Effect of Shot Peening on the Retained Austenite and Residual Stress of Carburized Cases

Shao Quan Lu[1*1], Liu Ho Chiu[1*2]

[1]*Department of Mechanical and Materials Engineering, Tatung university, Taipei 100-8862, Taiwan*

In this paper, the effect of shot peening on the hardness profile, residual stress and retained austenite of carburized steels has been studied. The results show that the shot peening process could reduced the thickness of the grain boundary oxide layer and the hardness can be increased. Moreover, the retained austenite near the surface will be transformed due to mechanical stress, and the content of retained austenite can be reduced. If the carburized parts had shot peened treatment, the residual compressive stress depth will be increased with the increase of Almen intensity. The residual compressive stress of surface will increase with the coverage increase. When the coverage was 100% and treated by 0.41 mmA of almen intensity, residual compressive stress value is -450 MPa. Increased the coverage to 200%, the surface compressive stress of carburized parts can be increase to -800 MPa.

Keywords: *Carburizing, Shot peening, Retained Austenite, Residual Stress*

1. Introduction

Mechanical parts used in industry are usually required to have good wear property and fatigue life, so that the mechanical parts can work successfully. Carburizing method can not only increase the surface hardness of the parts, but also retain the toughness of the core [1-3].

Quenching the steel after carburizing will produce martensite and retained austenite, and cause various residual stress due to the presence of retained austenite [4-8]. These residual stresses can cause various problems such as, stress corrosion cracking and deformation.

For the fatigue life and residual stress of carburized parts, that the results showed fatigue life can be significantly improved after shot peened process. Shot peening will significantly increase the compressive residual stress in the subsurface region, but still cannot significantly increase influence depth of the stress [9-12].

In this paper, the specimens were made of JIS SCM415 steel that commonly used in mechanical parts. Heat treatment was carried out by gas carburizing, and treated in shot peening with different parameters. To discussion the effect of shot peening on carburizing parts, that perform microstructure and hardness analysis to compare quality in this paper. And used X-ray diffraction method be used to analyze the residual stress and retained austenite in the carburizing case.

2. Experimental

2.1 Material

The material in this work is JIS SCM415 steel. The dimensions for specimens were 15 mm in diameters and 10 mm in length.

2.2 Heat treatment

The carburizing specimens with different ECD of 0.2 mm and 0.7 mm were set, and the hardness of surface is 58~62 HRC, and the core is 30~45 HRC.

2.3 Shot peening treatment

The shot pressure is 20 kg/cm^2, the flow rate is 6 kg/min, the size of shot is 0.3 mm, peening angle is 90°, and the distance from the nozzle to specimen is controlled as 60~180 mm. The carburized specimens with an ECD of 0.2 mm, which was treated by 100% coverage and almen intensity of 0.34 mmA, to 0.49 mmA. For the carburized specimens with an ECD of 0.7 mm, fixed almen intensity with 0.41 mmA and treated with 100% to 200% coverage.

2.4 Measurement Methods

Microstructures of specimens were characterized by using an optical microscope. Hardness test was conducted by Vickers hardness tester at an applied load of 100 g. The residual stress and content of retained austenite were measured with a portable X-ray diffractometer (Pulstec, μ-X360s), applying the measuring principle of the single incident angle method (cosα method) [13-17].

3. Results and discussion

3.1 Microstructure

The microstructure of the carburizing specimens was as shown in Fig. 1. The carburized case of the 0.2 mm ECD presents some of retained austenite on the finer high-carbon martensite base (Fig. 1a). The carburized case of the 0.7 mm ECD presents more of retained austenite (Fig. 1c).

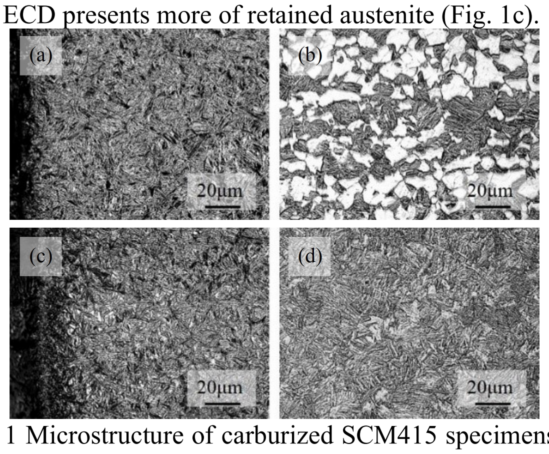

Fig. 1 Microstructure of carburized SCM415 specimens for (a) carburized case at 0.2 mm case depth, (b) core, (c) carburized case at 0.7 mm depth and (d) core.

