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(54) Title: MULTI-PHASE STEEL ESPECIALLY FOR PRODUCTION OF STANDARD-GAUGE RAILS

(57) Abstract: Object of the invention is multi-phase steel, used for production of standard-gauge rails, characterized by the fact that the content of basic elements in the steel is no less than: C - 0.15% wt, Si - 0.60% wt, Mn - 1.20% wt, Cr - 1.20 % wt, Ni - 0.20% wt, Mo - 0.10% wt, and additionally contains: Ti - 0.01 - 0.25% wt, satisfying the relationship (% wt Mo)/(%mas. Ti) > 1; Al - 0.01-0.80 % wt; B - 0.001-0.003% wt., H₂ ≤ 2 ppm, N ≤ 80 ppm, volume of individual constituents is in relation to the total weigh of multiphase steel.



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Multi-phase steel especially for production of standard-gauge rails

This invention relates to the multi-phase steel of which bainite is the most important structural component. Multi-phase steel according to the invention is preferably used for production of standard-gauge rails of enhanced durability in service, specifically of enhanced resistance to contact - fatigue defects initiation and growth.

Method of obtaining multi-phase steel and its composition is disclosed in Japanese patent application JP2009221909(A), which has the following range of elements in composition: 0.01 - 0.3 C wt.%, 0.01 - 0.5 Si wt.%, 0.01 - 3.0 Mn wt.%, 0.001 - 0.01 B wt.%, 0.001 - 0.01 wt.% N, 0.01 - 0.5 wt.% and 0.01 - 0.10 Ti wt.%. The steel also contains: P, S, O; in amounts not exceeding 0.03 wt.%, 0.01wt.% and 0.01wt.%, respectively. The rest of the composition is represented by unavoidable impurities and Fe. Steel of such composition is used to manufacture standard-gauge rails in connection with using liquid phase diffusion bonding.

Composition of multi-phase steel is disclosed also in the Japanese patent application JPH02133544(A) aimed at manufacturing of high strength steel rails, characterised also by good ductility, resistance to wear, good weldability, resistance to cracking and high hardenability, obtained by using alloy additives and Ti in order to bind N to prevent against the BN formation in the steel. Steel according to invention contains: 0.50 - 0.85 wt.%C, 0.10 - 1.00 wt.% Si, 0.50 - 1.50 wt.% Mn, < 0.035 wt.%P, <0.035wt.% S, 0.05wt.% Al and 0.0005 - 0.005wt.% B, with addition of at least one constituent enhancing hardenability: 0.05 - 1.50wt.%Cr, 0.02 - 0.20wt.% Mo, 0.01 - 0.10wt.% V, 0.10 - 1.00 wt.% Ni and 0.005 - 0.50 wt.% Nb, 0.003 - 0.1wt.% Ti, independently or in combination.

Due to the increasing load on the tracks and high traffic speeds, it is necessary to replace rails more frequently as a result of intense wear and initiation of contact -fatigue defects. To improve railway transport efficiency through limitation of the frequency of rails' replacement, it is necessary to improve their resistance to these processes.

According to the state of art, increase of rails resistance to wear or contact - fatigue defects initiation can be achieved by application of bainitic steels and steels of hyper-

eutectoid composition for their production. Heat treatment of rails made of carbon and manganese pearlitic steels, leading to the reduction of cementite inter-lamellar distance, or modified chemical composition of such steels, which also leads to the reduction of cementite inter-lamellar-distance, were applied so far.

Each of the cited methods can be characterized by advantages and drawbacks. Rails of pearlitic and hyper-eutectoid steels show high resistance against wear, however, they are less resistant to the initiation and development of contact - fatigue defects. In turn, rails of bainitic steels are characterized by superior resistance against the initiation and growth of contact - fatigue defects, however their resistance to wear is lower compared to rails of pearlitic structure subject to thermal treatment.

Patent subject matter is to design the multi-phase steel structure, especially for rails production, by proper design of steel chemical composition, wherein such steel after cooling down the rail in still air directly after rolling process, would exhibit high resistance to contact and fatigue defects and resistance to wear, corrugation and plastic creeping within rail head area.

