Preparation and characterization of a new type of 304 stainless steel metalocking key

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Abstract. The preparation process of metalocking key from 304 stainless steel was studied, and the mechanical properties of raw materials and metalocking key were studied. It is found that after this preparation process, the hardness of metalocking key increases by more than 20%, the tensile strength increases by more than 50%, the yield strength increases by more than 120%, and the elastic limit increases by more than 50%. Finally, scanning electron microscope (SEM) element analysis and metallography were used to characterize the microstructure analysis. It indicated that much of the austenitic stainless steel is converted to martensite due to cold rolling, which led to the significant strengthening of metalocking key properties.

1. Introduction

The exploration, exploitation and transportation of offshore oil resources are the important links, and the equipment is the most important factor. On the other hand, the transportation mode of oil and gas also includes oil tankers, and the propeller of oil tankers is an important part of the ship propulsion system, so the importance of ship safety is self-evident. During the navigation of oil tankers, such as impinging foreign bodies (such as reef, sunken ship, fishing net, etc.), the propeller will produce the mechanical damage and defects caused by the bending of the blade, the crack, the corrosion of the seawater, the cavitation effect of the propeller and so on. More complex, propeller damage will lead to a significant decline in tanker transport efficiency [1].

In recent years, various studies have been carried out at home and abroad to solve this problem. First of all, the welding repair process is a more extensive repair method, mainly by heating the welding wire and parts of the metal melting, and then cooling, so that the repaired metal will be joined together. However, however, this repair process has many disadvantages, such as: it is prone to secondary fracture by improper operation; secondly, the metal parts after welding are likely to appear deformation, welding tumor and so on, affect welding quality. And this repair process can not be used in many occasions, as a hot working process, there must be limited working conditions. Welding, in many cases, such as fire protection requirements of the area, or prone to heat deformation of the machine; moreover, welding operations will also have a certain risk to operators [2].

Bond repair process is mainly to repair some parts with sealing requirements, usually using a binder
as a repair means. However, due to the role of binder, although it meets the requirements of sealing, but it results in the strength is not enough after reparation, anti-aging ability is relatively low, so this repair process is not easy to use.

Mechanical repair technology is a method of using mechanical equipment to repair parts, which can be subdivided into local processing repair, buckle strengthening repair and so on.

The so-called local processing repair means that when one part of the part is damaged, but the rest of the part can still be used normally, the damaged part can be removed and compensated with the new part structure, mainly aims at the repair of some gear fracture [3].

In this study, fastening and strengthening repair are the key technical operation in the metal buckle method, mainly aimed at some large cast parts, which are carried out by drilling holes on the surface of these parts, and then putting fasteners into the holes, which is connected with riveting the fastening pieces to fill the entire groove [4].

Metal fastening process (Metalock) is a unique cold repair process, which can repair cast iron, steel, aluminum and other alloy cracks, suitable for casting cracks or fracture. Using this technology to repair the equipment can usually be carried out in the field without disassembly, and the technology is considered to be a real substitute for cast iron welding. The material needed for this repair process is called metalocking key, which is also the main content of this study. The material selection, preparation process, performance test, repair method and repair effect of wave bond are studied systematically.

2. Material production

Due to the limitations of laboratory equipment, researchers went to off-campus cooperative companies to operate to prepare Metalocking Key.

First of all, the preparation of Metalocking Key is roughly divided into four steps.

1) Cutting

Firstly, the annealed raw materials are cut into the desired shape (70mm × 6mm × 5mm). Secondly, the cutting parts are polished, then cleaned and dried. So well surface impurities and metal debris are removed completely.

The cutting device is shown in figure 1.

![Figure 1. Metal cutting equipment](image)

Set the relevant size of the sample by using the connected external computer equipment, and then start the cutting equipment.
2）Surface treatment
In order to prevent the phenomenon of impurities and particles on the surface of the material, the cut metal was treated to reduce the influence of other related factors in the test process. The main treatment method used here is sandblasting.

3）Phosphorus saponification
Before rolling, in order to prevent the metal parts from sticking to the mold, it is necessary to coat the surface of the parts with a layer of cold forged leather film, that is, phosphorus saponification treatment (soap powder), which can improve the plasticity of the workpiece and promote the flow of metal during extrusion.

4）Rolling
Finally, the parts to be processed are put into the rolling equipment and rolled into shape. The rolling equipment is shown in figure 2:

Figure 2. Metalocking key rolling equipment
The finished product of the rolled metalocking key is shown in figure 3:
3. Experimental

3.1. Pretreatment
The formed metalocking key samples were pretreated, that is, they were polished with 1200 sandpaper, cleaned with ethanol solution for 10 minutes, then dried in an oven, and finally set aside in a drying dish.

