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RESISTANCE TO WEAR AS A FUNCTION OF THE MICROSTRUCTURE AND SELECTED MECHANICAL PROPERTIES OF MICROALLOYED STEEL WITH BORON

ODPORNOŚĆ NA ZUŻYWANIE W FUNKCJI MIKROSTRUKTURY I WYBRANYCH WŁAŚCIWOŚCI MECHANICZNYCH MIKROSTOPOWYCH STALI Z BOREM

Key words:

steel resistant to abrasive wear, performance characteristics, structural and mechanical properties, XAR steel, TBL Plus steel, B27 steel

Słowa kluczowe:

stale odporne na zużywanie ścieranie, charakterystyki użytkowe, własności strukturalne i mechaniczne, stal XAR, stal TBL Plus, stal B27

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Abstract

The paper presents the structure and the results of abrasive wear resistance tests of XAR®600, TBL PLUS, and B27 steel. As a result of the tests conducted by means of light and scanning microscopy, it has been proven that these types of steel are characterised by subtle differences in their structures, affecting their strength and performance properties. In the delivered condition, all types of steel are characterised by a fine-grained structure with post-martensitic orientation with insets of carbide phases. The structural type of the discussed steel types disclosed in the course of the research, as well as the results of the conducted spectral analyses of the chemical composition, indicate that their properties are shaped in the course of specialist procedures of thermomechanical rolling. According to the above-mentioned test results, it can be concluded that the analysed steel types were designed in compliance with the canons of materials engineering in relation to low-alloy steel resistant to abrasive wear. Due to this, the obtained results of the structural tests of XAR®600, TBL PLUS, and B27 steel were subjected to verification in the course of abrasive wear resistance tests by means of the "spinning bowl" method. The tests, conducted in real soil masses – loamy sand, light clay, and normal clay, compared with the results of hardness measurements, indicated a strict dependence of abrasive wear resistance ratios as a function of structure and the heat treatment condition of the tested types of steel. All the obtained test results were referred to 38GSA steel in a normalised condition.

INTRODUCTION

Due to its high functional value, in most cases, steel still remains a basic construction material, and it is used in the working elements of tools and the selected components of machines. This is caused, on the one hand, by the advantageous relation of its production costs, and, on the other hand, by its universality of use, susceptibility to machining, satisfactory weldability, and constantly increasing mechanical properties. Due to the above, microalloyed steel with boron is becoming increasingly significant, especially in the areas of intense abrasive wear. These types of steel produced today are characterised by a micro-addition of boron amounting to 0.002–0.005 wt%. In this range of concentrations, boron dissolves in austenite, resulting in a homogeneous structure of bainite or martensite with highly dispersed grains that may be obtained over the whole cross-section of an element as early as during ordinary volumetric hardening. The martensitic structures obtained in low and medium carbon steel do not require the necessity to perform tempering processes after hardening, while resulting in very high ratios of static resistance and plastic limit (1800–2000 MPa), retaining advantageous plastic properties. This is why the examination of the selected properties of steel should primarily be based on their structure, which is the result, apart from the chemical composition, of the used heat treatment, as well as the heat and forming processes. Steel types with boron additives, described by their producers as resistant to abrasion, are delivered in various conditions of heat treatment and are characterised by a very diverse morphology of microstructure. Generally speaking, microalloyed steel with boron after proper heat treatment (heat and forming processes) is characterised by high strength ratios, retaining satisfactory ductility, high flexibility, and resistance to buckling, as well as a high capability of absorbing loads of a dynamic nature. Simultaneous fulfilment of all of the above-mentioned requirements, combined with the previously declared resistance to the impact of abrasive environments, creates very wide possible areas of application for these materials, unavailable for the most frequently used construction materials **[L. 1–6]**.

When referring to the available literature data, it is concluded that the chemical composition, microstructure, hardness, and the remaining mechanical properties of steel considerably affect the resistance to wear in abrasive soil mass. Due to the above, the purpose of the present paper is to evaluate the wear intensity processes of the selected types of microalloyed steel with boron in natural soil mass as a function of microstructure, the heat treatment condition, and selected mechanical properties.

