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INFLUENCE OF PRODUCTION PARAMETERS ON THE QUALITY OF SEMIFINISHED RIFLED PISTOL BARRELS

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Abstract: *In this paper several semi-finished rifled pistol barrels produced with different parameters were examined. The goal of the investigation was to determine the optimal production parameters for the barrels. Visual examination, microscopic analysis, SEM/EDS analysis and hardness tests were performed. The material of the barrels is 42CrMo4 steel. The caliber of the barrel is 9mm, and spiral grooves at the inside surface of the barrels were observed. Micro-cracks at the groove roots and geometrical deviances of the grooves were revealed in the specimens that were heat-treated by quenching and tempering. This indicates that improper rifling and/or heat treatment parameters were used during the production process for these specimens. On the specimen heat-treated by austenitization + continuous cooling no micro-cracks and geometrical deviances were observed, indicating that these heat treatment parameters are optimal for the subsequent process of rifling.*

Keywords: *pistol barrel, rifling, heat treatment*

INTRODUCTION

Rifling is a process of making spiral-shaped grooves in the inside surface of a gun barrel [1]. The purpose of these helical grooves is to give a spin to the projectile, thus stabilizing it and improving accuracy of the gun. Technical drawing of the investigated barrels that shows the required geometry of the grooves is shown in Figure 1.

The main objective of this paper is to determine the cause of defects on the spiral grooves inside the pistol barrels, as well as to determine the optimal production parameters for the barrels, specifically in regard to the quality of the spiral grooves produced in the process of rifling.

1. EXPERIMENTAL WORK

1.1. Material and technology

Initial investigation was performed on three barrel specimens (specimens A, B and C), each in different stages of the production. A fourth barrel was produced after adjustments of production parameters and a specimen taken from this barrel was subsequently examined (specimen D). The specimens are shown in Figure 2. The examined semi-finished pistol barrels were made of steel 42CrMo4 / SRPS EN 10083-3. The heat treatment of the barrels A, B and C consisted of austenitization at 850°C for 10 minutes, quenching in water, and tempering at 680°C for 1.5 hours. The heat treatment of specimen D consisted of austenitization at 850°C for 10 minutes and continuous cooling to 500°C for 10 minutes. The center of the barrels is drilled and rifled to a caliber of 9 mm.

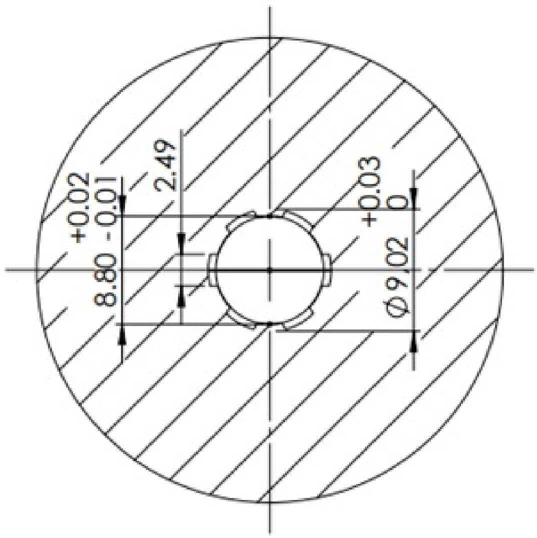
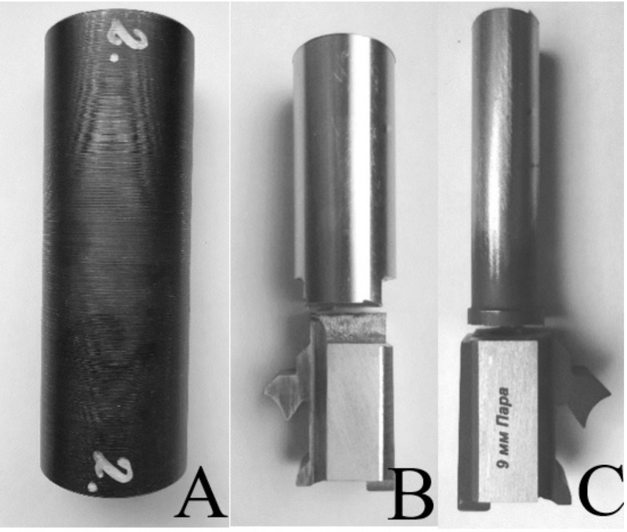


