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Investigation of Thermophysical Properties of Three Barrel Steels

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Abstract: In this paper, thermal diffusivity and heat capacity measurements were performed for three types of barrel steel, 38HMJ (1.8509), 30HN2MFA, and duplex (1.4462). Thermal diffusivity tests as a function of temperature were performed in the range of room temperature (RT) to 500 °C, and specific heat in the range of RT to 1000 °C. All tests were carried out using NETZSCH specialized measuring stands: LFA 467 light flash apparatus and DSC 404 F1 Pegasus differential scanning calorimeter. In the measurements of thermal diffusivity, the reference material Inconel 600 was used. This made it possible to determine thermal conductivity and specific heat as a function of the temperature of barrel steel. The results of specific heat tests of the 38HMJ and the 30HN2MFA steels show a ferrite–austenite phase transition in the 750–810 °C temperature range. This transition was not observed in the duplex steel.

Keywords: 38HMJ (1.8509); 30HN2MFA; duplex (1.4462); barrel steels; thermophysical properties

1. Introduction

During the operation of small automatic arms, a rapid decrease in ballistic parameters such as muzzle velocity of the missile is noted after a short period of intense fire. It is caused by the passage of some gunpowder gases before the bullet due to the increased diameter of the barrel, resulting from degradation of the barrel duct due to the effects of hot powder gases [1–3]. The traditional and most commonly used method of protecting the barrel against wear is to apply a galvanic chromium layer in the barrel to ensure high hardness, abrasion, and corrosion resistance [4–10]. For technological reasons, the thickness of this layer does not exceed 0.1 mm. During heavy fire, the chromium layer and the steel surface heat intensively [2]. If the temperature of the ferrite–austenite phase transition is exceeded in the steel under the chromium layer, structural changes occur [11]. The reduction in the volume of steel in the phase transition zone results in a network of cracks under the galvanic chromium layer [12]. The cracked substrate affects the stability of the chrome coating and causes its fragmentation and then detachment from the surface of the barrel duct. This is demonstrated by cracks that are particularly visible on cross-sections throughout the surface of the barrel line (Figure 1) [13].

Figure 1. SEM scans of a cross-section through the wall of a 30HN2MFA steel barrel covered with a layer of chromium (JEOL 5400 scanning electron microscope): (a,b) cracking of steel substrate and chromium layer; (c,d) detachment of chromium layer [13].

Views of the chrome surface structure with cracks are shown in Figure 2.

Figure 2. SEM scans of surface structure of chromium layer with visible cracks on the wall of a 30HN2MFA steel barrel (JEOL 5400 scanning electron microscope): (a) magnification $\times 200$, (b) magnification $\times 500$ [13].

The cracks are much wider in the steel than in the chromium coating. An analysis of metallographic photos of 30HM2MFA steel presented in Figures 1 and 2, as well as the results of our tests of thermal expansion [1] and apparent specific heat, allow us to determine the mechanism of chromium layer destruction. It is connected with the occurrence of ferrite–austenite phase transition at a temperature of 728 °C (onset of apparent specific heat of 30HM2MFA steel, second heating; Section 3.2). The ferrite A2 crystal lattice has less packing than the austenite A1 crystal lattice [12]. This causes the material

to shrink/relax during a series of shots, thus cracks form and develop. Cracks in the substrate cause the chromium layer to crack [1]. Deformed chromium plates break off, exposing the substrate. This process is also affected by a pressure change in the barrel during firing, which further accelerates the destruction process of the chromium layer. As a result of the cyclical heating and cooling of the barrel, further development of cracks in both the substrate and the chromium layer occurs, which in turn leads to the destruction of the chromium layer. The phenomenon of chromium coating destruction in the barrel ducts can be inhibited by using steel with a higher phase transformation temperature or in which structural transformations occur in a limited range. Currently, barrel production in Poland uses a steel grade dating back to the Cold War. It is steel-marked according to old Polish standards (converging with GOST) with the symbol 30HN2MFA. This steel does not appear in European standards and has not been registered as a separate grade by digital classification. In this study, 30HN2MFA steel was treated as a reference material, the replacement of which with new grades could increase the durability of small automatic arms. As a substitute for the currently used 30HN2MFA steel, two grades were selected that meet the strength and technological criteria required in the production of barrels by forging the cable on a hard core. One is steel from the group intended for nitriding, 38HMJ (1.8509), and the second belongs to the group of two-phase duplex ferritic–austenitic steels (1.4462). Knowledge of the thermophysical properties of barrel steels is necessary to carry out numerical simulations of heat transfer in the barrel of a rifle during shooting. In the calculation process, approximate specific heat characteristics are usually assumed, which are described by correlation formulas. In dynamic conditions, the temperature field is affected mainly by thermal diffusivity. Hence, in this paper, the results of our research on the thermal diffusivity of barrel steels in a range of room temperature (RT) to 1050 °C were published in conference proceedings [1].