Object of the invention is multi-phase steel, preferably used for production of standard-gauge rails, characterized by the fact that the content of basic elements in the steel is no less than:

C: 0.15 wt.%;

Si: 0.60 wt.%;

Mn: 1.20 wt.%;

Cr: 1.20 wt.%;

Ni: 0.20 wt.%;

Mo: 0.10 wt.%;

and, additionally, multi-phase steel contains:

Ti in the range 0.01 - 0.25 wt.%, preferably satisfying the following relationship:

$(\text{wt. \% Mo})/(\text{wt. \% Ti}) > 1;$

Al: 0.01 - 0.80 wt.%;

B: 0.001 - 0.003 wt.%;

H₂ ≤ 2 ppm;

N ≤ 80 ppm;

and at the same time, contents of alloy additives and carbon satisfy the following

relationship:

$$0.15 \leq C \leq 0.77 * CE; \quad (1)$$

where CE is a carbon concentration in an eutectoid point, calculated using the following equation:

$$CE = 0.768 - 0.0522(\text{wt.}\% \text{ Mn}) - 0.037 (\text{wt.}\% \text{ Cr}) - 0.113(\text{wt.}\% \text{ Si}) - 0.012 (\text{wt.}\% \text{ Mo}) - 0.068 (\text{wt.}\% \text{ Ni}) - 0.006 (\text{wt.}\% \text{ Cu}); \quad (2)$$

and content of Al, Si, Ti, C and N is within the following limits:

$$[(\text{Al}) + (\text{Si})]/C \geq 2.5 \quad (3)$$

and

$$\frac{(\%Ti)}{\left[(\%C) + \frac{12}{14}(\%N) \right]} \geq 0.03 \quad (4)$$

the amount of individual constituents is in relation to the total weigh of multi-phase steel. Preferably, temperature of the bainitic transformation initiation (temperature B_s) of multi-phase steel according to the invention is no higher than 460°C, and temperature of martensitic transformation M_s is no less than 300°C.

In a preferred embodiment, content of bainitic ferrite is above 70 vol. % of steel, allotrimorphic ferrite below 10 vol.% of steel, self-tempered martensite below 10 vol.% of steel, retained austenite linked to bainitic ferrite of carbon content min. 1.25 wt.% - above 10 vol.% of steel, and the bainitic ferrite is hardened with carbon nano-particles TiC.

The relationships (1) – (4) defining relationships between individual constituents content are used to determine the specific chemical composition of the multi-phase steel according to the invention and were developed based on experimental studies performed on a group of 30 heats.

The result of assumptions made using condition (1), equation (2), condition (3) and (4) is a unique technical solution representing an embodiment of the invention.

Based on experiments, it was determined that fulfilment of a criterion resulting from condition (1) leads to obtaining granular bainite structure (lower limit) or degenerated upper bainite (upper limit) with retained austenite present between bainitic ferrite laths of carbon content above 1.25 wt.% which accounts for work hardening of rail running surface during contact with a wheel. This phenomenon slows down the process of

contact - fatigue defects initiation.

Fulfilment of the condition resulting from formula 3 prevents against cementite particles precipitation in steels resulting in the formation so called carbide-free bainite. Moreover, addition of aluminium limits segregation of alloy additives in steel during the solidification process and especially favourably affects the mechanical stability of retained austenite during contact between wheel and rail.

In turn, the condition resulting from condition (4) for the lower limit allows for protecting boron against formation of boron nitride (BN) and at value above 0.03 wt.% leads to obtaining fine-grained austenite during the process of rails rolling and provides the capacity for bainitic ferrite strengthening with TiC nano-particles.

It was determined experimentally that lowering the size of austenite grains increases the resistance to wear of multi-phase steel. Maintaining the proportion between molybdenum and titanium content allows for controlling TiC particles growth during the technological processes of continuous casting and rolling.

Nickel is used to stabilize retained austenite and to increase the resistance to cracks propagation.

The final content of alloy additives in steel according to invention is determined in order to get specified value of bainite start transformation temperature (B_s) and martensite transformation start temperature (M_s). In the process of designing the final chemical composition of steel according to invention, additional condition is applied, namely, that the B_s temperature preferably should be less than 460°C, and temperature M_s should be higher than 300°C.

Temperature B_s and M_s is calculated using the following formulae developed by K.W. Andrews (*K.W. Andrews: J. Iron and Steel Inst., 1965, 203, 721-729*).

$$B_s(^{\circ}\text{C}) = 844 - 597(\%C) - 63(\%Mn) - 16(\%Ni) - 78(\%Cr) \quad (5)$$

$$M_s(^{\circ}\text{C}) = 512 - 453(\%C) - 16.9 (\%Ni) - 15(\%Cr) - 9.5(\%Cr) - 9.5(\%Mo) + 217C^2 - 71.5(\%Mn)*(\%C) - 67.7(\%Cr)*(\%C) \quad (6)$$

Designing chemical composition of steel using equation (5) allows for obtaining the assumed level of hardness, as lowering B_s leads to an increase of hardness. In turn, increasing the distance between B_s and M_s limits martensite formation in the steel structure; especially in the form of blocks of dimensions above 5 μm .

