Difference of Cylindrical Locks Break Resistance in the Dependence on Outdoor Temperature

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Abstract: The present study is focuses on the interaction of temperature with cylindrical lock break resistance. It is based on an analysis of fundamental temperature and mechanical impacts on lock systems with regard to the provided protection, presenting verification and analysis of laboratory measurements and documentation of the testing methodology, describing the relevance of temperature for break resistance and emphasising the significance of temperature dependence of the material.

Keywords: break resistance; hardness; cylindrical lock; cylinder; lock systems.

1 Introduction

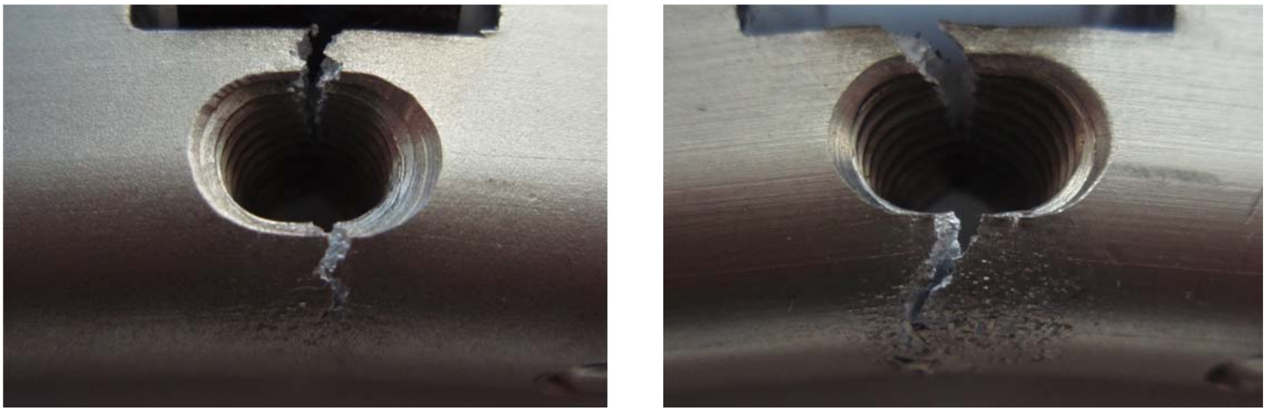
Lock systems have guaranteed protection of our property, privacy and security for thousands of years. They have gradually been introduced worldwide and nowadays they are used by millions of people. Since their beginning they have become a fundamental component of the access control system in the area of mechanical protection systems. A topic issue in access control is nowadays enlarging the user identification possibilities and increasing their security, sometimes achieved through changes in technology of the inner mechanisms retaining however the time-proven fundamental course of functions resulting in the targeted unlocked/locked status. The most important requirement for lock systems is their reliability, i.e. stability of the system properties. Regardless of the weather or time of the day, we expect them to retain their primary functions.

2 Analysis and Verification of the Measured Values

Cylindrical locks of the entrance door are during the year exposed to temperatures ranging approximately (for the Czech Republic conditions) from -30°C to +40°C; their material therefore must cope with the temperature difference up to 70°C (however, in reality the working temperature range is reduced by the indoor temperature in the house). These differences result in changes in material properties, which is the subject of the following section of the report. Phenomenological thermodynamics describes behaviour of a macroscopic system for a thermal energy region characterizing changes in physical values and in the system status during a dynamic development of the system energy. Static thermodynamics focuses on this issue with regard to elementary particles and micro-volumes. When choosing materials for mechanical protection systems it is necessary to determine the required properties of the material under process which will correspond to the requirements on the future security element in an appropriate way. Hardness tests mostly present their results in the form of a dimensionless number. It is important to record properties of the environment in which the tests are conducted as these may have a significant impact on the values obtained. For example hardness decreases with increasing temperature energy because the atom bonds become looser. Measurement of bending strength of the tested samples forms the major part of practical tests of the study. Strength is defined as resistance of material to external forces, such as pressure, tension, shear and bending. Natural reaction to the application of force is a change in shape. The change may be momentary or lasting and these factors divide deformation into an elastic or plastic deformation. Fractography is an analytical method of studying fracture processes indicating factors which will help us define kinetic behaviour of destruction of material in time. Fracture identification is carried out based on fracture morphology, magnitude of the total energy necessary for destruction of the sample and the extent of the plastic deformation. The laboratory measurements were carried out using devices *Zwick 1456* and *Integral 2 E*. The cooled down samples, 422 in total, were placed in a Liebherr freezer with the minimum temperature reached at -25.5°C. The measured samples were double sided cylindrical locks of the Extol Craft 65 mm and FAB 200 – 1000 types made mostly of brass plated by nickel to provide protection against corrosion. They are cylindrical locks for buildings which meet the requirements that we have for lock systems designed for security systems. The lowest material support for breaking resistance of the lock system is in the weakest point of the cylindrical lock situated at the revolving tooth and the hole for the fixing screw (about 3 mm under the screw hole at the widest point, about 2 mm above the hole and near the tooth about 14 mm of non-homogenous and non-compact material). The difference lies in choosing higher speed of stress to which the tested samples are subjected (Fig. 1). The experiment was carried out using a device made by Zwick. Product Zwick 1456 is designed for compression, tensile and bending tests of materials which can be conducted at different temperatures (within the range from -80°C to +250°C). The device is equipped with the testXpert II software providing the necessary setting options and input data, the calculating part of the measurement followed by visualization of the obtained data. One of the essential parts of Zwick 1456 enabling measurements within the temperature ranges above is a thermal chamber. It is a thermally insulated space which can be positioned so that it surrounds the measured sample. Break resistance was tested by determining bending strength. The cylindrical lock is during the bending strength test placed on two points 50 mm from each other. The third point is situated between them in the centre in the opposite direction to the support. This third acting point applies force to the weakest part of the cylindrical lock body between the both cylinders of the lock.