*[1]Doctoral Student, Tatung University
*[2] Professor, Tatung University

Fig. 2 reveal the microstructure of carburized specimens treated with different almen intensity of 0.34 mmA, 0.41 mmA and 0.49 mmA, respectively. The retained austenite was be reduced after shot peening process.

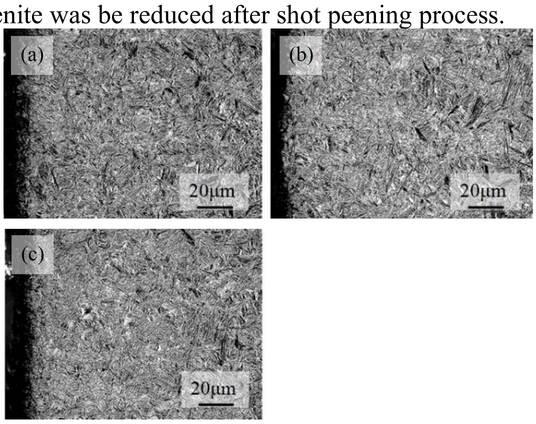

Fig. 2 Surface microstructure of carburized SCM415 specimens at 0.2 mm case depth, with shot peening coverage at 100% coverage for (a) 0.34 mmA, (b) 0.41 mmA, (c) 0.49 mmA.

Fig. 3 reveal the microstructure of carburized specimens treated with 100%, 150% and 200% coverage, respectively. The retained austenite was be reduced, too.

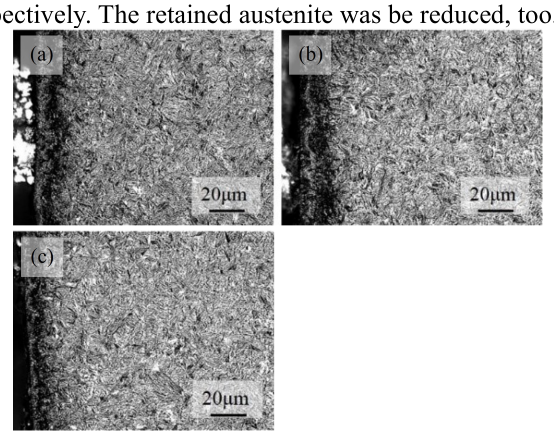

Fig. 3 Surface microstructure of carburized SCM415 specimens at 0.7 mm case depth, with shot peened intensity at 0.41 mmA for (a) 100%, (b) 150% and (c) 200% coverage.

3.2 Microhardness

The hardness curve of carburized specimens at 0.2 mm depth with 100% coverage, and shot peened with different intensity is shown in Fig. 4. After shot peening, the hardness at a almen intensity of 0.34 mmA was increase from 720 $HV_{0.1}$ to 725 $HV_{0.1}$. When increase the almen intensity, the hardness increase to 750 $HV_{0.1}$ at 0.49 mmA.

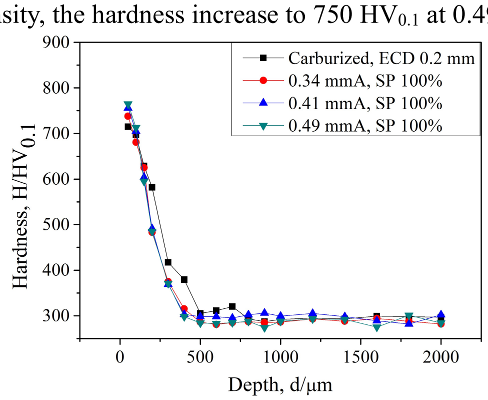

Fig. 4 Microhardness profile of carburized SCM415 specimens at 0.2 mm case depth, with shot peening coverage at 100% coverage of different shot intensity.

