

# Effect of Rolling Processing on Mechanical Properties of Material Cr12

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**Abstract.** The rolling process changes the mechanical properties of the specimen's surface material, and it also directly affect the fatigue strength and service life of the workpiece. The effects of rolling parameters on surface residual stress, microhardness, surface roughness and surface microstructure are studied by rolling test of Cr12 specimens. After rolling, the residual stress on the surface of Cr12 specimens changes from tensile stress to compressive stress, and the maximum compressive stress is -216MPa. With the increase of contact stress and rolling passes, the residual compressive stress increases at first and then remains stable. Rolling processing can effectively improve the surface hardness of specimens up to 30%, and the surface roughness can be reduced by 25%-67%. The fine grains aligned with the rolling direction, and the 50-60  $\mu\text{m}$  grain refinement layers were observed, which resulted in the changes in the surface mechanical properties of the specimens.

## 1. Introduction

The generation and growth of fatigue cracks are mainly concentrated on the materials' surface. By applying strengthening treatment, increasing the strength or changing the prestressing state of surface materials can effectively restrain the fatigue cracks, thereby improving the working performance and service life of parts [1,2]. Zheng et al.[3] demonstrated the influence of optimal processing parameters on surface roughness, microhardness and residual stress. Jiang et al.[4] reported the effects of different rolling times on surface morphology, roughness, residual stress and microhardness. When the load reaches a certain value, elastic and plastic deformations occur on the surface of the workpiece, which results in dislocation configuration and phase changes. At the same time, subgrains of the rolling layer are refined to form gradient nanocrystalline layer [5,6]. After rolling, the roughness of the workpiece surface is reduced[7,8], while the work hardening phenomenon[9] and the residual compressive stress are introduced on the workpiece surface[10,11], which can prevent the occurrence of fatigue failure and improve the fatigue strength and the fatigue life of the workpiece [12-14].

## 2. Experimental Procedure

### 2.1. Experimental Material

The testing material is Cr12 (the chemical composition is shown in Table 1), and it is reshaped into specimens with a diameter of 40 mm and a length of 300 mm by turning after being quenched and tempered.



**Table 1.** The chemical constituents of Cr12

Element	C	Cr	Mn	Si	P	S	Others
Content (wt.%)	2.00-2.30	11.50-13.00	≤0.40	≤0.40	≤0.030	≤0.030	≤0.025

## 2.2. Experimental Method

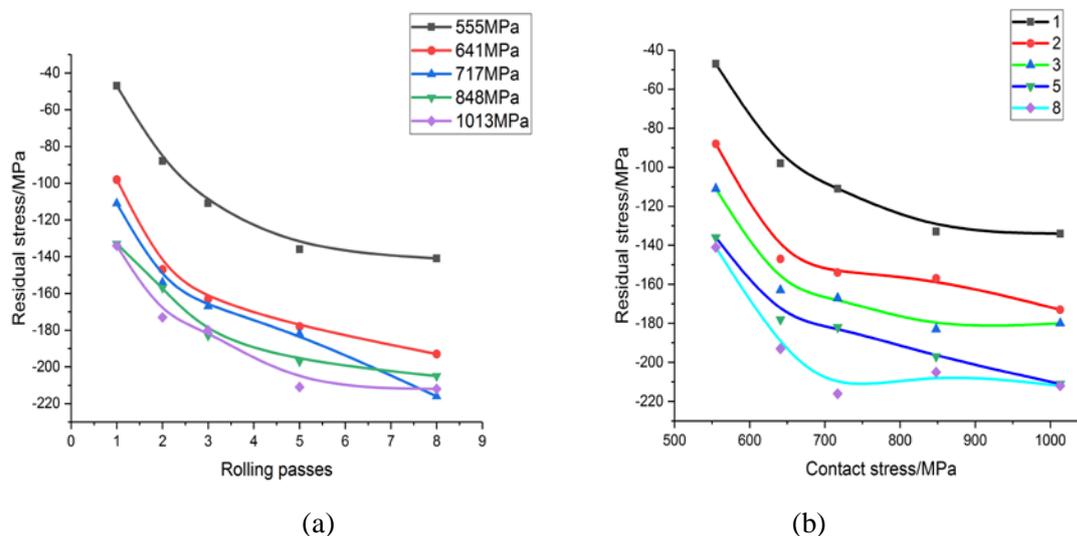
In the experiment, the iXRD stress analyzer produced by Proto Company of Canada was used to measure the residual stress of the specimen. A digital microhardness tester measured the surface microhardness of the rolled specimens. The surface roughness Ra of the specimen is measured by Mitutoyo SJ-410 surface roughness tester. Microstructure along the depth direction was observed using a scanning electron microscope (SEM, EVO/LS15).

In this work, the two-factor test was designed, where contact stress and rolling passes were selected as test variables. The set forces were 300N, 400N, 500N, 700N and 1000N, and the maximum contact stresses were 555 MPa, 641 MPa, 717 MPa, 848 MPa and 1013 MPa, respectively. In addition, rolling passes were selected as one, two, three, five and eight times. Meanwhile, the rolling test was carried out at a fixed speed of 44 r/min.