Fig. 1: Testing of cylindrical locks outside and inside the thermal chamber.

The measured values of the break resistance were within the range from 2630 to 2150 N. It is obvious from the values that critical stress increases as a result of increasing temperature and distribution of the applied force into the neighbouring zone of the fracture defined by plastic deformation. The increase in the critical stress in the negative region of the temperature axis due to higher elastic modulus is also of interest. The escalation of the critical stress for the specified area is very significant. The samples tested for break resistance were subjected to fractographic analysis in order to define the type of fracture resulting in the destruction of the cylindrical lock. Specifically they were specimens tested at -20°C and +40°C, i.e. the suprema and infima samples of the selected temperature interval. Substantial differences in the tested samples were already obvious from the macroscopic point of view. The analysis revealed a difference between both fractures where in the case of the cooled down sample (temperature -20°C) the style of deformation corresponded to brittle fracture while the warmed up sample (temperature +40°C) showed a process of considerable plastic deformation (Fig. 2).



a) -20°C b) +40°C

Fig. 2: A close-up of the fracture surface formed at -20°C and +40°C.

The micro-fractographic analysis was carried out using the Carl Zeiss Jena light microscope equipped with a video camera connected to a computer. The tested objects were lit by an illumination arm in order to emphasise details. The surface images for microscopic analysis were obtained at 15-fold magnification. The application of higher, 50-fold magnification, was rejected due to significant differences in height of the fracture areas surfaces which made required focusing of the image impossible (Fig. 3).

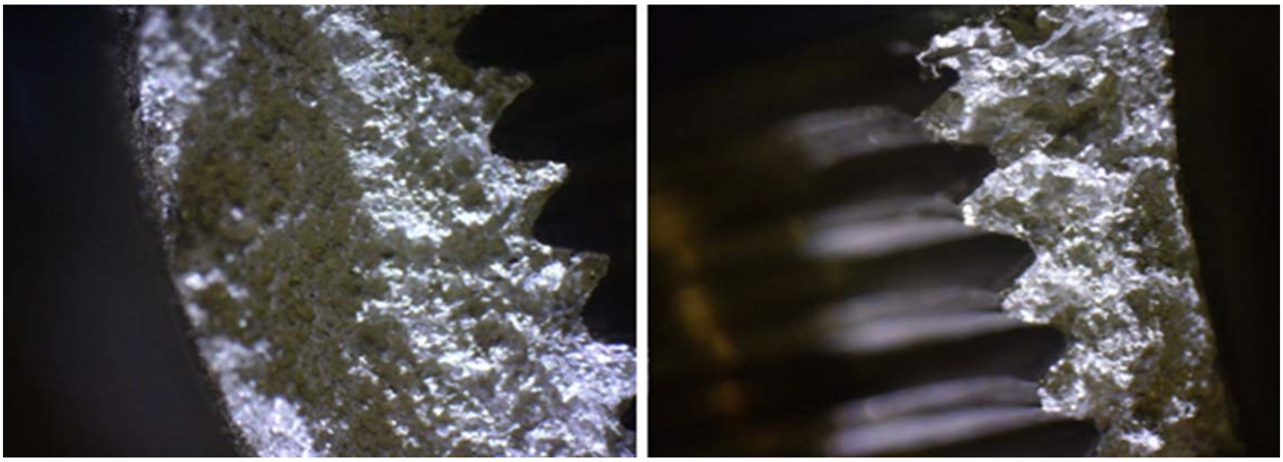


Fig. 3: Microscopic close-up of the fracture (-20°C).