In this work, experimental investigations of thermal diffusivity and the specific heat of three barrel steels (38HMJ (1.8509), 30HN2MFA, and duplex (1.4462)) were carried out. In the tests, NETZSCH-Gerätebau GmbH–Selb, Germany instruments were used: LFA 467 in the temperature range of RT to 500 °C and DSC 404 F1 Pegasus in the temperature range of RT to 1000 °C. The purpose of this work was to determine the thermophysical properties, particularly to calculate the thermal conductivity, of three barrel steels as a product of thermal diffusivity, specific heat, and density in the temperature range of RT to 1000 °C. The missing data for calculations, thermal diffusivity in the range of RT to 1000 °C, were taken from [1]. Additionally, the specific heat of the three barrel steels was determined in the range of RT to 500 °C using a comparative method and the LFA 467.

2. Materials and Methods

The subject of research was 3 types of barrel steel: duplex (1.4462) with a density of 7.72 g/cm³, 38HMJ (1.8509) with a density of 7.65 g/cm³ at room temperature (RT), and 30HN2MFA with a density of 7.75 g/cm³ at RT. The chemical composition of these steels, determined using a Foundry Master spectrometer 01D0058 (Optic 01D0059, HITACHI, Japan) is given in Table 1 [14].

Table 1. Chemical composition of tested steels [13].

Steel Grade	Chemical Composition, (wt. %)								
	Fe	C	Si	Mn	Cr	Mo	Ni	Al	V
Duplex	67.99	0.04	0.33	1.80	21.83	3.14	4.45	-	0.11
38HMJ	95.21	0.44	0.24	0.54	1.61	0.26	0.19	1.20	-
30HN2MFA	96.42	0.29	0.26	0.36	0.65	0.24	2.21	-	0.23

Duplex 1.4462 steel is austenitic–ferritic two-phase steel. It is resistant to intergranular and pitting corrosion. It has high tensile strength, higher than austenitic steels. Its tensile strength is about twice the yield strength. The higher hardness of duplex steel compared to austenitic steels is directly related to the greater strength of the two-phase structure. Higher hardness makes this steel exhibit high resistance to abrasion and erosion. The value of Young’s modulus at room temperature is 200 GPa [15].

It is not lacking in drawbacks, the most important of which is the tendency to separate brittle phases at elevated temperatures. This affects the deterioration of corrosion resistance and the reduction of plastic properties [15–17].

38HMJ (1.8509) steel is an alloyed steel intended for nitriding [18]. After the nitriding process, it obtains high hardness and abrasion resistance of the surface layer, without the need for heat treatment. The hardness of the nitrided layer remains unchanged during prolonged heating. This steel is mainly used for the manufacture of cylinders, shafts, piston pins, and other parts of internal combustion engines. It is also used as a barrel material. It has a higher ferrite–austenite phase transition temperature, which is 792.2 °C (onset of apparent specific heat of 38HMJ steel, second heating; Section 3.2) compared to 30HN2MFA steel. High surface hardness is obtained by thermo-mechanical treatment combined with high tempering. The value of Young’s modulus at room temperature is 209 GPa [19].