THE MATERIAL AND METHODOLOGY OF THE TESTS

Three types of steel described as resistant to abrasive wear were chosen to test the resistance to abrasive wear by means of the "spinning bowl" method: XAR®600, TBL PLUS, and B27. 38GSA type microalloyed steel in a normalised condition was used as REFERENCES material, developed as special use steel, and most frequently used in Poland for ploughshares in the agricultural sector. The REFERENCES of the test results to 38GSA steel is motivated by the fact that it constituted the main point of REFERENCES in numerous abrasive wear tests in abrasive soil mass **[L. 7–16]**. 38GSA steel samples were obtained from the working elements of farming machines, and they were made by means of the hot rolling technology of a flat rod and normalising annealing, in order to fragment the microstructure. Due to the very numerous applications of this material in the described delivered condition (without additional heat treatment by hardening) **[L. 17]**, for the needs of the present paper, the decision was made to use this steel only in its normalised condition. For the same reason, in relation to this steel, the presentation of structural images was omitted, being limited only to its verbal description.

XAR®600 steel samples were collected from 10 mm-thick sheet metal delivered directly by the producer of this steel. XAR®600 steel is described by the producer as fine-grained special construction steel resistant to abrasive wear **[L. 18]** in which nitrogen is bound in the form of nitrides by an aluminium additive and (if present) a niobium or titanium additive. It is delivered in the form of sheet metal 4–50 mm in thickness in many heat treatment options, including annealing (hardness ≤ 300 HBW), as well as hardening in water (hardness > 550 HBW). It is also possible to order XAR®600 steel in a condition hardened and tempered at temperatures below A_{C1}. The producer makes the heat treatment method for this steel dependent on the chemical composition and the thickness of the sheet metal. Moreover, in order to retain its mechanical properties, it is not recommended to overheat sheet metal made of this steel above 250°C.

The samples of TBL PLUS steel were cut from 10 mm-thick sheet metal, also delivered directly by the producer of this steel. The producer of TBL PLUS steel offers it in their commercial range as fine-grained construction steel **[L. 18]**. Similar to XAR®600 steel, nitrogen is bound in it in the form of nitrides. It is delivered as sheet metal with a maximum thickness up to 12 mm in a normalised annealed condition, or after normalising rolling. According to the producer's information on TBL PLUS steel, it is possible to perform its heat treatment processes via hardening directly by the user. However, the corresponding data involving the recommended parameters of this process are not defined.

The samples of B27 were acquired from 10 mm-thick sheet metal delivered by the distributor of this steel in a hardened condition. According to the producer's information **[L. 19]**, B27 steel is delivered hot rolled (hardness 170 HB), and it is meant for hardening in water. B27 steel is available in a wide range of semi-finished products. It is most frequently used as thin and thick sheet metal with respective thicknesses of 2.5–13 mm and 5–80 mm. Additionally, B27 steel may be subjected to welding processes, provided that preliminary heating is used. In order to retain good hardness in a hardened condition, it is not recommended to overheat sheet metal made of this steel above 200°C.

All the tested steel samples were collected as cuboids with dimensions of 30 × 25 × 10 mm, using methods that ensured the stability of their structure. A cutting method using a high-energy jet of water with abrasive grains was used to cut the samples. The surface finishing of the samples to the required surface roughness was performed using a flat material grinding machine, and by subjecting them to a polishing process in order to obtain roughness amounting to Ra 0.20–0.26 μm.

The analyses of the chemical composition were performed by means of the spectral method using a GDS500A emission analyser with glow discharge from the Leco company, using the following parameters: U = 1250 V, I = 45 mA, and argon. The obtained results constituted an arithmetic mean of five measurements.

The hardness of the tested samples was measured by means of the Brinell method in accordance with the quality standard PN-EN ISO 6506-1:2008P. A ZWICK ZHU 187.5 hardness tester with a 2.5 mm sintered carbide ball was used, with a load of 1875 kgf applied for a duration of 15 s. The measurements were conducted for samples previously subjected to an assessment of their microstructure in their core areas.