## 3. Results and Discussion

### 3.1. Surface Residual Stress

The surface residual stress of the machined specimens is 108MPa. After rolling, the surface residual stress of Cr12 specimens has changed significantly from tensile stress to compressive stress. As shown in Figure 1. During the change of rolling passes and contact stress, a certain change rule can be observed. After rolling, the residual stress on the surface of Cr12 specimens changes from tensile stress to compressive stress, and the maximum can reach -216 MPa. With the increase of contact stress and rolling passes, the residual compressive stress increases first and then keeps stable.

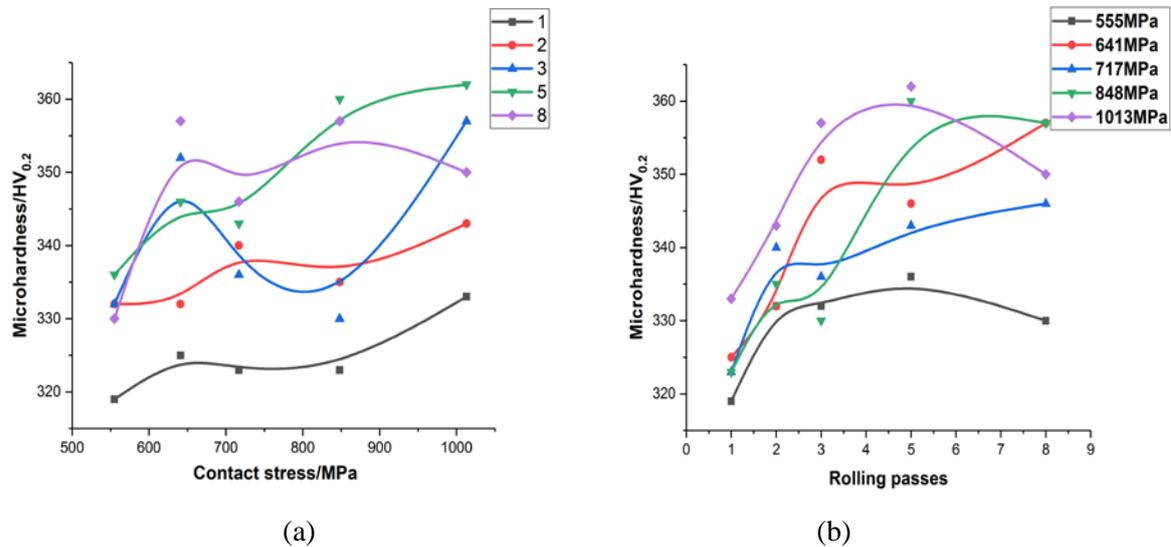


**Figure 1.** Surface residual stress of the specimens at different contact stress and rolling passes. (a)influenced by contact stress. (b)influenced by rolling passes.

### 3.2. Microhardness

The surface microhardness of the non-rolling specimens is 270HV<sub>0.2</sub>. After rolling, the surface microhardness of the specimens increases in varying degrees. As shown in Figure 2. With the increase of contact stress and rolling passes, the surface microhardness of the specimens reveals improving tendencies. By comparison, the parameters of rolling passes have a stronger impact on the

microhardness of the material. In particular, the microhardness increases significantly before the third rolling pass, and then gradually reaches out to stabilization.

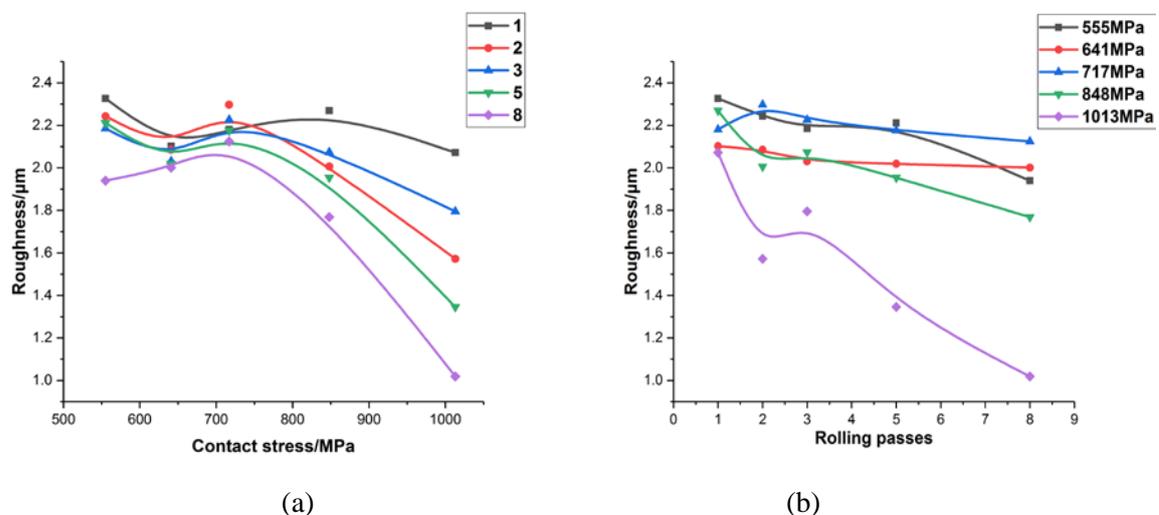


**Figure 2.** Microhardness of the specimens at different contact stress and rolling passes. (a) Influenced by contact stress. (b) Influenced by rolling passes