30HN2MFA steel is an alloy mainly used to make barrels of small-caliber cannons. It is characterized by high impact strength, which is especially important at high rates of increased stress typical of the shot phenomenon. Compared to 38HMJ steel, it has a lower ferrite–austenite phase transition temperature of 728 °C (onset of apparent specific heat of 30HN2MFA, second heating; Section 3.2). The value of Young’s modulus at room temperature is 216 GPa [19]. Compared to duplex and 38HMJ steel, barrels made of 30HN2MFA steel need to be covered with a layer of chromium as corrosion protection.

Thermal diffusivity measurements applying the NETZSCH LFA 467 low-temperature light flash apparatus were made in the temperature range of RT to 500 °C. Inconel 600, with a density of 8.34 g/cm³ at RT, was used as reference material together with the tested barrel steel samples. Measurements were made for the 38HMJ and duplex steel. The technique for measuring thermal diffusivity is as follows: A pulse 25 µs to 1200 µs in duration generated by a xenon lamp, with voltage limited to 600 V, is absorbed by the front surface of a test sample, increasing its temperature. The resulting temperature difference causes heat diffusion toward the back surface of the sample, and as a result its temperature increases. Because the pulse duration is many times shorter than the measurement time, the signal from the IR detector (CdHgTe) corresponding to the excess temperature on the back surface has a characteristic maximum. This point allows us to determine the half-time $t_{0.5}$, which is the basis for determining thermal diffusivity by the Parker method [20]. In our case, the pulse duration was 600 µs and the lamp voltage was 250 V. These parameters were set in Proteus v. 7.1 software according to NETZSCH recommendations. The measurement time duration and signal gain were set at the beginning using trial and error. Argon with a flow of 20 mL/min was used during the experiment. A standard Cape–Lehman model of heat transfer with pulse correction was applied. This model takes into account heat loss by radiation from the surfaces of the test sample. In order to enable calculation of the specific heat and thermal conductivity of test samples, Inconel 600 reference material was applied. The following relationship (Equation (1)) was used to calculate the specific heat capacity [21]:

$$c_p^s(T) = \frac{T_{\infty}^{ref}}{T_{\infty}^s} \cdot \frac{\rho^{ref}(T)}{\rho^s(T)} \cdot \frac{d^{ref}}{d^s} \cdot \frac{Q^s}{Q^{ref}} \cdot \frac{V^s}{V^{ref}} \cdot \frac{d_{Orifice}^{2,s}}{d_{Orifice}^{2,ref}} c_p^{ref}(T), \quad (1)$$

where d is the diameter, V stands for the signal amplitude gain, T_{∞} is the corrected signal of the detector voltage taking into account heat loss and is proportional to the adiabatic temperature increase, ρ is the density, Q is the pulse energy, and c_p is the specific heat capacity under constant pressure. Superscript s means sample and ref is reference material, and subscript Orifice is the diameter of the IR detector measuring area.

Specific heat calculations based on our test results were made for the 38HMJ and duplex steel. For comparative purposes, data for the 30HN2MFA steel were derived from [3], for the 38HMJ steel from [4], and for the duplex steel from [5]. Then, taking into account specific heat $c_p^s(T)$ and thermal diffusivity values of tested samples $a(T)$, thermal conductivity $k^s(T)$ was calculated using Equation (2):

$$k^s(T) = \frac{\rho_0}{[1 + \epsilon(T)]^3} \cdot a(T) \cdot c_p^s(T), \quad (2)$$

where $\epsilon(T)$ is the relative length change of the samples [1,21].

