

Research on Pin Tumbler Locks and the Characteristics of Surface Traces Formed by Unlocking Guns

Gao Yi¹ Jin Yifeng^{2,*} Bai Yanping^{2,*} Mei Hongcheng² Xu Zhen²

¹ Key Laboratory of Evidence Examination and Identification Technology, Ministry of Public Security, Criminal Investigation Police University of China

² Department of Public Security Document Identification Center

*E-mail: jinyifeng5685 @163.com, yp0916 @163.com

Abstract. In this paper, taking the structure of the pin tumbler locks and the principle of opening and closing locks as breakthrough point, we have studied the machining traces of pin tumbler components and trace characters of pin surface during normal operating. At the same time, taking the unlocking gun as an example, the paper analyzes the unlocking technology and the formation of traces ,and summarizes the changing rules of the surface traces of elastic bead locks by comparing the positions and the characteristics of the traces, which provides technical support for the future study of traces of pin tumbler locks.

1. Introduction

The pin tumbler lock is also known as the marble lock, the spring lock, or the pin lock, is one of the most common lock structures. The principle is to use a number of cylindrical parts of different heights(called the lock spring, pin or beads)to lock the cylinder. When the correct key is inserted, the round -headed pins are pushed to the same height and the cylinder is released. In this paper, taking the unlocking gun as an example, we focus on the trace characteristics of the pin tumbler's part structure and summarize the characteristics of surface trace changes when the pin tumbler lock is unlocked.

2. The opening and closing principle of the pin tumbler lock

The pin tumbler lock is usually used in a cylindrical lock. The center of the cylindrical lock is a cylindrical hole with a cylindrical cylinder. When opened, the cylinder should be able to rotate.

The middle of the cylinder is for the slot into the key, the end of the slot open to insert the key, the end is a lever. When the key is fully inserted, the key bits cooperate with the pins, so that the bottoms of round -headed pins flush with the outer surface of the lock cylinder ,and the lock cylinder has the opportunity to rotate. There is a long protrusion in the same direction inside the key slot, and the projection cooperate with the key slot to fix the key, which is also used to prevent the round -headed pin(also known as the ball, Beads) from falling ,and increase the difficulty to unlock doors with unlocking tools. The end of the round -headed pin which contacts the key is spherical, so that the key can be easily inserted through . On the top of each round -headed pin,there is a corresponding flat -headed pin (also known as the marbles, the upper spring or the beads). The flat -headed pin is pressed down by the spring. Each round -headed pin is only equipped with a flat pin. There will be two and more flat -headed pins on each round -headed pin in a more complex lock. (For example,a lock can be locked by multiple keys) .

When the pin tumbler lock is assembled, the pins are pressed down into the lock cylinder by the spring. The lock cylinder and the lock body connect at a place called cut-off point. After the appropriate key is inserted into the lock cylinder, the work part of the key(key bits) will push the round -headed pin upwards so that the gap between the round -headed pin and the flat -headed pin is exactly at the cut-off



point, and the lock cylinder can be rotated, then turned on. After the key is pulled out, the pins fall, the flat-headed pin stop the cut-off point, and the lock cylinder can not rotate, as shown in Figure1.

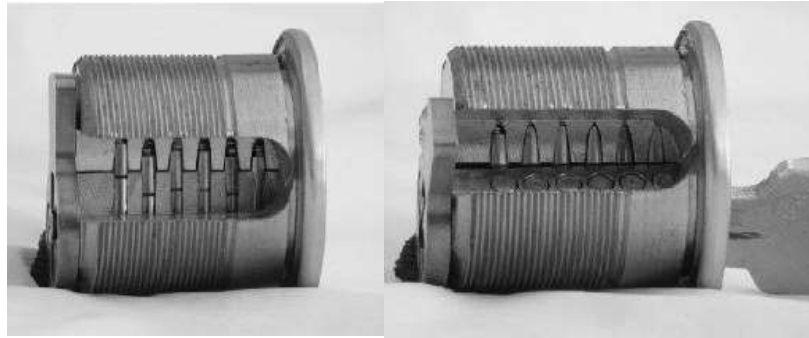


Fig. 1. Opening and closing states of the lock

3. Study on pin tumbler lock components

When unlocking with technical methods, the main parts of the lock which the tool contacts are the pin, the cylinder surface and the keyhole. Because the lock can not be observed into the keyhole without anatomy, the project did not take pictures inside the keyhole before research ,but photographed and fixed the keyhole after unlocking with technical methods and sawing.The following describes the shapes of each component processing trace.