The hardness curve of carburized specimens at 0.7 mm depth with 0.41 mmA shot peened intensity of different coverage is shown in Fig. 5. The hardness at a 100% coverage was increase from 770 $HV_{0.1}$ to 805 $HV_{0.1}$. When increase coverage, hardness increase to 855 $HV_{0.1}$ at 200%.

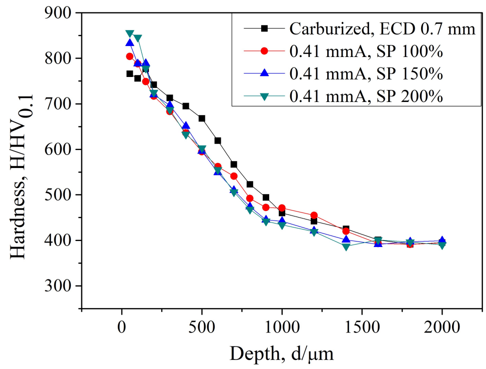

Fig. 5 Microhardness profile of carburized SCM415 specimens at 0.7 mm case depth, with shot peened intensity at 0.41 mmA for different coverage.

3.3 X-ray diffraction

3.3.1 Retained austenite

The retained austenite profile of carburized specimens at 0.2 mm depth, and shot peened with different intensity is shown in Fig. 6. After shot peening, retained austenite was decrease from 10% to about 2%.

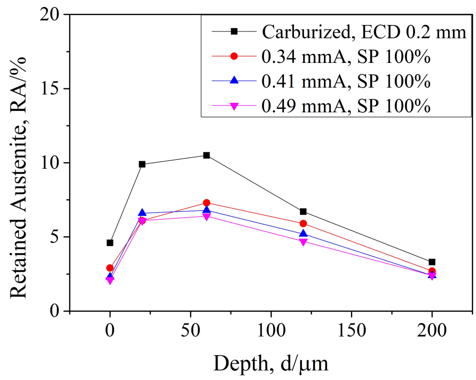

Fig. 6 Retained austenite profile of carburized SCM415 specimens at 0.2 mm case depth, with shot peening coverage at 100% coverage of different shot intensity.

The retained austenite profile of carburized SCM415 specimens at 0.7 mm depth, and shot peened with different coverage is shown in Fig. 7. When the almen intensity was fixed at 0.41 mmA, and the the retained austenite of surface at different coverage can decrease to 1%.

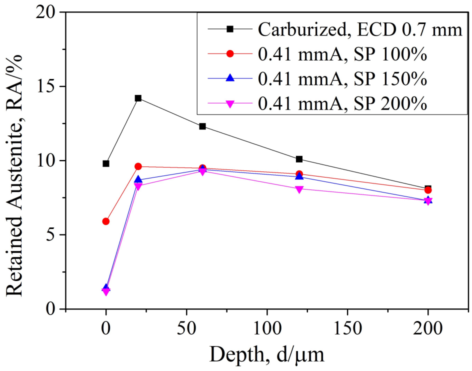

Fig. 7 Retained austenite profile of carburized SCM415 specimens at 0.7 mm case depth, with shot peened intensity at 0.41 mmA for different coverage.

3.3.2 Residual stress

The residual stress profile of carburized SCM415 specimens at 0.2 mm depth with 100% coverage, and shot peened with different intensity is shown in Fig. 8. The compressive residual stress of surface at different almen intensity, that transformed from 100 MPa to -500 MPa.

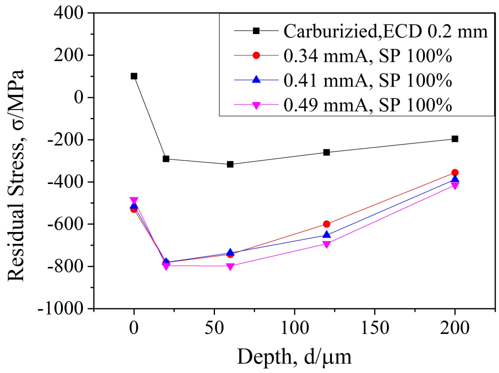

Fig. 8 Residual stress profile of carburized SCM415 specimens at 0.2 mm case depth, with shot peening coverage at 100% coverage of different shot intensity.

The residual stress profile of carburized SCM415 specimens at 0.7 mm depth with 0.41 mmA and shot peened with different coverage is shown in Fig. 9. It can be seen that residual stress of carburized surface increase from -250 MPa to -450 MPa at 100% coverage. When increase the coverage, the compressive residual stress can increase up to -800 MPa at 200%.