A Nikon Eclipse MA200 light microscope was used in examinations by means of the light microscopy method (LM). The observations were conducted with magnifications ranging between 100 and 1000 times. Microstructural images were recorded by means of a Nikon DS-Fi2 digital camera using NIS Elements software. The observations of the microstructure at greater magnifications, as well as the microanalyses of the chemical composition and the morphology and type of phases, were conducted using a JEOL JSM-5800LV scanning electron microscope (SEM) coupled with an Oxford LINK ISIS-300 X-ray microanalyser. Accelerating voltages of 20 and 25 kV were used during the tests. The observations of the microstructure were conducted in a material contrast using SE and BSE detectors. Prior to microscopic observations, the samples were sprayed with amorphous carbon.

The tests of the resistance to the abrasive wear of the analysed types of steel were conducted by means of the “spinning bowl” method using an MZWM–1 device. Figure 1 presents the general layout of the construction and the principle of operation of the used device. During the tests, each sample travelled a complete friction distance of 20000 m, with a velocity of approximately 1.7 m/s, and with a unit pressure of 67 kPa. The mass of a sample was measured every 2000 m on a laboratory weighing scale with an accuracy of 0.0001 g. The pH of the abrasive masses ranged between 6.3 and 6.9. The following types of soil were selected for the laboratory tests: normal clay, light clay, and loamy sand. Soil moisture ranged between 10% for loamy sand and 15% for normal clay, which corresponds to moist soil. Grain size tests were conducted by means of the laser diffraction method using a Mastersizer 2000 laser particle size analyser in accordance with the quality standard ISO 13320. The characteristics of the abrasive soil mass selected for the tests are presented in **Table 1**.

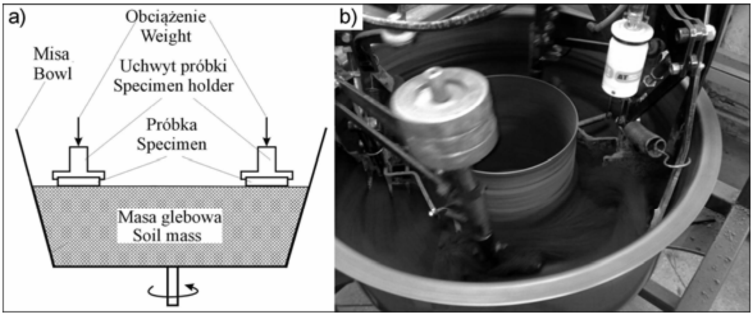

Fig. 1. A "spinning bowl" type laboratory wear test stand: a) a general layout of the device presenting the main operating elements; b) a fragment of the device during its operation

Rys. 1. Laboratoryjne stanowisko zużyciowe typu „wirująca misa": a) ogólny schemat urządzenia z oznaczeniem głównych elementów wykonawczych; b) fragment urządzenia w czasie jego pracy

Table 1. Characteristics of the abrasive soil mass

Tabela 1. Charakterystyka glebowej masy ściernej

Grain size groups	Grain diameter [mm]	Grain size content [%]		
SAND	2.0 - 0.05	33.62	52.66	77.48
SILT	0.05 - 0.002	49.92	40.32	20.83
CLAY	< 0.002	16.56	7.02	1.69
Designation acc. to PTG 2008		**Normal till**	**Light till**	**Loamy sand**

TEST RESULTS

Based on the conducted analyses of the chemical composition **(Table 2)**, it can be concluded that the carbon contents of the analysed materials generally range between 0.28 and 0.38%. The hardenability of the tested steel types was obtained by introducing alloying additives such as manganese (all steel types), chromium (XAR®600), nickel (XAR®600), molybdenum (XAR®600), and especially boron (XAR®600, TBL PLUS, B27). This last element's percentage exceeding the alloy value (0.0015–0.0025%) in the chemical compositions is a common feature of these steel types. Nickel, whose content in the tested steel ranges between 0.05 and 1.21%, is added in order to lower the temperature of austenitisation and lower the temperature of the material's transition into a brittle state. Heavily carbide-generating elements, Cr, Mo, and Ti, delay diffusional transformations, which results in the increased hardenability of steel. In order to additionally strengthen this effect, chromium and molybdenum are often used jointly. The presence of molybdenum in steel is all the more important, because chromium (as well as nickel and manganese) in its presence increases the susceptibility to steel tempering brittleness. It needs to be emphasised that the above statement should be particularly referred to XAR$^{®}$600 steel, whose chemical composition exhibits considerably elevated Mn, Cr, Ni, and Mo contents compared to the remaining types of steel. Due to this, the higher Mo content of this steel justifies the possibility to conduct tempering processes, which is additionally pointed out by its producer. Moreover, the additions of aluminium and titanium in the tested steel (not listed in the chemical compositions provided by the producers) bind the nitrogen and prevent the expansion of austenite grains during heat treatment processes. Additionally, a characteristic feature of the analysed steel is the lowered amount of harmful additives: sulphur (0.001–0.010%) and phosphor (0.009–0.014%).