### 3.3. Surface Roughness

After rolling, the specimen surface produces elastic-plastic deformation, which will cause the change of surface roughness. The initial value of surface roughness of the specimen is  $3.079\ \mu\text{m}$  and that of the roller is  $0.413\ \mu\text{m}$ . As shown in Figure 3. It can be seen that the surface roughness indicates a decreasing tendency with the increasing rolling passes. Especially, when the contact stress is 1013 MPa, it is clear see that the minimum surface roughness is  $1.019\ \mu\text{m}$ , and the roughness decreases by 67%.

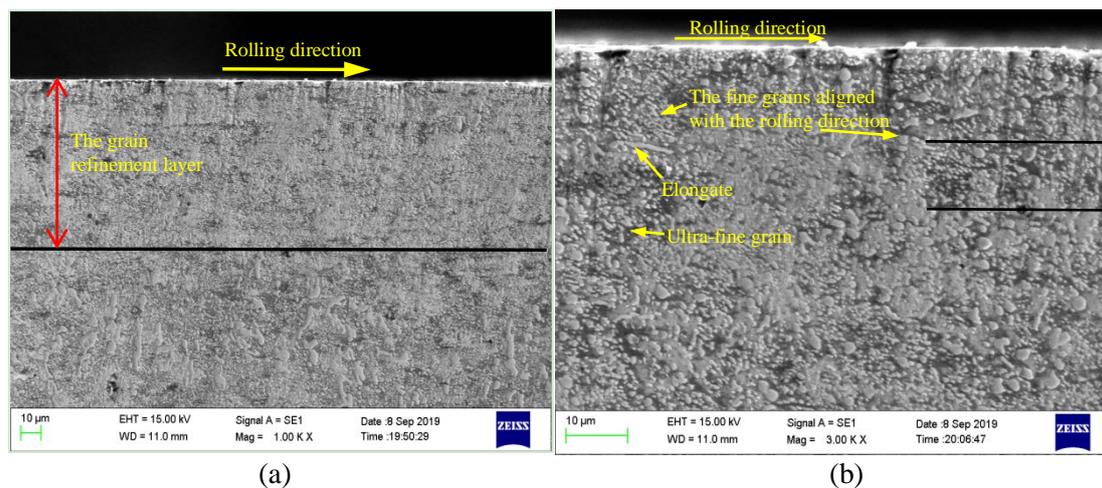
During the rolling process, the main reason for the reduction of surface roughness is that the peak of surface roughness is filled into the trough by plastic flow. After rolling, the surface morphology of the roller will be reproduced on the surface of the specimen to a certain extent, that is, the surface roughness of the specimen will gradually reach to the surface roughness of the roller.



**Figure 3.** Surface roughness of the specimens at different contact stress and rolling passes. (a)influenced by contact stress. (b)influenced by rolling passes.

### 3.4. Microstructure

In order to explore the intrinsic mechanism of rolling technology, the surface microstructures of the rolled surface of specimens were observed and studied. Samples with contact stress of 1013MPa and rolling passes of 8 times were selected to observe SEM images along the depth direction. Figure 4 shows that the surface morphology of sample surface becomes smooth and flat, and the grains are crushed into fine grains and ultra-fine grains, which flow along the direction of rolling. With the increase of depth along the surface of the specimen, grain refinement layers of about 50-60  $\mu\text{m}$  are observed, and the grain size gradually increased. This is the main reason for improving the surface performance. It is clear see that the degree of grain refinement is the most serious when the grain refinement layer is 20 microns to 30 microns away from the surface layer.



**Figure 4.** (a) Microstructure of specimen along the depth direction (b) Partial enlarged view of the surface layer

## 4. Conclusions

In this work, the main conclusions can be drawn as follows:

- 1) After rolling, the residual stress on the surface of Cr12 specimens changes from tensile stress to compressive stress, and the maximum compressive stress is -216MPa. It is found that the influence depth of residual compressive stress is about 0.2 mm.
- 2) Rolling processing can effectively improve the surface microhardness of the specimens and reduce the surface roughness of the parts. The experimental results show that the maximum surface microhardness increased by 33% and the maximum reduction of surface roughness is 67%.
- 3) After rolling processing, the surface of the specimens undergoes plastic deformation, and the grains are elongated and refined. It can be clear found that the degree of grain refinement is the most serious when it is 20 microns to 30 microns away from the surface layer.

## 5. Acknowledgments

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