Figure 1. Technical drawing of the perpendicular plane projection of the pistol barrels.



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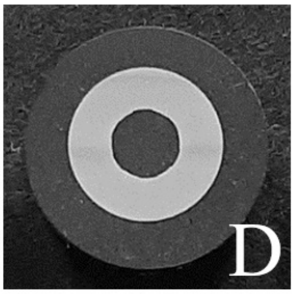


b)

Figure 2. Pistol barrel specimens. (a) Initially examined pistol barrels A, B and C, in three different stages of barrel production. (b) Sample D cut in perpendicular direction from the subsequently produced pistol barrel.

1.2. Methods

Visual observation performed by naked eye and magnifying glass, and was documented with photographs.

The chemical composition of the pistol barrels A, B and C was analyzed by Optical Energy Spectrometer (OES) Belec Compact Port.

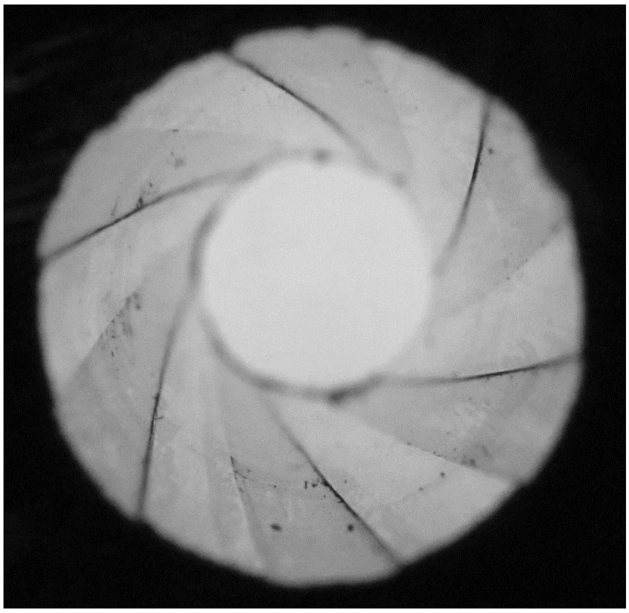
Hardness of all barrel samples was measured by Rockwell method (HRC), according to SRPS EN ISO 6508-1 [2].

In order to investigate the microstructure, samples were cut in perpendicular direction from the pistol barrels and prepared by grinding and polishing, followed by etching. A 3% nital etchant was used to reveal the microstructure. The polished and etched surfaces were examined using light microscopy, as well as scanning electron microscopy (SEM-JSM 6610 LV). An EDS analysis of an observed surface layer was performed on specimen C.

3. RESULTS

3.1. Visual examination

Visual examination of the inner surface of the barrels showed that the spiral grooves on the specimen C have defects. Such defects were not observed on specimens A, B and D. The spiral grooves as observed on specimens B and C are shown in Figure 3.