Density is not required for measurement of thermal diffusivity but only in a direct way. So, when measuring thermal diffusivity, the thickness of the sample changes, thus its volume, which, with a constant mass of the sample, leads to a change in its density. If we take Parker's formula to calculate the thermal diffusivity ($a = 0.1388 \cdot L^2/t_{0.5}$), then we see that $a \sim L^2$. Taking into account that $L(T) = L_0 \cdot (1 + \epsilon(T))$, then $a_{correct}(T) = a(T) \cdot [1 + \epsilon(T)]^2$. Measurement of thermal diffusivity using LFA 467 took into account the impact of thermal expansion tests on the results [20]. Measurements of specific heat capacity were conducted using the NETZSCH DSC 404 F1 Pegasus apparatus operated in helium atmosphere with a flow rate of 20 mL/min. This heat flux with disc-type measuring system is based on continuous scanning of the thermal response difference between tested and standard samples while heating uniformly at a fixed rate. To ensure the correctness of measurements, the DSC method requires a stable and repeatable baseline. This can be achieved by at least double evacuation of the measuring chamber and entering 20 min isothermal segment at the beginning of the temperature program. In addition, temperature and sensitivity calibration of the microcalorimeter was performed using five reference materials: indium, bismuth, tin, zinc, and gold. Samples for specific heat tests were cut from as-received material. They were in the shape of disks with a diameter of 6.1 mm and a thickness of 1.6 mm for 38HMJ steel and 30HN2MFA steel, while for duplex steel the thickness was 1.8 mm. Sample weights were 347.30 mg (38HMJ), 335.41 mg (30HN2MFA), and 383.39 mg (duplex). The total mass of the platinum crucible with the lid amounted to 273.81 mg (volume of Pt crucible: 85 μ L). The crucibles were put on the Al_2O_3 pad in the form of a disk with a diameter of 6.6 mm, thickness of 0.5 mm, and weight of 52.24 mg. The weight of the platinum crucible + platinum lid + Al_2O_3 pad set was 326.05 mg. The temperature program of investigation set in Proteus v.6.1 consisted of two heating/cooling cycles in the following order: isothermal at 20 °C (RT) for 5 min; heating up to 1000 °C with a heating rate of 10 K/min; isothermal segment at 1000 °C for 5 min; cooling down to 25 °C with a cooling rate of 10 K/min; isothermal at RT for 15 min. Calculation of apparent specific heat was based on the three-curve method (base line, sapphire line, and sample line).

3. Results

3.1. Thermal Diffusivity Results

In order to compare the results of specific heat values obtained independently using the DSC measurement and LFA calculation (Equation (1)), both results are presented in Section 3.2. The results of calculated thermal conductivity values are shown in Section 3.3. The results we obtained of thermal diffusivity measurements using the LFA 467 and LFA 427 (published in [1]) were compared with available data in literature and are shown in Figure 3.

As can be seen from the results shown in Figure 3, the thermal diffusivity of 38HMJ and 30HM2MFA steel decreases continuously with temperature outside of the ferrite–austenite phase transition region and reaches the minimum value at about 741.0–743.3 °C. The temperature dependence of the thermal diffusivity of both types of steel above 741 °C shows an increasing trend. However, the rise in thermal diffusivity as a function of temperature is small. This effect does not occur in the duplex steel. Thermal diffusivity increases linearly over the entire temperature range. In the temperature range of RT to 74 °C, thermal diffusivity of 30HN2MFA steel drops three times, and of 38HMJ steel twice, reaching the same value of 3.39 mm²/s at 741 °C. For the duplex steel in the entire temperature range, thermal diffusivity increases quasi-linearly from 4 mm²/s to 5.2 mm²/s. The results of thermal diffusivity using the NETZSCH LFA 467 (in the temperature range of RT to 500 °C) are higher than results obtained using the LFA 427 in the same temperature range. The differences are the largest around 500 °C and are about 10% compared to the values obtained from the LFA 427.

Figure 3. Comparison of thermal diffusivity of barrel steels obtained using LFA 467 and LFA 427 (own measurements vs. literature data).

3.2. Specific Heat Results

The results of specific heat investigations of the three barrel steel types obtained only during the heating cycle are presented in Figures 4–6. These figures also show the available data in literature: 38HMJ steel in [19], 30HN2MFA steel in [22], and duplex steel in [15], which coincide with data received in the experiment. DSC studies of the tested barrel steels revealed the existence of ferrite–austenite phase transition only in 30HN2MFA and 38HMJ at 728 °C and 792.2 °C (onset, second heating). This transition was not observed in the duplex steel (Figure 6). For the duplex steel, in the entire temperature range apparent, the specific heat was almost fixed, i.e., 550 J/(kg·K). In the 30HN2MFA steel, a second peak also appears at around 809.7 °C. It should be noted here that while the thermal diffusivity was determined at discrete points of the temperature range of tests, the apparent specific heat was measured continuously using the three-curve technique. The visible peak of 30HN2MFA steel shown at a temperature of about 363.9 °C shown in Figure 5 occurs only during the second heating.