Standard-gauge-rails of multi-phase steel according to invention are characterized by increased resistance to contact - fatigue defects initiation in relation to pearlitic steels

and comparable resistance to wear, corrugation and plastic creeping in rail's head. Such combination of service properties is achieved by obtaining fine-grained austenitic structure during hot rolling process and proper phase composition of rail structure after cooling down in still air, especially by the presence of retained austenite resistant to thermal and mechanical loads. Fine-grained structure of austenite is provided by the presence of fine particles of titanium nitride TiN (of dimensions less than 20 nm) in steel and dynamic precipitation of titanium carbide TiC particles during rolling.

Control of titanium nitride TiN particles size is realised by application of cooling conditions in a secondary cooling zone during the process of continuous casting, providing achievement of cooling rate in the ingot corner within 12-15°C/s and within the near-surface layer on the sides within 8-10°C/s.

Key phase constituent of steel according the invention is retained austenite of proper mechanical and thermal stability, containing carbon in solid solution in the amount not less than 1.25 wt.% which during contact of rail head subsurface layer with wheel is subject to gradual transformation into martensite (TRIP effect).

Structure of multi-phase steel for production of standard-gauge rails according to the invention allows for obtaining better durability of compared to rails of pearlitic steel, cooled in still air after rolling process.

Designing chemical composition of multi-phase steel according to invention allows for obtaining retained austenite within the rail structure of the following parameters:

- carbon content min. 1.25%;
- volume fraction - min. 10%;
- uniformly distributed within the structure in the form of small regions (of dimensions below 5 μm) or layers between bainitic ferrite laths having thickness below 1 μm .

Retained austenite in the rail head running surface according to invention is subject initially to gradual fragmentation and transformation (TRIP effect) into martensite during contact with wheel, and then martensite is transformed into ferrite containing fine cementite particles. Prolonged - gradual transformation of austenite into martensite causes work hardening of the subsurface region during rail service, which slows down the wear processes and initiation of the contact-fatigue defects.

Examples of multi-phase steel and mechanical properties of rails

Example 1

Chemical composition of multi-phase steel according to the invention is presented in

table 1, and DCTP_c diagram for this steel is presented in fig. 1.

Table 1. Chemical composition (wt.%) of multi-phase steel

Steel	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Ti	B	Al	N
1	0.34	1.01	1.09	0.011	0.008	1.51	0.40	0.30	0.20	0.170	0.0023	0.420	0.006

Steel of chemical composition given in table 1 is characterised by low sensitivity of austenite microstructure to hot rolling parameters, which is responsible for developing a fine grained austenite at the end of hot rolling. This is presented in fig. 2 which shows the dependence of austenite grain size on temperature and strain. Investigation was performed using Gleeble 3800 simulator.

From fig. 1 one can see that within the cooling rate range of rail head after hot rolling from 0.2 to 1.0°C/s, bainite and small amounts of martensite are formed in the steel structure. Structure under the rail 60E1 running surface, made of steel according to the invention, is presented in fig. 3, mechanical properties are given in table 2 and hardness distribution HB within rail cross-section is presented in fig. 4. Microstructure includes around 6% of allotrimorphic ferrite, the rest is granular bainite and degenerated upper bainite. Fraction of retained austenite in the structure, determined using x-ray method is 18%. Fig. 5 presents an example of TiC nano-particles precipitated in bainitic ferrite.

