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DOI: 10.62022/FOMI.issn3005-5466.2024.01.003

ISSN: 3005-5466
EISSN: 3005-5474

ARTICLE Open Access

Discussion on the Free Quenching Heat Treatment Process of Automotive Leaf Springs

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Abstract: Free quenching of automotive leaf springs is a new technology that has gradually started to be applied in the industry in China in recent years. Only a few manufacturers are applying it in the industry. Through more than half a year of on-site practice, the changes in the hot forming of spring plates before free quenching have been explored, and finally a heat treatment process that meets the production requirements of our company has been developed, achieving normal production.

Keywords: automotive leaf springs; free quenching; heat treatment; technology

Introduction

Steel plate spring is the most widely used elastic component in automotive suspension. It is an approximately equal strength elastic beam composed of several alloy spring plates of equal width but not equal length (thickness can be equal or not). When the steel plate spring is installed in the car suspension and bears a positive vertical load, each spring plate undergoes force deformation and tends to arch upwards. At this point, the axle and frame approach each other. When the axle and frame are far away from each other, the positive vertical load and deformation on the steel plate spring gradually decrease, and sometimes even reverse. The flat rectangular steel plate is curved in shape and is used as a chassis spring with multiple or fewer pieces stacked together. It is widely used in non independent suspensions [1].

In the production process of steel plate springs, one of the key steps is the quenching treatment of the spring plate, and the production and processing quality of this step directly affects the factory quality and later installation reliability of the plate spring.

At present, there are about 150 domestic automobile leaf spring manufacturers, and each leaf spring enterprise basically adopts the forming heat treatment process when producing automobile leaf springs. That is, after the leaf springs are heated to a certain temperature, they are bent to a certain curvature through a mold (or fixture), and then the mold (or fixture) continues to clamp while being quenched and cooled in oil. After the leaf spring cools to a certain temperature, the mold is loosened and the forming quenching is completed. This quenching method, also known as constraint quenching, is basically manually operated throughout the entire production process. Of course, some domestic enterprises also use robot operations to replace manual labor [2].

In recent years, the automation equipment in the industry has been updated and developed rapidly, and the heat treatment process of leaf springs has also undergone disruptive changes. Free quenching has been maturely applied in some leaf spring enterprises. In 2021, Baosteel Metal Products Co., Ltd. also launched a new fully automatic heat treatment production line, which adopts a free mode quenching method. After the plate spring is heated to the process temperature, the feeding robot takes the material from the furnace and places it on the forming press (as shown in Figure 1). The press starts, and the middle section is first compressed and fixed. Then, the upper and lower molds are used to complete the curvature forming according to the adjusted curvature. The material retrieval robot grabs the workpiece and places it on the lifting bracket of the quenching oil pool. The lifting bracket descends, and the leaf spring begins to cool in oil, while the spring continues to cool in the oil groove to complete quenching [3].

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1 Heat treatment process

For free quenching of leaf springs, the heat treatment process mainly has two aspects: one is whether the quenching process of the leaf spring can complete the complete transformation of the material's structure, achieve the quenched martensitic structure, and obtain the corresponding hardness; The second issue is whether the curvature of the quenched plate spring is consistent with the design, and whether the clearance between the plates is closely matched with other plate spring assemblies, meeting the mechanical performance of the plate spring assembly[4].

The complete transformation of the structure of the plate spring after quenching, reaching the martensitic structure after quenching, mainly depends on the temperature of the spring before quenching and the cooling rate after oil injection. Based on years of on-site production experience, it is sufficient to ensure that the temperature of the spring plate before quenching reaches above 890 ℃. In order to verify the free quenching cooling method, a 20 * 100 specification 50 CrV material was used as the experimental object. After multiple on-site quenching, the surface hardness was tested. Through hardness value testing, it was found that there were always individual points with low hardness after each quenching. Technicians investigated multiple factors such as the pipeline design, oil circulation method, mixing method, flow rate, and oil injection direction of the on-site quenching oil tank, and ultimately found out that the cause of the soft spots on the plate spring was due to the end connection method of the circulation pipeline. That is, the outlet pressure at the far end was relatively small, and the flow rate was relatively slow after the oil was sprayed out, resulting in weak cooling ability and subsequently the phenomenon of soft spots on the spring quenching, This problem has been solved through on-site improvement (adopting a central connection method for the loop pipeline connection). Further testing showed that the hardness of the spring blades was between HRC53-57.

2 Production of hot formed curvature templates

There is a fundamental difference between the hot formed curvature templates used for free quenching and constrained quenching. Traditional constrained quenching uses hot formed curvature templates, which ignore the curvature changes caused by the stress caused by the transformation of the microstructure during the quenching process. The post quenching curvature of plate spring products is basically consistent with the hot formed curvature. The hot formed curvature used for free quenching is different, mainly because after hot forming, the spring is still in a high temperature state, and the leaf spring will have a natural rebound. The curvature of the hot formed spring template is R2. After hot forming, the spring will have a rebound phenomenon, and both ends of the spring will naturally pry up. Before oil is injected, the curvature of the spring has actually become R1. According to several on-site tests, the curvature change of different materials, specifications, and lengths under normal quenching furnace temperature varies, that is, there is a significant change in the corresponding height over the entire length, that is, the original H2 is reduced to H1. So, the forming curvature template is the most important factor in ensuring the final quality of the product.

3 Derive the formula for curvature variation in hot forming

In order to further derive the law of curvature variation in hot forming, the required hot forming curvature template for the production site was made and several experiments were conducted. Taking the 20 * 100 specification 51CrV4 as an example.

From the data, it can be seen that the 9th group of data is abnormal. Considering that it was abandoned due to various factors during the test process, the average of the other 9 groups of data was obtained to be 26.89 mm. Then, according to this change, a hot formed curvature template for production was made. After on-site verification, the heat treated product was qualified and met the process requirements.

According to this test method, tests were conducted on products with thicknesses of 16, 18, and 25 mm, and the test results were analyzed and organized. Finally, the calculation formula for the deformation of the arc height after the curvature change of the leaf spring forming was derived.

H=(L3-S3)/h3 * A Unit: mm

Among them: H-spring blade arc height deformation; The straight length of the L-spring; The length of the straight section in the middle of the S-spring; The thickness of the h-spring plate; A-coefficient. For the raw material with a thickness of 16 mm, after extensive data verification, the coefficient A is 0.0000416. Other thicknesses of leaf springs correspond to a coefficient, which will not be repeated this time.

4 Conclusion

After a large amount of on-site experimental work and statistical analysis of data, the calculation formula for the change in arc height of hot forming with different thicknesses was finally derived. Combined with the theoretical arc height value of the plate spring, the relevant data of the free quenching compression curvature template can be calculated. Produce curvature molding templates for production and achieve normal production. At present, the company's heat treatment free quenching automatic production line is fully put into use. This year, the line has produced a total of 6500 tons, and the per capita shift output has increased by 260%, completing 42% of the total output. The functions of automation equipment are gradually playing their huge role. At present, although the heat treatment automatic production line has been mass-produced, it has been found that different manufacturers' raw materials, environmental temperatures,

quenching media, etc. can also have a slight impact on the deformation of spring sheets during the production process. Further exploration and research are needed in future production processes. Continue to improve product quality and improve heat treatment processes. Maximize the functionality of automation equipment, contribute to the high-quality development of the company, and enhance the core competitiveness of the enterprise.

Received: January 08, 2024 Accepted: January 17, 2024 Published: March 20, 2024

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