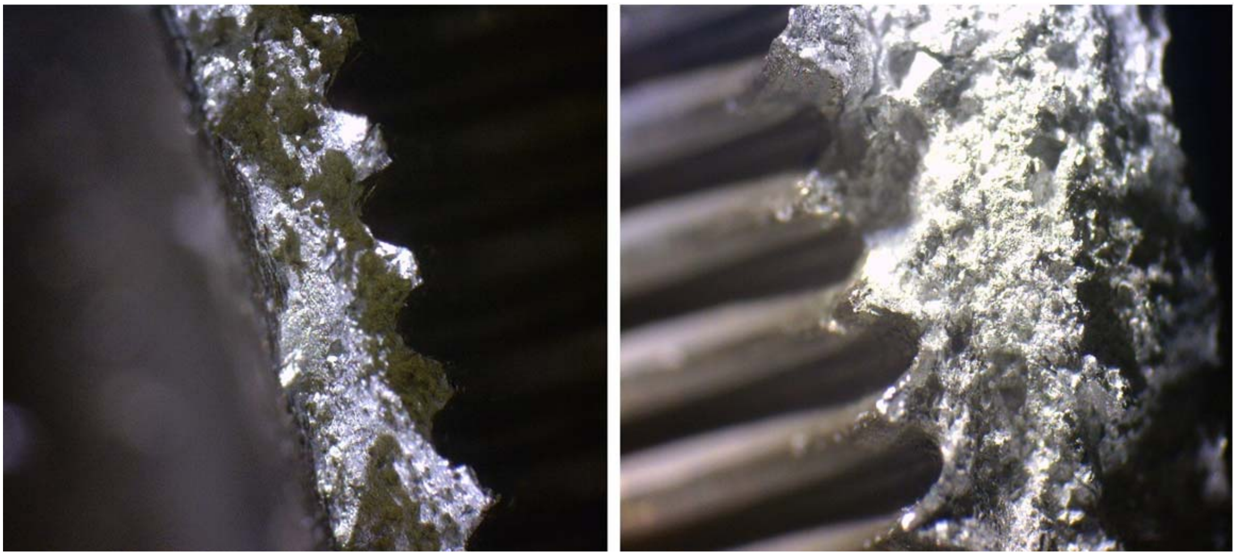


Fig. 4: Microscopic close-up of the fracture (+40°C).

Lower necessary energy of the critical flow stress and higher looseness of atoms in their bonds is obvious from the warmed-up sample analysis. It can be clearly seen that the destruction progressed in the direction of the flow planes at the approximate angle of 45°. Much larger plastic deformation in the course of destruction also caused substantial changes in height on the fracture surface (Fig. 4).

Measuring the samples revealed transitional fracture behaviour (transition between brittle and ductile fracture).

Tab. 1: Selected values of break resistance in testing the product FAB 200.

temperature[°C]	temperature difference [°C]	time interval [s]	average values of break resistance [N]
+40	0	14	2630
+35	0	14	2460
+30	0	14	2340
+25	0	14	2360
+20	0.0065	14	2770
+15	0.0877	14	2300
+10	0.169	14	2130
+5	0.25	14	2210
0	0.331	14	2360
-5.5	0.42	14	2360
-10.5	0.5	14	2900
-15.5	0.583	14	2950
-20.5	0.664	14	2750

3 Conclusion

The tests of break resistance simulating attempts at breaking the cylindrical lock were conducted with homogenous thermal structure of the material. In the real conditions there is a temperature transition within the locking system between the indoor temperature in the house and the outdoor temperature. The temperature difference in question however is of negligible significance (unless temperature differences in hundreds of degrees Celsius are involved) as the characteristic of the fracture occurring in the cylindrical lock under a great pressure is perpendicular to the supremum (maximum) temperature variations and is therefore situated in the part with resumed temperature homogeneity. In conclusion, based on the measured values we can say that break resistance (measured for temperature -20°C) is temperature unstable and for the tested lock systems it reached the variation up to 15% of the reference value.

Acknowledgement

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