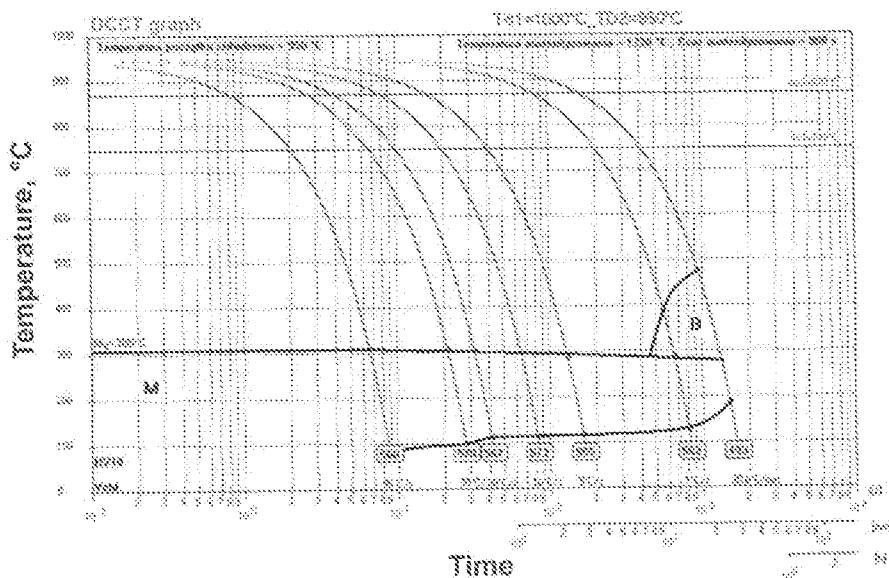


Fig.1 DCTP_c diagram of steel 1.

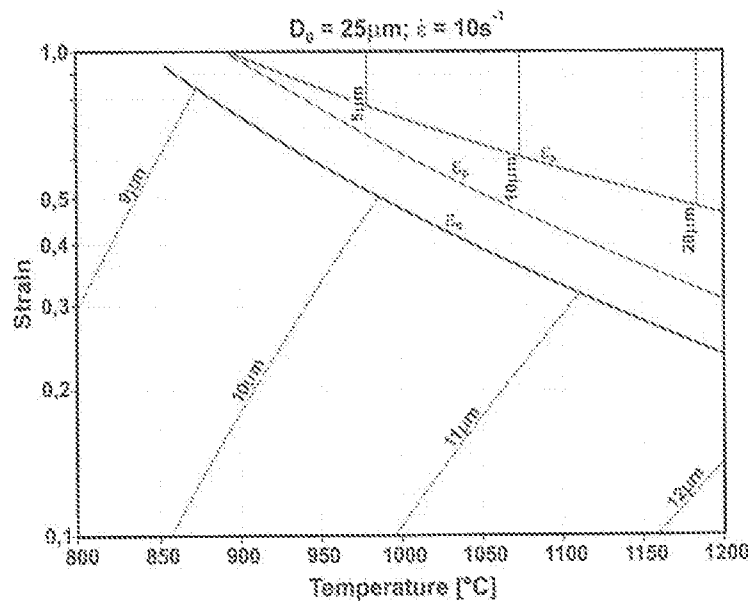


Fig. 2. Relationship between austenite grain size and strain and deformation temperature. Before deformation, samples were held at temperature 1200°C for 10 minutes and the rate of deformation was 10s⁻¹; ϵ_c - critical deformation to initiate dynamic recrystallization, ϵ_p - deformation to peak in the stress - deformation curve, D_0 is initial austenite grain size (mean linear intercept) and $\dot{\epsilon}$ strain rate.

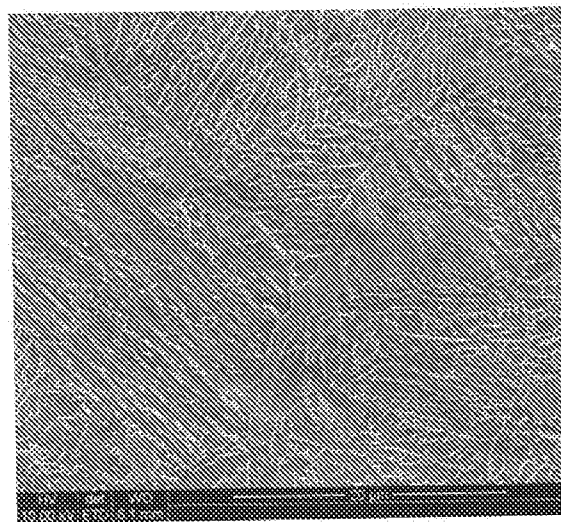


Fig. 3. Structure of rail head subsurface region (10 mm below the surface) 60E1;
SEM.