Table 2. The chemical compositions and selected mechanical properties of the tested types of steel based on the authors' own research and the producer's data [L. 17, 19]

Tabela 2. Składy chemiczne i wybrane właściwości mechaniczne badanych stali na podstawie badań własnych oraz danych producenta **[L. 17, 19]**

Element [wt%]	**38GSA**		**XAR$^{®}$600**		**TBL PLUS**		**B27**	
	BW – based on the authors' own research; DP – producer's data							
	BW^1	DP^2	BW^3	DP^3	BW^4	DP^1	BW^4	DP^4
C	0.38	0.34–0.42	0.37	≤ 0.40	0.34	0.31–0.38	0.28	≤ 0.32
Mn	0.97	0.70–1.10	0.85	≤ 1.50	1.25	1.20–1.50	1.26	≤ 1.50
Si	0.90	0.80–1.10	0.19	≤ 0.80	0.21	≤ 0.40	0.23	≤ 0.40
P	0.011	≤ 0.035	0.014	≤ 0.025	0.012	≤ 0.040	0.009	≤ 0.020
S	0.007	≤ 0.040	0.001	≤ 0.010	0.010	≤ 0.030	0.006	≤ 0.015
Cr	0.05	≤ 0.30	0.83	≤ 1.50	0.25	≤ 0.50	0.32	≤ 0.60
Ni	0.08	≤ 0.30	1.21	≤ 1.50	0.08	-	0.05	-
Mo	0.02	-	0.15	≤ 0.50	0.03	-	0.001	-
Cu	0.25	≤ 0.30	0.03	-	0.08	-	0.04	-
Al	0.02	0.02–0.06*	0.10	-	0.04	-	0.03	-
Ti	0.002	0.03–0.06*	0.003	-	0.04	-	0.03	-
Co	0.01	-	0.005	-	0.001	-	0.01	-
B	-	-	0.0021	≤ 0.005	0.0025	0.0008–0.0040	0.0015	0.0008–0.0050
HBW	272 ±7	440	555 ±6	> 550	520 ±5	≤ 560^4	503 ±4	470
R_e [MPa]	-	1200	-	1700	-	420	-	1200
R_m [MPa]	-	1500	-	2000	-	620	-	1600
A_5 [%]	-	8	-	8	-	18	-	6
KCV_{-20} [J/cm^2]	-	30**	-	20	-	-	-	-

^{1} in a normalised condition; ^{2} condition after hardening (870–900°C/water) and tempering (200–250°C in air or oil); ^{3} in the delivered condition; ^{4} in a hardened condition; *if combined, then Al+Ti ≥ 0.03 wt%; **KCU_{+20}

As a result of the conducted structural tests, it can be concluded that 38GSA steel is characterised by a fine-grained structure of non-equilibrium grains of ferrite with areas of quasi-eutectoid. Pearlite in 38GSA steel exhibited a fine platy structure, locally irregular. Pearlite colonies with a finely dispersed structure could be locally observed.

The microstructure of XAR$^{®}$600 steel in the delivered condition **(Figs. 2a––4a)** consisted primarily of hardening martensite with a finely slatted structure with uniformly distributed areas of tempering martensite. Moreover, it was characterised by very strong structural banding features. Very scarce insets of carbide phases were observed inside the slats of martensite.