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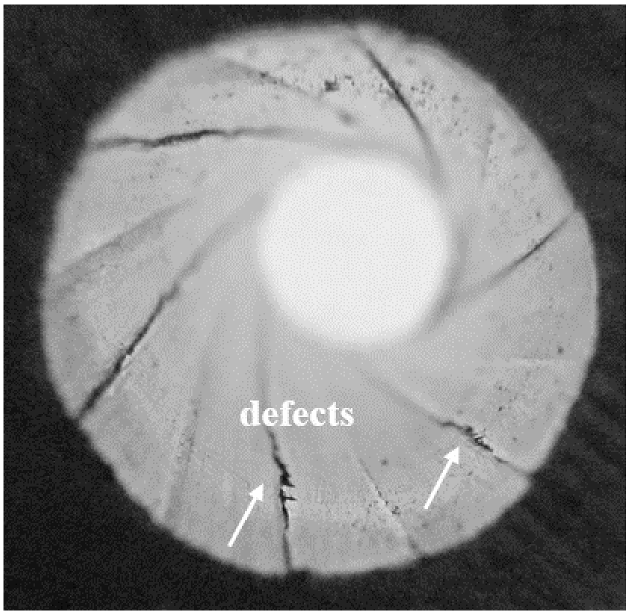

b)

Figure 3. Inner surface of barrels (a) B without defects and (b) C with present defects.

3.2. Chemical composition

The chemical composition of the specimens A, B and C are given in Table 1. Results showed that chemical composition of the pistol barrels is according to the chemical composition of steel 42CrMo4 as required by the standard SRPS EN 10083-3 [3].

Table 1. Chemical composition of the specimens A, B and C.

element	mass%		
	A	**B**	**C**
C	0.46	0.39	0.43
Si	0.24	0.24	0.23
Mn	0.84	0.78	0.78

P	0.017	0.013	0.011
S	0.027	0.007	0.003
Cu	0.25	0.17	0.18
Al	0.033	0.03	0.017
Cr	1.05	0.98	0.98
Mo	0.21	0.17	0.17
Ni	0.11	0.08	0.08
Fe	bal.	bal.	bal.

3.3. Hardness

Results of the hardness measurements of the specimens A, B, C and D are given in Table 2.

Table 2. Hardness of the pistol barrels, HRC.

specimen	Hardness, HRC			average
A	24.9	25.0	26.5	**26**
B	21.9	22.2	21.4	**22**
C	27.6	28.5	28.8	**28**
D	24.3	25.7	24.2	**25**

3.4. Microstructure

Micro-structural analysis of the specimens A, B and C as polished revealed cracks propagating from the sharp groove corner to the inner side of the barrels, Figure 4. Cracks length around 100 μm were observed on every groove on the specimens. The presence of cracks probably caused the macroscopic defects of the spiral grooves on specimen C. The angle of the groove corners is acute. It was also observed that the groove depth does not meet the requirements of the technical drawing of the barrels.

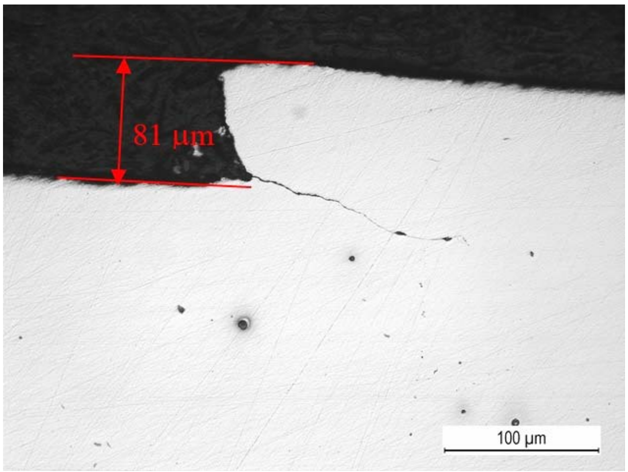

Figure 4. Microstructure of specimen A, as polished. Cracking at the groove corner.