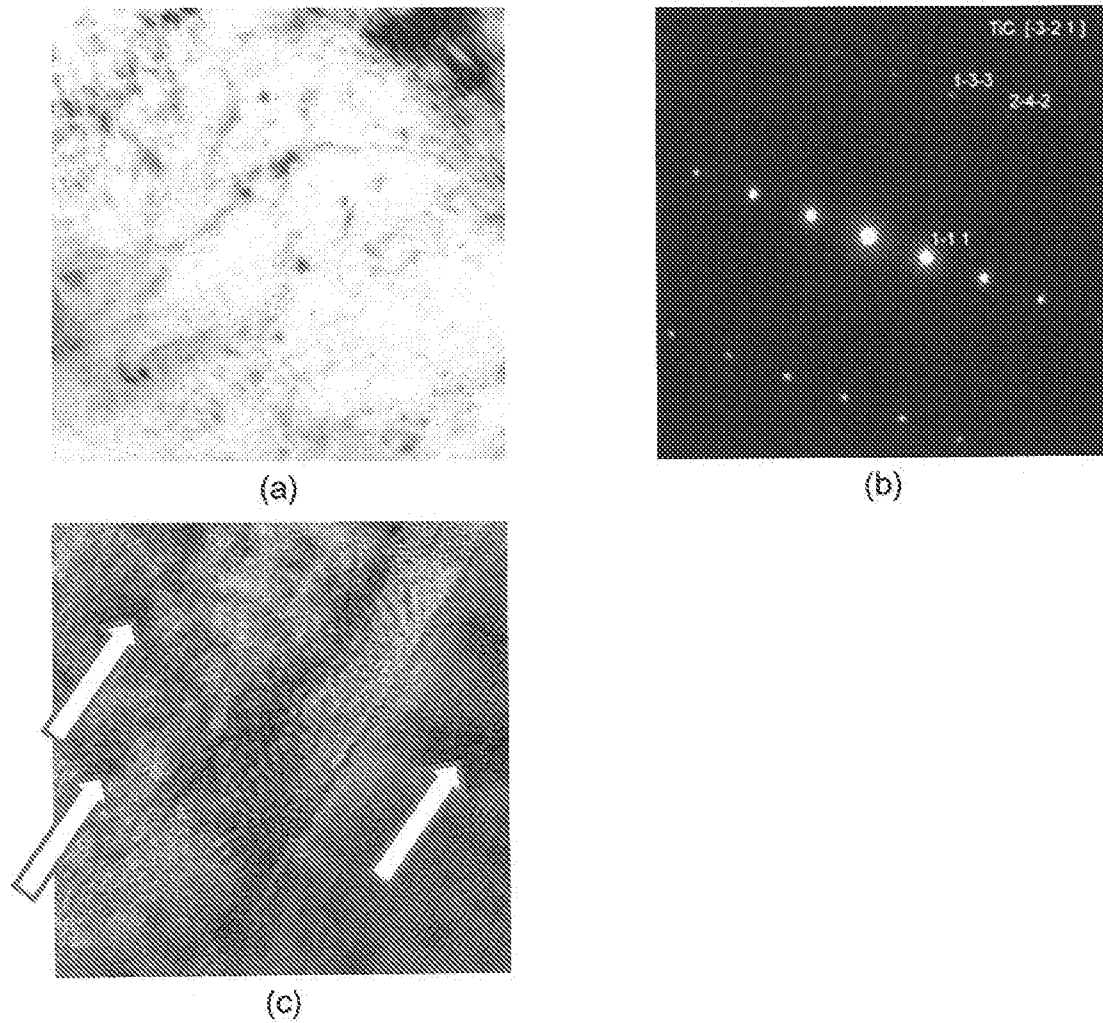


Fig.4. TiC nano-particles in the steel being the subject of invention observed using high resolution transmission electron microscopy. (a) – bright field image; (b) – electron diffraction with indicated reflexes from TiC; (c) – high-resolution transmission micrograph with indicated TiC particles.

Table 2. Mechanical properties of 60E1 rail

Steel	R _{p0.2} , MPa	R _m , MPa	A ₁₀ , %	K _{IC}	Z, %	BH
1	775	1330	11.5	53	25.9	405

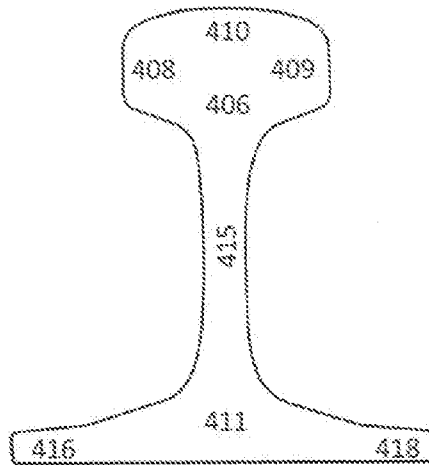


Fig. 5. Distribution of HB hardness in rail cross-section of rail made of steel according to the invention.