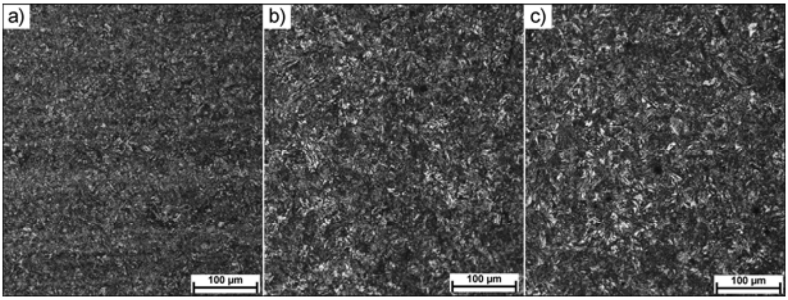

Fig. 2. The microstructures of the tested types of steel in the delivered condition: a) XAR$^{®}$600 steel; b) TBL PLUS steel; c) B27 steel. Pickling in 2% HNO$_3$; LM; Magnification ~200×

Rys. 2. Mikrostruktury badanych stali w stanie dostarczenia: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Traw. 2%HNO3; LM; Pow. ~200×

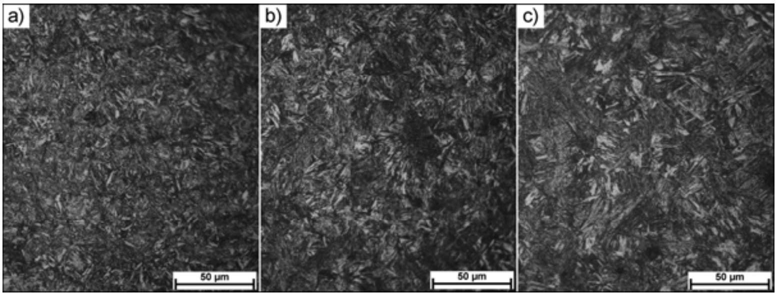

Fig. 3. The microstructures of the tested types of steel in the delivered condition: a) XAR$^{®}$600 steel; b) TBL PLUS steel; c) B27 steel. Pickling in 2% HNO$_3$; LM; Magnification ~500×

Rys. 3. Mikrostruktury badanych stali w stanie dostarczenia: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Traw. 2%HNO3; LM; Pow. ~500×

In the delivered condition, B27 steel has a structure characteristic for the hardened and lowly tempered condition **(Figs. 2c–4c)**. It exhibits a structure with post-martensitic orientation with insets of fine carbides inside martensite with a slatted morphology. According to paper **[L. 20]**, it can be indicated that the following coherent carbides are the phases that are most frequently present in the matrix of B27 steel in an analogical heat treatment condition: MoC, Cr_7C_3, $Cr_{23}C_6$, Cr_3C_2, and borides $M_{23}B_6$.

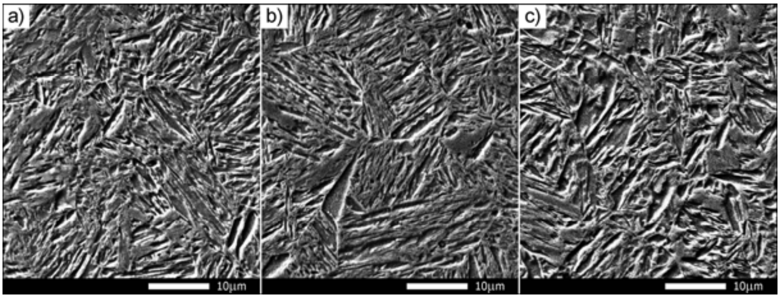

Fig. 4. Magnified images of the microstructures of the tested steel shown in Fig. 2: a) XAR®600 steel; b) TBL PLUS steel; c) B27 steel. Pickling in 2% HNO_3; SEM; Magnification ~2000×

Rys. 4. Powiększone obrazy mikrostruktur badanych stali pokazanych na **rys. 4**: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Traw. 2%HNO3; SEM; Pow. ~2000×

TBL PLUS steel in the delivered condition is characterised by a structure typical for the hardened condition **(Figs. 2b–4b)**; it exhibits a structure with post-martensitic orientation, with a very small number of carbide phase insets inside the slats of martensite. Due to the chemical composition of this steel being very similar to the composition of B27 steel, it can be assumed that the identified carbide phases are of the following types: MC, M_7C_3, and $M_{23}C_6$.