3.2. Mechanical property test
Vickers hardness test, testing equipment HV-1000 micro Vickers hardness tester, first, the alloy is made of reflective grinding disc sample, placed in the microhardness measurement stage, through the loading device to press the tetrahedral conical diamond head, adjust the load, Until the diamond head is pressed into the alloy sample.

Tensile test, equipment DNS200 microcomputer controlled electronic universal testing machine, including tensile strength, yield strength and elastic limit.

3.3. Microstructure analysis
Element analysis, the rolling metalocking key samples were detected by metal element analyzer.

The initial unrolled samples and rolled wave bond samples were characterized by SEM.

Metallographic analysis, the above formed metalocking key samples are treated into metallographic samples. and then analyzed on the metallographic microscope to explore the effect of this rolling process on 304 stainless steel and its mechanism.)

3.4. Chemical property analysis
The electrochemical corrosion test of rolled wave bond samples was carried out by electrochemical workstation.

4. Results and discussion

4.1. Mechanical property test
4.1.1. Vickers hardness
The test results are shown in Table 1:

| 304 stainless steel | vickers hardness   |
|---------------------|--------------------|
| Raw materials       | 216±3.56           |
| metalocking key     | 266.67±1.25        |

Vickers hardness is a kind of hardness calculated according to the test force per unit area of indentation. The diamond positive pyramid with an angle of 136 °on the opposite side of the two phases is used. From the above table, we can see that the hardness of the processed metalocking key has been significantly improved, 304 stainless steel made of wave bond than the original increased by more than 20%.

4.1.2. Tensile test
The results are shown in Table 2:

| 304 stainless steel | Tensile strength (Mpa) | Yield strength (Mpa) | Elastic limit (Mpa) |
|---------------------|------------------------|----------------------|---------------------|
| Raw materials       | 527.33±3.30            | 210±2.45             | 180.33±3.68         |
| metalocking key     | 827.33±4.19            | 473±3.56             | 281.33±3.40         |

As can be seen from the above table, compared with the original, the tensile strength, yield strength and elastic limit of the metalocking key processed by cold pier process are increased by more than 50%, 120% and 50%, respectively. The cold pier process is significant for the improvement of metal mechanical properties.

4.2. Microstructure analysis

4.2.1. Element analysis
304 stainless steel as a general-purpose stainless steel material, corrosion resistance and high temperature resistance are very good. The element analysis before and after processing is as follows:

| 304 stainless steel | Element analysis (%) |
|---------------------|----------------------|
| Raw materials       | C(0.023) Si(0.37) Mn(1.10) P(0.027) S(0.00038) Ni(10.23) Cr(16.58) |
| metalocking key     | C(0.023) Si(0.37) Mn(1.10) P(0.027) S(0.00038) Ni(10.23) Cr(16.58) |

The other margin was Fe. As can be seen from the table above, this cold rolling process does not affect the element composition of the material.
4.2.2. Metallographic analysis

Figure 4. Comparison of micrograph of 304 stainless steel before and after cold heading

Test equipment: metallographic microscope

As shown in the figure, 304 stainless steel is a plate-shaped γ-austenitic stainless steel. After cold heading process, the Austenite phase decreases obviously and a large amount of α-martensite phase is formed. From the original face-centered cubic structure to the body-centered cubic structure, so the wave bond after cold heading has higher hardness than 304 raw materials. Combined with the above mechanical properties tests, it can be found that due to the emergence of a large number of martensite in austenitic steel, the strength of 304 stainless steel is improved, which is consistent with the effect of cold rolling mechanism studied by Ali Hedayati et al on the microstructure of stainless steel.[5]

4.2.3. SEM analysis

Figure 5. Wave structure of Metalocking key samples at different multiples

The above figure shows the structure of the metalocking key under microscopic observation of 500x and 1000 times. As we can see, the alloy matrix is Austenite, and also the thin line mark in the figure is the extension trace of the matrix grain in the rolling direction during the casting process. This can be explained by the so-called forging streamline process, which does not affect the significant change of metal structure during cold rolling. On the contrary, the strength of 304 stainless steel is increased due to grain refinement.[6]

5. Conclusion

The following remarks can be concluded from the present work:

it is found that the hardness of the wave bond made of 304 stainless steel is more than 20% higher than that of the original, the tensile strength is increased by more than 50%, the yield strength is
increased by more than 120%, and the elastic limit is increased by more than 50%. Through the observation of microstructure and metallography, it is found that the cold pier process can make the metal appear uniform forging streamline, and most of the Austenite phase of 304 stainless steel has been transformed into martensite, so the hardness has been greatly improved.

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