Machining traces on pins: The pin surface without uses is relatively clean, and there is no dust, grease or dirt and other attached substances. The traces on the pin spheres are fresh and concentric round sometimes with mild wear ;There are longitudinal strip traces on the surface of the pin cylinder or it's smooth without any traces. as shown in Figure2.



Fig. 2 Traces on new pins

Machining traces on the surface of the lock cylinder: the new lock cylinder surface is relatively clean, and occasionally there are scratches, depression, dirt or wear traces.The machining traces on the cylinder surface vary according to different surface shapes. Under normal circumstances ,the shapes can be concentric rounds or parallel lines.

Lock cylinder slot traces: the new lock cylinder surface is relatively clean,and there are very few scratches, depression, dirt or wear traces,machining traces of the lock keyhole are generally vertical strip traces.

4. Study on the normal use traces of the pin tumbler lock components

The shape of the original key and the shape of the keyhole are coordinated with each other so that the original key can only be oriented in the space defined by the lock cylinder slot. When unlocking, the key enters the slot along the lock cylinder axis, when the key enters the lock cylinder positioning ,at the same time, the round -headed pin finishes cooperating with the key bits. At this point ,the key is applied to torque, so that the lock cylinder rotates to complete the unlock. After unlocking, the key is pulled out. So in the process of the whole unlocking, the key works on the pin twice. This form of

movement makes the key surface and the top of the key bits is always in a sliding friction state with the key slot and the pin sphere surface.,in which the top of the key bits and there is the most friction effect on the pin sphere surface. This is also the main reason for the formation of the using traces of pins.

The wear of the lock components is mainly related to the material of the lock and key.The most commonly used material for the components (including the pin, shrapnel, etc.) and the key is copper.The cylinder and the components are sometimes made of nickel brass, steel and other materials. The materials of machining keys are a lot,, in addition to copper, but also nickel brass, aluminum, iron, steel and various alloys. At the same time, the wear of the lock components is also related to the design of the key and components.However,this project is not enumerated.

In order to better study the situations of each pin tumbler lock component, we simulate the normal use process of the key , and respectively observed a key used 50 times(simulating using for a month), 1000 times (simulating using for a year) and 3000 times (simulating using for 3 years) . We found that normally plugging the key 50 times in the ball on the spherical surface can form a bunch of relatively slight scratches through the center of the ball. Around the scratches,the sporadic distribution of scratched line traces; And there are clear wear traces sporadically around the scratches.There are wear traces on the outer surface of the lock cylinder caused because of the friction between the flat -headed pins and the outer surface of the lock cylinder when rotating,as shown in Figure3. When normally plugging 1000 times, the ball surface appears very obvious scratches traces, scratches to the vertex of the spherical surface as the center radially outward;The lock cylinder outer surface's wear traces increased, as shown in Figure 4. When normally plugging about 3000 times, the ball surface appeared serious wear, and the original machining traces on the ball are almost abrasive.The original using traces have been polished.Slight scratch traces are occasionally seen such as Figure 5 shows. The pin close to the surface of the ball gets the most heavy wear.The pin away from the surface is worn gradually slightly. The lock surface gets a certain degree of wear,and the constant use of the keyhole in the lock slot (key bit side) will cause pressure traces, which should be distinguished from the traces caused by bump unlocking.



Fig. 3 Traces formed of inserting and removing the key 50 times

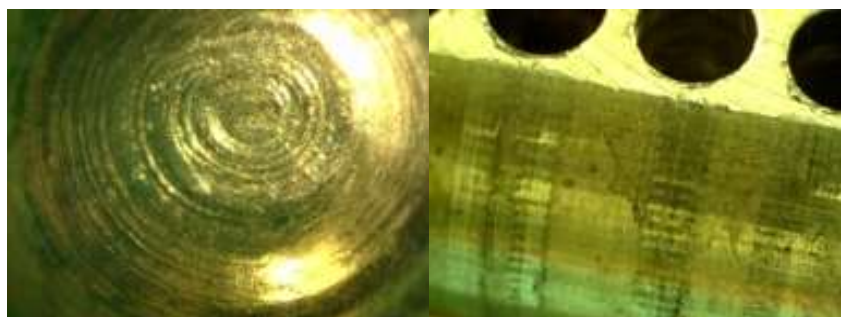


Fig. 4 Traces formed of inserting and removing the key 1000 times



Fig. 5 Traces formed of inserting and removing the key 3000 times

5. Research on technology of unlocking with unlocking guns and its traces

The unlocking gun is a tool to open the pin tumbler lock, making use of the shake of the swiftach in the front of the gun, so that the round-headed pins and the flat-headed pins separate immediately and achieve the purpose of unlocking. Unlocking guns are divided into manual and automatic ones. Manual unlocking guns are equipped with a swiftach in front of the toy guns, which can be replaced. As shown in Figure 6 and Figure 7.