Figs. 5–10 and **Table 3** present the results of the abrasive wear tests conducted for the examined types of steel by means of the "spinning bowl" method. Regardless of the type of steel, the highest values of wear were

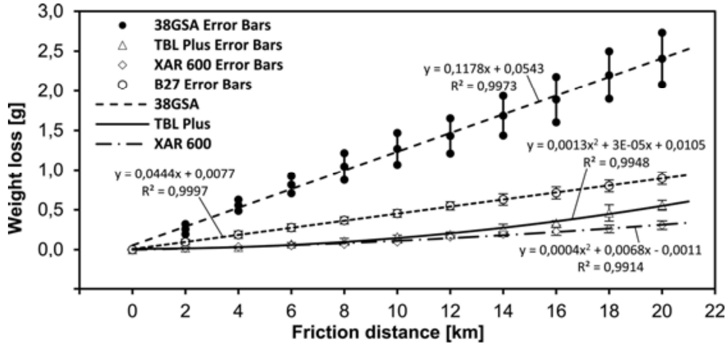

Fig. 5. The loss in the mass of the tested types of steel as a function of the friction distance. Tests conducted in a light soil mass

Rys. 5. Ubytek masy badanych stali w funkcji drogi tarcia. Próby zrealizowane w masie glebowej lekkiej recorded during tests in heavy soil mass. This soil was characterised by a high share of clay and silt grains (66.46%), with a relatively high share of sand grains (33.62%). In a moist condition, the impact of the clay and silt grains involved the reduction of the extent of the looseness of sand grains (approximately 1200 HV_{10}).

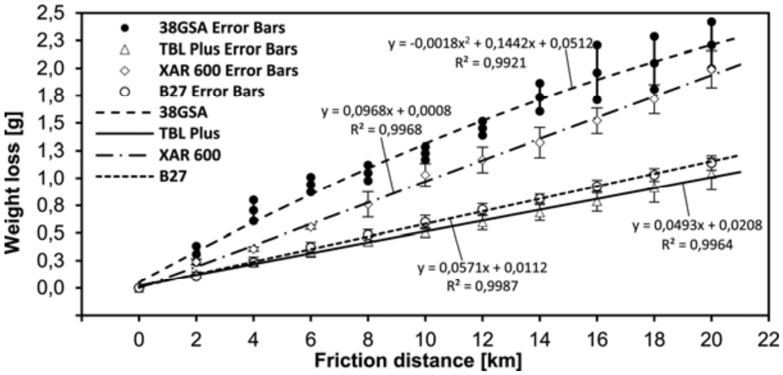

Fig. 6. The loss in the mass of the tested types of steel as a function of the friction distance. Tests conducted in a medium soil mass

Rys. 6. Ubytek masy badanych stali w funkcji drogi tarcia. Próby zrealizowane w masie glebowej średniej

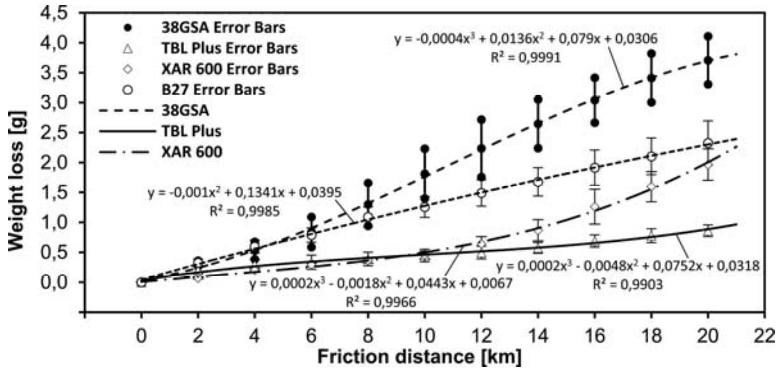

Fig. 7. The loss in the mass of the tested types of steel as a function of the friction distance. Tests conducted in a heavy soil mass

Rys. 7. Ubytek masy badanych stali w funkcji drogi tarcia. Próby zrealizowane w masie glebowej ciężkiej

Table 3. The mass wear of the tested samples over a friction distance of 20000 m in various kinds of abrasive soil masses

Tabela 3. Zestawienie zużycia masowego badanych próbek na drodze tarcia 20000 m w różnych rodzajach glebowych mas ściernych