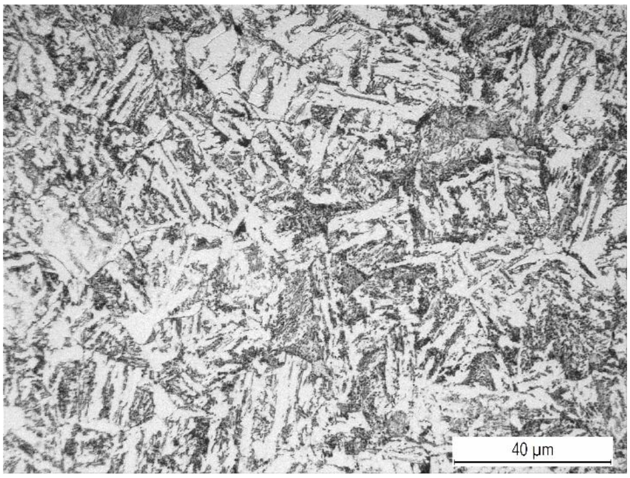

Figure 5. Microstructure of specimen B, etched.

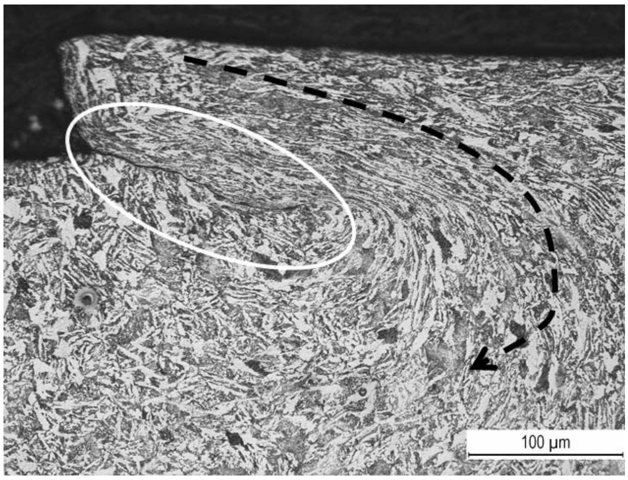

Figure 6. Microstructure of specimen A in the groove zone. The arrow indicates the material flow direction. Encircled is the crack at the groove corner.

Microstructure of the specimens A, B and C is tempered martensite, with a few visible ferrite grains. Figure 5 shows the microstructure of specimen C after etching.

Significant material flow in the groove zone was observed on specimens A, B and C, Figure 6. The cracks on the grooves appear to follow the material flow direction.

Presence of a surface layer was observed on specimen C, Figure 7. This layer is also present around the groove cracks.

Figure 8 shows the microstructure of specimen D, as polished. No cracks were observed at the grooves. The grooves are of sufficient depth, as required by the technical drawing of the barrels (Figure 1).

The microstructure of etched specimen D is shown in Figures 9 and 10. The microstructures consist predominately of fine pearlite and ferrite grains. The material flow around the groove corners is less pronounced than in specimens A, B and C.

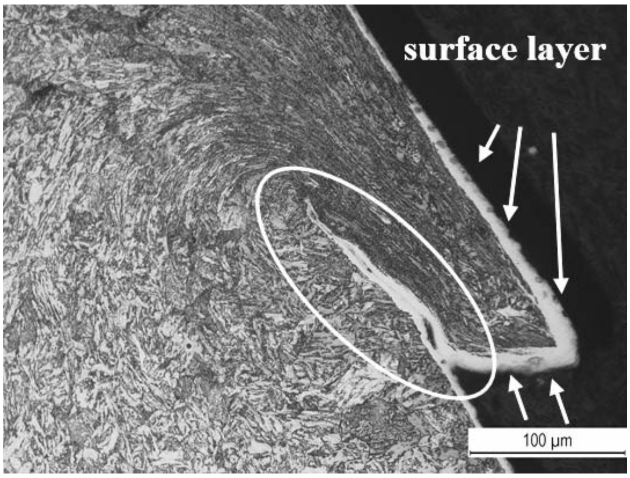

Figure 7. Microstructure of specimen C, etched. Encircled is the crack at the groove corner.