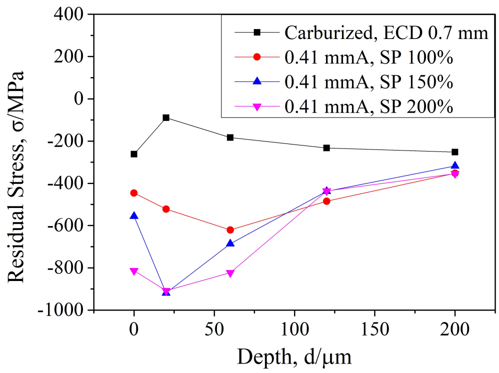

Fig. 9 Residual stress profile of carburized SCM415 specimens at 0.7 mm case depth, with shot peened intensity at 0.41 mmA for different coverage.

4. Conclusion

1. The retained austenite content of the carburized case of the carburized specimens are about 10~15 %, that shot peening treatment can reduce to a content about 2% or even below. The reason for the retained austenite is due to plastic deformation to induced the unstable austenite to transformed into martensite.
2. After the shot peening treatment is applied to the carburized parts, the compressive residual stress of surface can be increased from about -200MPa to about -500 MPa, and the value of compressive residual stress of surface, increase with the increase of coverage.
3. Both of shot intensity and coverage, will slightly increase the effective depth of compressive residual stress of the carburized case with the increase of the shot intensity.

Acknowledgments

This research is partially supported by the National Science and Technology Council, Taiwan, R.O.C. under Grant no. NSTC 111-2622-E-036-002.

References

1. K. Obayashi: Metals and Alloy New and Improved Steels Carburizing of Steels, (Reference Module in Materials Science and Materials Engineering, 2020) pp. 162-172.
2. P. Ostermayer, T. Allam, X. Shen, W. W. Song, K. Burkart, B. Blinn, B. Clausen, W. Bleck, T. Beck: Mat. Sci. Eng. A. **877** (2023) 145204.
3. S. Roy, S. Sundararajan: JMRT. **119** (2019) 238-246.
4. P. Hiremath, S. Sharma, M. C. Gowrishankar, M. Shettar, B. M. Gurumurthy: JMRT. **9** (2020) 8439-8450.
5. G. F. Guimarães, A. R. Faria, R. R. Rego, and A. L. R. D'Oliveira: Finite. Elem. Anal. Des. **223** (2023) 103987.
6. S. Roy, G. T. C. Ooi, S. Sundararajan: Materialia. **3** (2018) 192–201.
7. B. Z. Li, C. S. Li, Z. X. Li, J. B. Dong: Procedia Manuf. **15** (2018) 1612-1618.
8. C. L. Xu, X. Wang, Y. X. Geng, Y. M. Wang, Z. W. Sun, B. Yu, Z. H. Tang, S. L. Dai: Int. J. Fatigue. **172** (2023), 107668.
9. J. Z. Wu, H. J. Liu, P. T. Wei, C. C. Zhu, Q. J. Lin: Surf. Coat. Technol. **384** (2020) 125273.
10. Q. J. Lin, H. J. Liu, C. C. Zhu, D. F. Chen and S. S. Zhou: Surf. Coat. Technol. **398** (2020) 126054.
11. S. G. Qu, C. F. Duan, X. F. Hu, S. Y. Jia and X. Q. Li: Mater. Chem. Phys. **274** (2021) 125116.
12. Chao Song, Chang Yang, Shan Hu, Fei Yin: J. Manuf. Process. **101** (2023) 982-989.
13. D. Delbergue, D. Texier, M. Lévesque and P. Bocher: Mater. Res. proc. **52** (2017) 55–60.
14. J. Ling and S. Y. Lee: Characterization of a portable X-ray device for residual stress measurements in: Advances in X-ray analysis, (The International Centre for Diffraction Data, USA, 2015.)
15. T. Miyazaki and T. Sasaki: J Appl Crystallogr. **49** (2016) 426–432.
16. S. S. Ao, C. J. Li, Y. F. Huang, Z. Luo: Measurement. **161** (2020) 107892.
17. K. Tanaka: Mech Eng. **6** (2019) 378.