Soil mass type	**38GSA**		**XAR®600**		**TBL PLUS**		**B27**	
	Loss in mass: AVG – average value [g]; UN – unit value [g/km/cm^2]							
	AVG	UN	AVG	UN	AVG	UN	AVG	UN
LIGHT	2.4049 ±0.3260	0.0160	0.3065 ±0.0536	0.002	0.5572 ±0.616	0.004	0.8957 ±0.0761	0.006
MEDIUM	2.2084 ±0.2112	0.0147	1.9900 ±0.1678	0.013	1.0392 ±0.1447	0.007	1.1395 ±0.0662	0.008
HEAVY	3.7087 ±0.4008	0.0247	1.9653 ±0.2626	0.013	0.8604 ±0.0976	0.006	2.3278 ±0.3668	0.016

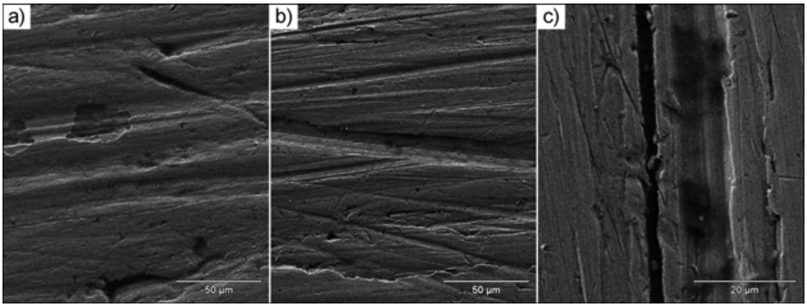

Fig. 8. Surface images of the examined steel samples after abrasive wear resistance tests in light soil mass: a) XAR®600 steel; b) TBL PLUS steel; c) B27 steel. No pickling; SEM

Rys. 8. Obrazy powierzchni próbek badanych stali po testach odporności na zużywanie ścierne w masie glebowej lekkiej: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Stan nietrawiony; SEM

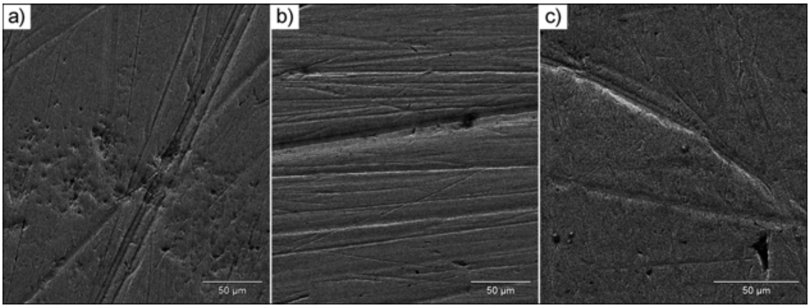

Fig. 9. Surface images of the examined steel samples after abrasive wear resistance tests in medium soil mass: a) XAR®600 steel; b) TBL PLUS steel; c) B27 steel. No pickling; SEM

Rys. 9. Obrazy powierzchni próbek badanych stali po testach odporności na zużywanie ścierne w masie glebowej średniej: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Stan nietrawiony; SEM

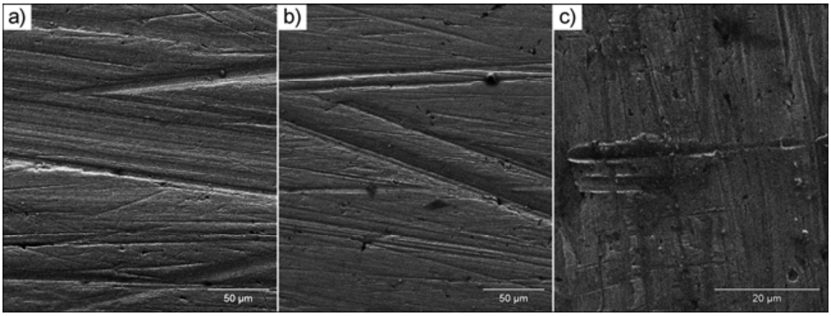

Fig. 10. Surface images of the examined steel samples after abrasive wear resistance tests in heavy soil mass: a) XAR®600 steel; b) TBL PLUS steel; c) B27 steel. No pickling; SEM