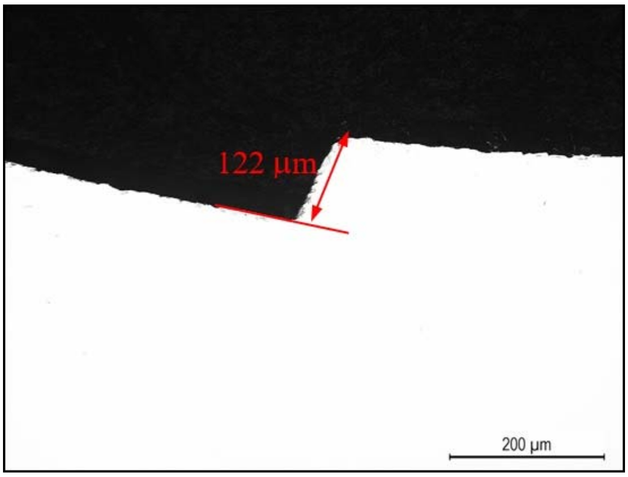

Figure 8. Microstructure of specimen D, as polished.

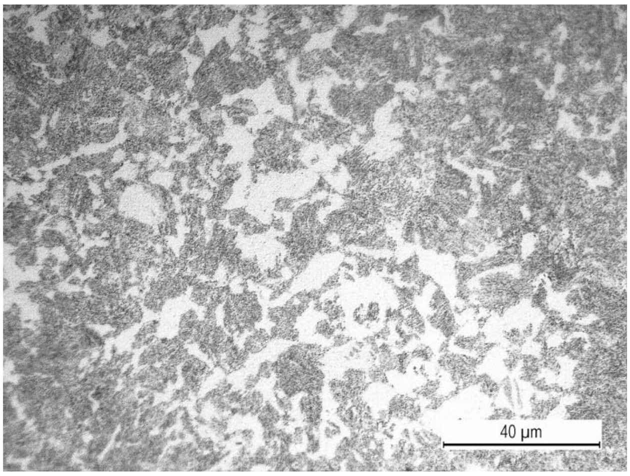

Figure 9. Microstructure of specimen D, etched.

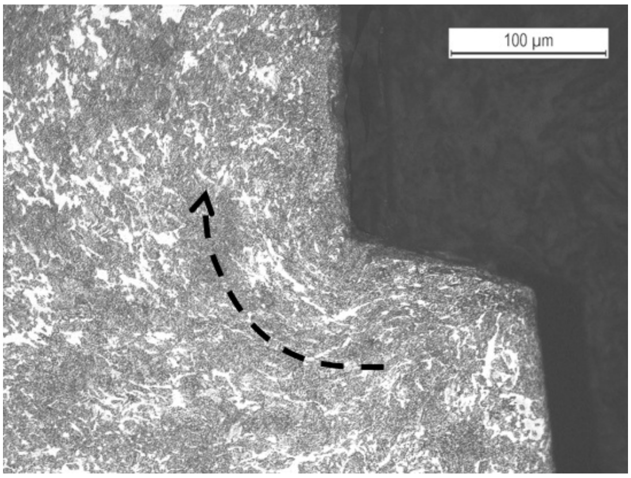

Figure 10. Microstructure of specimen D in the groove zone. The arrow indicates the material flow direction.

3.5. SEM / EDS analysis

SEM and EDS analysis of specimen C identified the presence of a nitrogen-rich surface layer on the inner side of the pistol barrel, Figures 11 and 12. The nitride layer thickness is between 12 and 19 µm. The EDS analysis results are shown in Table 3.

