1. Introduction

The aim of this article is to find out the mechanical resistance of cylinder pin tumbler locks against the non-destructive methods. The first part deals with description and characteristics of cylinder pin tumbler locks; basic terms that are necessary for understanding this field of study; structure of cylindrical pin tumbler locks and the principles of their function. The next section is focused on methods of breaking the cylinder pin tumbler locks, specifically using bumping, picking and racking, which will also be discussed in more detail. The article also includes a proposal for a testing method, which does not have a normative basis for the selected breaking methods. The final part is focused on connecting the results from the tests performed with their implementation in practice.

2. The cylinder pin tumbler lock - characteristics

The effort to increase safety brought with it a focus on locking systems for cylinder pin tumbler locks. The principle of their function is based on controlling a latch by a cylinder pin tumbler lock. And it is the cylinder pin tumbler locks which increase the level of passive safety in terms of disallowing entry using unauthorized keys. This type of lock is wide-spread in our territory and it’s used in most houses, flats and industrial objects, [1], [2]. The principle of cylinder pin tumbler lock’s function is based on inserting a key into the keyhole. Every key is unique in its profile, which ensures the tumblers and driver pins, which are being pressed towards the key using springs, to line up and create a separation between the cylinder and the plug (Figure 1).

As can be seen in Figure 1 left, a common cylinder pin-tumbler lock is made of several basic parts. The main part is the shell and its shape depends on the use and type of the locking system. Its main function is to connect all parts of the cylinder pin tumbler lock into one compact unit. Plug is the rotating part which can be rotated by 360° and thus move the locking mechanism. The plug contains in itself all the openings used for inserting the key pins, usually of a cylindrical shape. Their function is to level the surface between the plug and the shell to allow rotation. The key pins can be put into this position only by inserting the correct key. Opposite to the key pins lay the driver pins, which are used to block the plug. Driver pins can be of various shapes, which influence the ability to resist breaking. In case of protecting against bumping, longer driver pins are preferred. Movement of the driver pins is governed by springs, which are placed in the pin changers inside the shell. They serve to block any movement between the shell and the plug of the lock.
pin tumbler locks. However, there is not an existing norm, which would contain the methodology for testing the resistance of a cylinder pin tumbler locks through the non-destructive methods of entry in realistic conditions. The absence of such norm makes it impossible to evaluate the delay time of the mentioned locks without resistance class assignment. Without those values, in turn, one cannot evaluate the level of safety for secured objects where such elements are installed [2].

In relation to cylinder pin tumbler locks, we distinguish three most commonly used methods of breakthrough these locks through non-destructive means:

- **Bumping,**
- **Picking,**
- **Racking** [7].

### 3. The bumping method

Bumping represents a dynamic non-destructive method of overcoming a cylinder pin tumbler lock. This method requires the use of a specially modified key. By hitting this key, the energy gets transferred onto the key pins and driver pins, which then jump out of the way and release the plug. The plug can then be rotated and the locking system is deactivated. The whole process begins with preparation, selection or creating of the so-called bump key. The key is inserted into the cylinder pin tumbler lock, its profile and shape must allow for smooth insertion and pulling out of the key. The key is then hit with the rubber part of the screwdriver shown in Figure 3. The hits and rotation of the key require some sensitivity, skill and training.

When performing the testing, the cylinder pin tumbler locks from security class 1, 2, and 3 underwent the bumping method. In the case of the security class 3, it was not important to establish a breakthrough time. The test should only verify the claimed resistance against this method. Representatives of the security classes 1 and 2 had the maximum breach time set for 3 minutes and 5 minutes, respectively. For the practical use of the bumping
The picking method is generally considered as the most difficult way of overcoming the cylinder pin-tumbler locks. It requires a lot of skill, sensitivity and patience from the perpetrator. A potential criminal with sufficient theoretical and practical skills is, however, able to use this method to breach even the complicated security systems. Similar to other methods, the picking method uses imperfections in the factory processing, which allows slight rotation of the plug, as well as leaving it in the right position without using the correct key. Applying tension is the most important stage of the process, which determines the overall success of the operation. The amount of tension causes the driver pins to stay on the edge of the plug and not return back. The entire process has to be done using specialized tension tools shown in Figure 5 left. The second process, occurring simultaneously with continuous application of tension, is pushing individual key pins, which act on the driver pins with the aim of finding the correct unblocked position. This is done using different picks, their shape depending on the type of the cylinder.
3.3 The raking method

Raking is the fastest method of non-destructive breach of a cylinder pin-tumbler lock. The perpetrator does not need very skilled hands, but the method is less effective than the picking method. As with the picking method, there is a very important phase of raking, which is applying the correct tension on the plug. This is done in the same way, using the same tension tools. The important distinction lies in the way the driver pins are pushed by interacting with the key pins. In this method, different picks are used (Figure 8), which are generally longer and have more bends. These picks are inserted into the keyway and by repeated swift movements over the key pins, one is trying to find a position in which the plug can be rotated. The process of this method is shown in Figure 9.

Testing the resistance using the raking method was performed on identical samples as with the case of picking method. The RC1 representative was breached 18 out of 20 times, average time for opening the lock was 1 minute and 53 seconds. The second tested unit represented the RC2 category resisted only 7 times out of 20 tries. Average breakthrough time was 4 minutes and 13 seconds. Same as with the picking method, the RC3 locks were not broken. The reason for this is the aforementioned technical solution. For an easier understanding of all the results acquired from the testing, all the measured values are projected in graphs in Figure 10.

4. Conclusions

The article focused on the problem of testing the mechanical resistance of the cylinder pin tumbler locks. The first part focused on describing the testing of cylinder pin tumbler lock using the non-destructive bumping method. Then the methodology for testing the lock through this method was proposed. Based on the tests performed, one can state that breaching a cylinder pin tumbler lock requires some knowledge and skills, which can be
acquired in a relatively short time; this in turn creates a high level of risk in terms of securing objects. The main benefit of this article was the effort of the authors to point out to an absence of norms, which would regulate the testing of cylinder pin tumbler locks through non-destructive bumping, picking and racking methods and the need to address this situation. At the same time, these tests could be considered a starting point with the aim of creating a basis for further investigation.

Acknowledgments

This work was supported by the institutional grant project IGP 201701 and IGP 201704.
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