Table 1 friction coefficient

No	T=293K				T=77K			
	F_n[N]	F_s[N]	F_f[N]	μ	F_n[N]	F_s[N]	F_f[N]	μ
1	30.0	2.5	1.46	0.1456	30	1.4	0.81	0.081
2	34.8	3.1	1.803	0.1554	34.8	2.1	1.225	0.105
3	37.0	3.8	2.21	0.179	37	2.9	1.691	0.137
4	38.5	4.5	2.625	0.2065	38.5	3.3	1.925	0.15
5	39.3	5.1	2.975	0.2271	39.3	3.5	2.041	0.155
6	41.7	5.6	3.26	0.234	41.7	4.1	2.391	0.1725
7	44.2	6.3	3.675	0.2494	44.2	5.0	2.91	0.197

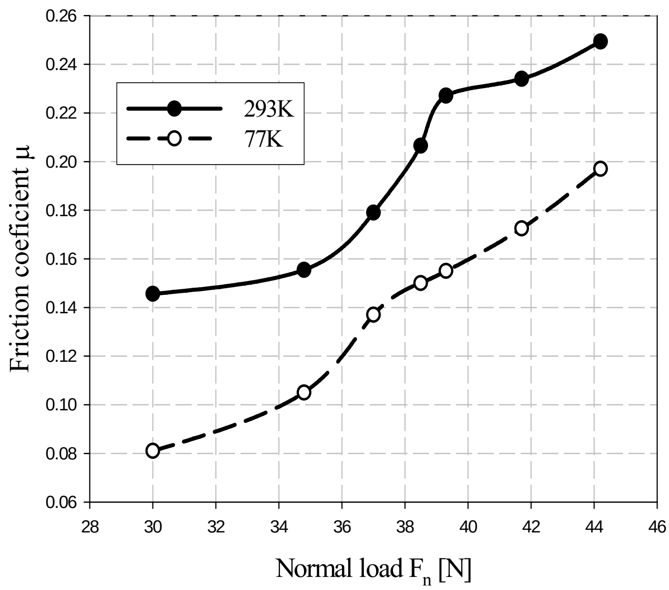

Fig. 3 Friction coefficient due to normal load

4. CONCLUSIONS

Friction coefficient has a well known shape of the curve no matter which temperature was used. It is growing with normal load increasing. The irregularities that appear are because of the technical conditions of testing.

In cryogenic conditions the shape of the curve is very much alike to that obtained at room temperature but with significantly lower values. This can be explained by the fact that under cryogenic conditions a very thin film of liquid nitrogen can be considered between the test bars and the sliding plate. Even that the evaporation is immediately, cryogenic fluid works as a lubricant. The difference between friction coefficient at 77K and 293K is higher than those obtained by using a normal lubricant [2]. The difference can be explained by considering that at very low temperatures the material has a higher value for mechanical resistance and so a lower wear appears.

A lower friction coefficient is a goal to take in consideration because of the reducing of energy consumption.

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