Using unlocking gun locks is also a better way to unlock, especially suitable for opening a lock with a shaped pin. When using manual unlocking guns, the push rod should be set first to form a push dislocation, and then push the swiftach into the keyhole, so that the swiftach can be placed under all the pins. Then pull the trigger to flick round-headed pins, so that round-headed pins can pass the kinetic energy to flat-headed pins to make flat-headed pins shake up and down in the pin hole. When all the flat-headed pins jump into the pin hole of the lock, the round-headed pins are all in the lock cylinder pin hole, and the top round-headed pins separate. Then the unlocking is completed. Electric unlocking guns' and manual unlocking guns' principle is similar. However the difference is that manual unlocking guns need to shock the swiftach backwards and forwards to make the swiftach shake. Electric unlocking guns are to control the shake frequency of the swiftach to fit the shake frequency of flat-headed pins, making the flat-headed pins all jump to the lock body pin hole to achieve the purpose of unlocking, as shown in Figure 8.



Fig.6 Manual unlocking gun



Fig. 7 Unlocking demo with the unlocking gun

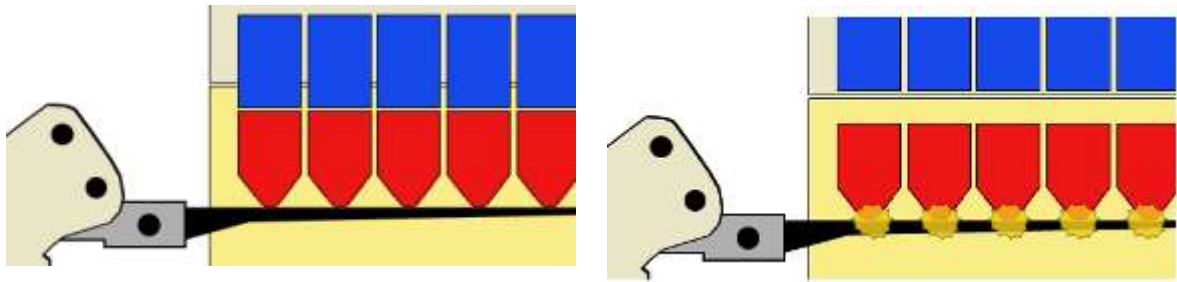


Fig. 8 Unlocking gun's principle

Traces caused by unlocking guns mainly concentrate in the pin sphere parts, that is, the parts of the swiftach hitting, as shown in Figure 9. Traces on the round-headed pin sphere caused by the unlocking guns are different from the scratch traces caused by single hook unlocking. Unlocking guns form pressing traces, and sometimes traces caused by vibration are similar to the arrangement of bicycle wheel spokes, as shown in Figure 10. Each shock of the unlocking will make the pin a slight rotation, so the number of unlocking gun vibration can be determined through the number of traces on the pin head. As with other techniques, the swiftach will form pressing traces on the inner wall of the key slot and the scratches are formed on the cam at the forefront of the keyhole. If the scratches are formed deep enough, the traces can be identified as shown in Figure 11. Electric unlocking guns sometimes form a relatively dense shades of different pit-like traces on pins. If the suspicious unlocking gun is found, whether there is residue on the swiftach should be paid attention to. When using the unlocking gun, it will form a long stripe, intermittent or indentation mark on the inner wall of the keyway, as shown in Figure 12, as shown in Figure 13.