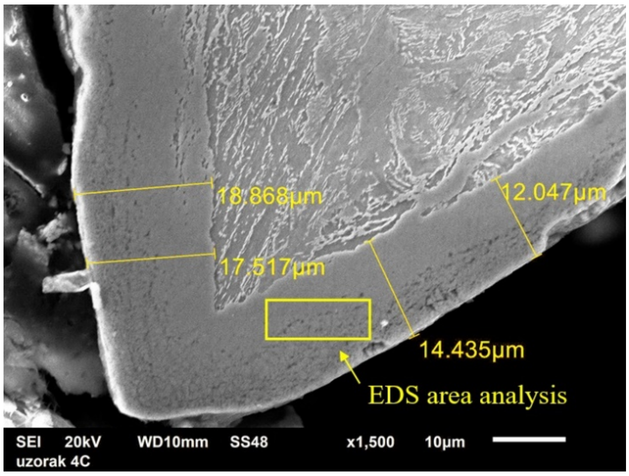

Figure 11. Microstructure of the groove tip zone on specimen C, as observed by scanning electron microscopy.

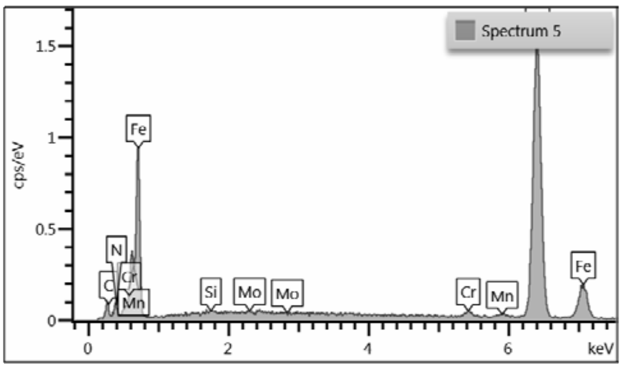

Figure 12. EDS analysis of the surface layer shown in Figure 11.

Table 3. Results of EDS analysis of the surface layer observed on specimen C.

Element	mass %
C	7.74
N	**4.63**
Si	0.07
Cr	0.87
Mn	0.62
Fe	85.65
Mo	0.41
total	100.00

4. DISCUSSION

The presence of cracks propagating from the spiral groove corners on each groove of specimens A, B and C, as well as the insufficient groove depth indicate that the material temper is not adequate for the rifling process. As a consequence, micro-cracks visible in early stages of production (specimens A and B) developed into macroscopic defects of the spiral grooves, as observed on specimen C. The acute angle of the grooves most likely contributed to the appearance of cracks [4].

The hardness of all specimens is in accordance with their respective microstructure [6]. A possible cause of the higher hardness of specimen C lies in the process of surface hardening that was performed on the specimen.

The microstructure of etched specimens A, B and C is in accordance with microstructure of steel 42CrMo4 in quenched and tempered condition [5,6]. There was significant material flow around the corners of the grooves, as a consequence of a rifling process involving cold deformation. The surface layer observed on specimen C is a consequence of a surface hardening process [7]. SEM/EDS analysis of specimen C confirmed the presence of a nitride layer on the barrel inside. This layer is also present around the groove cracks, indicating that the cracking occurred before the process of nitrating. The accicularity of the tempered martensite microstructure, as well as significant material deformation around the corners of the grooves, are factors that contributed to making the material more susceptible to cracking.

Microstructure of specimen D consisted of fine pearlite and ferrite grains [5,6]. Material flow in the groove zone is less pronounced than on specimens A, B and C. No cracking was observed at the groove corners on specimen D. The groove shape and depth meet the geometrical requirements.

5. CONCLUSION

Micro-cracks at the groove roots and insufficient groove depth were revealed on 9mm cal. rifled pistol barrels that were heat treated by quenching an tempering prior the rifling process. This indicated that the material temper and its resulting microstructure is not adequate for the rifling process.

In order remedy the observed defects, a further barrel (specimen D) was produced with different heat treatment parameters (austenitization + continuous cooling) and examined. No fractures at the grooves were observed on specimen D, and the microstructural analysis showed less pronounced material flow on the barrel inside and a better geometry of the grooves than on quenched and tempered specimens. It can be concluded that the production parameters of pistol barrel D are appropriate for the process of rifling.

References

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