Figure 4. Temperature characteristics of apparent specific heat for 38HMJ steel (own research results vs. literature data).

Figure 5. Results of apparent specific heat for 30HN2MFA steel (own research vs. literature data [22]).

Figure 6. Results of apparent specific heat for duplex steel (own measurements vs. literature data).

For all measured barrel steels, the correlation formula was proposed within the investigated temperature range, RT to 1050 °C. Figure 4 shows the fitting curve (dotted red line) for the specific heat capacity of the 38HMJ steel. The proposed formula has the following form (Equation (3)):

$$c_p(T[K]) = a_0 + a_1T + a_2T^2 + a_3T^{-\frac{1}{3}} \quad [\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}] \quad (3)$$

The values of coefficients a_i are given in Table 2.

Table 2. Coefficients for calculating specific heat capacity of 38HMJ steel based on Equation (3).

Coefficient	Value	Coefficient	Value
$a_0, [\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}]$	5.39×10^{-1}	$a_2, [\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-3}]$	-1.74×10^{-7}
$a_1, [\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-2}]$	3.25×10^{-4}	$a_3, [\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-\frac{4}{3}}]$	-0.31×10^{-9}

In case of 30HN2MFA steel, the correlation function for the specific heat capacity can be expressed as follows (Equation (4)):

$$c_p(T[K]) = a_0 + a_1T + a_2T^2 + a_3T^{-\frac{1}{2}} \quad [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}] \quad (4)$$

The values of coefficients a_i are given in Table 3 and the fitting curve is illustrated in Figure 3 as a dotted line.

Table 3. Coefficients for calculating specific heat capacity of 30HN2MFAJ steel based on Equation (4).

Coefficient	Value	Coefficient	Value
$a_0, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}]$	4.94×10^{-1}	$a_2, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-3}]$	-1.46×10^{-8}
$a_1, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-2}]$	1.92×10^{-4}	$a_3, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-\frac{3}{2}}]$	-0.38×10^{-9}

Finally, the correlation function for the specific heat capacity of the duplex steel is proposed in the form (Equation (5)):

$$c_p(T[K]) = a_0 + a_1T + a_2T^2 + a_3T^3 \quad [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}] \quad (5)$$

The values of coefficients a_i are given in Table 4 and the fitting curve illustrated in Figure 6 as a dotted line.

Table 4. Coefficients for calculating specific heat capacity of duplex steel based on Equation (5).

Coefficient	Value	Coefficient	Value
$a_0, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-1}]$	3.84×10^{-1}	$a_2, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-3}]$	-1.54×10^{-6}
$a_1, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-2}]$	9.31×10^{-4}	$a_3, [\text{J}\cdot\text{g}^{-1}\cdot\text{K}^{-4}]$	9.01×10^{-10}

Approximate characteristics of thermophysical parameters are used in the issues of temperature field simulation in barrels. For specific heat, a sensible heat capacity should be adopted that does not take into account the thermal effects associated with phase transitions. For this reason, correlation formulas might easily adopt Equations (3)–(5).

3.3. Thermal Conductivity Calculation

Figure 7 shows the thermal conductivity of the three barrel steels calculated from the measured results as a product of thermal diffusivity, specific heat, and density. In our opinion, the thermal conductivity of 38HMJ and 30HM2MFA steel in the temperature range of RT to about 300 °C is constant. The values are around $36 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ for the 30HM2MFA steel and $34 \text{ W}/(\text{m}\cdot\text{K})$ for the 38HMJ steel. A slight increase and then a decrease in thermal conductivity of both steels in this range is caused by the low accuracy of the specific heat determination. Similar to thermal diffusivity, the thermal conductivity of 38HMJ and 30HM2MFA steel decreases continuously with temperature outside the ferrite–austenite transition region and reaches the minimum value at about 741 °C. The temperature dependence of thermal diffusivity of both steels above 741 °C shows an increasing trend. For the duplex steel in the entire temperature range, thermal conductivity increases quasi-linearly from $13 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ to $26 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$.