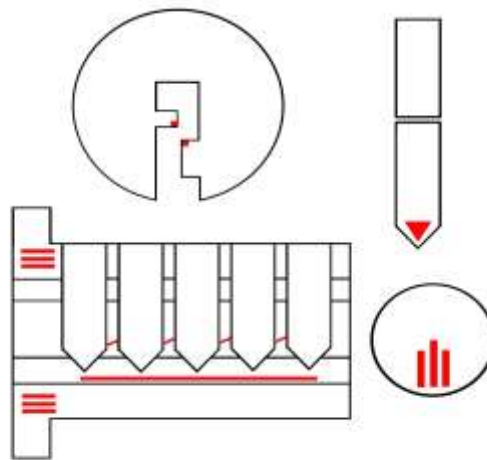


Fig.9 The location picture caused by single hook unlocking

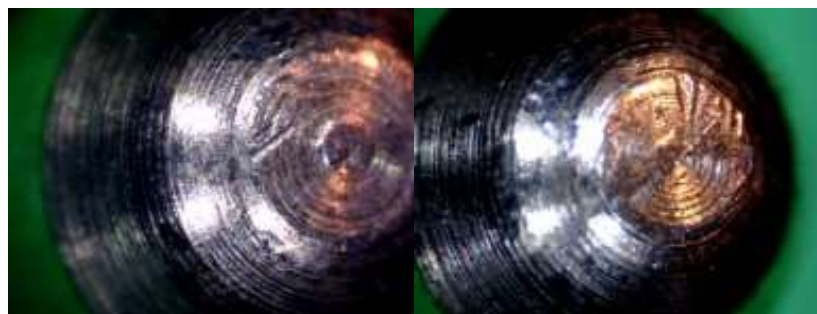


Fig.10 Traces on the pins caused by unlocking guns



Fig.11 The traces on the keyhole forefront components caused by unlocking guns



Fig.12 Pits formed on the pins.

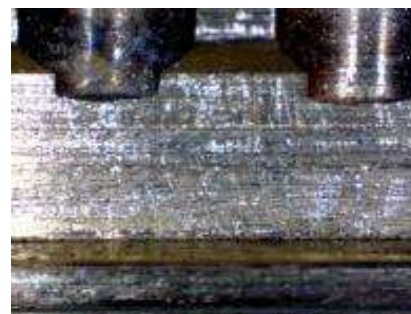


Fig.13 Traces formed on the inner wall of the keyhole

References:

1. Single Hui. Engineering Mechanics and Mechanics of Materials [M]. Beijing: Higher Education Press, 2004.
2. Liu Qingmin, Lin Chao, Yang Xin, Design of a Ballistic Separation Feed Device for Padlocks Automatic Assembly System [J]. Mechatronics, 2017 (5): 460-464
3. Zhao Xiao, Wei Machuan, Bi Jing, Study on the Technological unlocking traces of Axial Pin Tumbler Locks [J]. Police Technology, 2017 (2): 49-52
4. GUO Wei, ZHAO Yong-feng, Elementary Discovery of the Pin Tumbler Lock Unlocking Traces with Electrical Unlocking Guns [J]. Chinese People's Public Security University, 2007 (2): 12-16
5. Ma Yuan, Ao Qi, Experiment and Research on Unlocking Traces with Selected Keys [J]. Journal of Chinese People's Public Security University, 2009 (4): 35-36
6. Zhang Xuanguang, Research on Traces of Unlocking and Breaking Billiard Padlocks [D]. Gansu Political Science and Law, 2015
7. Zhu Honghui, the Impact of the Cylinder Material Hardness on the Single Hook Unlocking Traces [J]. Journal of Yunnan Police Officer Academy, 2014 (6): 76-79

Author: Gao Yi (1978-), male, Jilin Jilin people, master, professor in Criminal Investigation Police University of China, mainly engaged in traces inspection technology work, E-mail: 396406005@qq.com.

Corresponding Author: Jin Yifeng (1988-), male, Zhejiang Wenzhou, MA, Ministry of Public Security Evidence Identification Center at the assistant researcher traces, traces of inspection techniques in the work. E-mail: jinyifeng5685 @ 163.com;

Corresponding Author: Bai Yanping (1973-), female, Liaoning Tieling, Master, researcher at the Ministry of Public Security Evidence Identification Center traces of traces of inspection techniques in the work. E-mail: byp0916 @ 163.com

Mei Hongcheng, male, Hubei Suizhou people, 1984.12, associate researcher, trace material certificate, meihongcheng @ 163.com, the Ministry of Public Security evidence identification center

Xu Zhen, female, June 1986, Hubei Xiaogan, deputy chief physician, biochemical and molecular, forensic genetics, xuzhen@cifs.gov.cn, Ministry of Public Security evidence center

Fund Project: This paper is a staged achievement of "Research on Comprehensive Test Methods of Pin-type Mortise Lock" Support by Key Laboratory of Impression Evamination and Identification Technology, Ministry of Public Security (Project No. HJ2014003).