Rys. 10. Obrazy powierzchni próbek badanych stali po testach odporności na zużywanie ścierne w masie glebowej ciężkiej: a) stal XAR®600; b) stal TBL PLUS; c) stal B27. Stan nietrawiony; SEM

In the case of heavy soil, the wear process was characterised by the furrowing and micro-cutting of the surface layer **(Fig. 10)**. This was particularly apparent for B27 steel **(Fig. 10c)** for which the recorded values of wear were the highest of all the tested types of steel **(Tab. 3)**. As the clay grain content of the soil mass decreased, the intensity of wear dropped, except for XAR®600 steel. The highest drop in wear (double) was recorded for B27 steel. Microscopic images of the surface of samples after the tests reflect the resulting values of wear. **Fig. 10c** clearly shows a change in the manner of wear in relation to wear in heavy soil mass. A decrease in the share of typically mechanical wear (furrowing, micro-cutting) in favour of scratching and fatigue wear is visible. This does not apply to XAR®600 steel for which both the surface image and the value of wear did not change in relation to heavy soil. The lowest values of wear in light soil mass were recorded for XAR®600 steel, and they were the lowest among all the tested types of steel and soil masses. The image of the worn surface changed dramatically **(Fig. 8a)** in relation to the surface obtained during wear in the remaining soils. The processes of mostly fatigue wear are predominant here. The same relations can also be observed for the remaining types of steel **(Fig. 8)**. 38GSA steel was characterised by the highest values of wear among all soil types. Therefore, the use of this steel in a normalised condition in a tribological pair with soil mass is not reasonable.

SUMMARY

Based on the obtained results, it can be concluded that the right type of steel for working elements should be chosen with respect to the properties of the processed soil mass. TBL PLUS steel proved to be the least vulnerable to the change in the grain sizes of the soil mass and, therefore, to the manner of wear.

It is characterised by a structure with post-martensitic orientation with a very small number of carbide phase insets inside the slats of martensite. B27 steel, on the other hand, was also characterised by a structure with post-martensitic orientation with insets of fine carbides inside martensite, being susceptible to their chipping in soils with the intense impact of fixed sand grains. Moreover, when processing soils characterised by considerable looseness of soil grains, the lowest intensity of wear was observed for XAR®600 steel. It is characterised by a structure of hardening martensite, finely slatted and with uniformly distributed areas of tempering martensite.

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Streszczenie

W pracy przedstawiono budowę strukturalną oraz wyniki badań odporności na zużywanie ścierne stali XAR®600, TBL PLUS oraz B27. W wyniku przeprowadzonych badań metodami mikroskopii świetlnej i skaningowej wykazano, że stale te cechują się subtelną różnicą w budowie strukturalnej rzutującą na ich własności wytrzymałościowe i użytkowe. W stanie dostarczenia wszystkie stale charakteryzują się drobnoziarnistą strukturą o orientacji pomartenzytycznej z wydzieleniami faz węglikowych. Ujawniony w toku badań rodzaj budowy strukturalnej rozpatrywanych gatunków stali, a także wyniki przeprowadzonych analiz spektralnych składu chemicznego wskazują, iż ich właściwości kształtowane są w toku specjalistycznych zabiegów termomechanicznego walcowania. Zgodnie z powyższymi wynikami badań można stwierdzić, że analizowane stale zostały zaprojektowane zgodnie z kanonami inżynierii materiałowej w odniesieniu do niskostopowych stali odpornych na zużywanie ścierne. W związku z tym uzyskane wyniki badań strukturalnych stali XAR®600, TBL PLUS oraz B27 zostały poddane weryfikacji w toku prób odporności na zużywanie ścierne metodą „wirującej misy". Zrealizowane badania w rzeczywistych masach glebowych – piasek gliniasty, glina lekka oraz glina zwykła, w zestawieniu z wynikami pomiarów twardości, wykazały ścisłą zależność wskaźników odporności na zużywanie ścierne w funkcji struktury oraz stanu obróbki cieplnej badanych stali. Wszystkie uzyskane wyniki badań odniesiono do stali 38GSA w stanie normalizowanym.