Figure 7. Thermal conductivity of three barrel steels (own calculations (Equation (2)) vs. literature data).

4. Discussion

Figures 8 and 9 summarize the thermal characteristics of thermal diffusivity, physical alpha, and specific heat capacity of the two barrel steels in which the phase transition effect occurs, 30HN2MFA and 38HMJ. For clarity, in Figures 8 and 9, the thermal diffusivity results obtained using LFA 467 were omitted. For the duplex barrel steel, the results of thermal diffusivity were shown in [1] and will not be repeated here. In the framework of the present work only the specific heat results of tested barrel steels were obtained, while the results of thermal diffusivity and physical alpha were quoted from [1]. In the case of the 30N2MFA barrel steel, the measurements of thermal diffusivity, thermal expansion, and specific heat revealed the occurrence of ferrite–austenite transformation at a temperature of about 743–751 $^{\circ}C$. Considering different heating rates, i.e., 2 K/min for dilatometric tests and 10 K/min for DSC tests, peaks appear practically at the same temperature (about 750 $^{\circ}C$). Thermal diffusivity studies also revealed a peak at almost the same temperature, i.e., 743.3 $^{\circ}C$, despite measurements being carried out at discrete temperature points.

Figure 8. Thermal diffusivity, physical alpha, and apparent specific heat of 30HN2MFA barrel steel.

Figure 9. Thermal diffusivity, physical alpha, and apparent specific heat of 38HMJ barrel steel.

For the 38HMJ barrel steel, specific heat tests reveal two peaks, at 758.7 °C and 809 °C. Considering the dilatometric and DSC tests, a peak appears practically at 809 °C. Thermal diffusivity studies revealed a peak only at 741 °C, i.e., close to the first peak in DSC tests.

It should be noted that the first peak of apparent specific heat of the 38HMJ steel at 758.7 °C correlates with the small peak of physical alpha at 756.1 °C. Unfortunately, we are not able to state what kind of transition appeared at that temperature, because it requires XRD studies. It seems likely that this phase transition is related to the Curie point.

5. Conclusions

In this work, particular emphasis was placed on testing the temperature characteristics of the specific heat capacity of three types of barrel steel in the temperature range of RT to 1000 °C. Using Equation (2), the apparent thermal conductivity was calculated. Energy related to phase transition was taken into account only in material density and thermal diffusivity, whereas in specific heat that energy was omitted. In our opinion, the initial part of thermal conductivity temperature characteristics of the 38HMJ and 30HN2MFA steels from RT to about 300 °C seems unrealistic and is probably caused by the low accuracy of the specific heat determination.

The results of thermal diffusivity tests of the two types of barrel steel using LFA 467 enabled the calculation of specific heat based on reference material in the range of RT to about 500 °C, which was compared with DSC measurements and presented in Figures 4–6. In numerical simulations of heat transfer in barrels made of tested materials, we used Equations (3)–(5), shown in dashed lines in Figures 4–6, because phase transition energy should not be included many times. In this work, the uncertainty of measurement results was not estimated, because the manufacturer of LFA 467 and DSC 404 F1 (NETZSCH, a leader among manufacturers of equipment for testing thermophysical properties) guarantees the following measurement accuracy: thermal diffusivity $\pm 3\%$, specific heat $\pm 5\%$, thermal expansion $\pm 0.003\%$ of absolute value [18]. Accuracy in terms of thermal conductivity calculations was evaluated to be not greater than 6%. Complementary to earlier studies on temperature characteristics of thermal diffusivity and linear thermal expansion in the temperature range of RT to 1050 °C, published in conference proceedings [1], were measurements of apparent specific heat carried out in this work. They confirmed that for 38HMJ steel at 792.2 °C and 30HN2MFA steel at 728.0 °C, a ferrite–austenite phase transition occurred, which was responsible for the shrinkage of the material [1]. This paper explains that the reason for cracking of the chromium layer on the inner surface of rifle barrels made of 30HN2MFA steel is shrinkage of the material caused by the ferrite–austenite phase transition.

The results of research on thermophysical parameters of barrel steels presented in this paper fill the gap in available literature on the subject, which is mainly focused on testing the mechanical properties of this type of steel.

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