Sample taken from 60E1 rail head was subject to wear process using an apparatus according to own design (fig.6). The following test conditions were applied:

- number revolutions of counter-sample amounted to 3.33 rps;
- contact load around 500 N;
- total length of path route was 2000 m;
- sample temperature increase during test was within 127-155°C.

For comparison, sample from pearlitic steel grade R260 was also subject to wear test. The degree of wear of this sample, under given conditions, was around 50% higher comparing to the multi-phase steel sample.

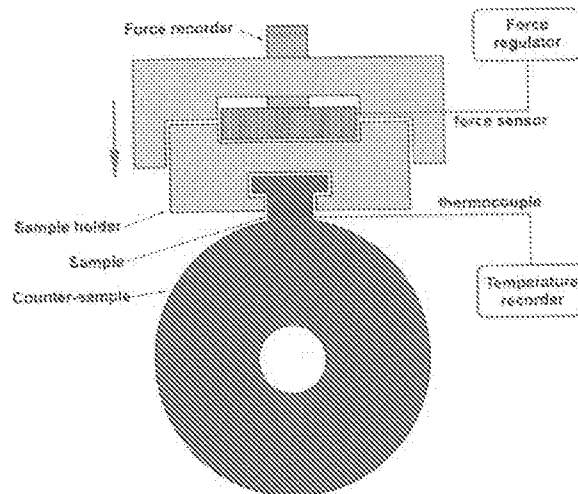


Fig. 6. Schematic picture of the apparatus used for wear investigation.

Fig. 7 presents structure of the sample of 1 steel after the wear test. As can be seen, the subsurface region is subject to strong plastic deformation. Deformed retained austenitic fibres are getting aligned parallel to the surface and afterwards they are fragmented. The EBSD examination shows that the described processes are

accompanied by gradual transformation of austenite to martensite, fig. 8. However, the retained martensite is still present in the severely deformed surface area.

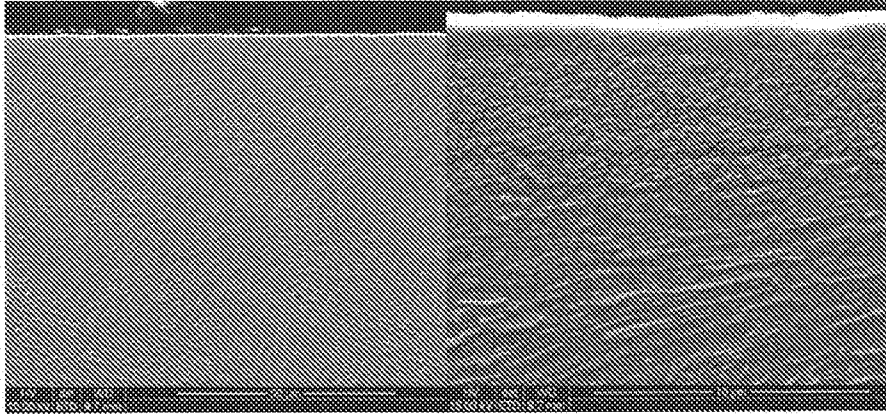


Fig. 7. Microstructure of the sample in the sub-surface area of the test sample, SEM.

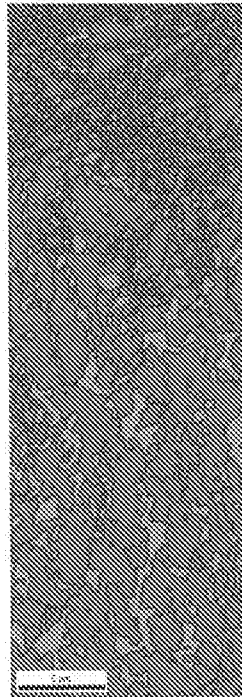


Fig. 8. Distribution of ferrite and retained austenite in the sample after wear test. Areas of retained austenite are presented in green and bainitic ferrite in red.

Example 2.

Table 3 shows chemical composition of manufactured multi-phase steel according to the invention and table 4 presents relevant mechanical properties of the 60E1 rail.

Table 3. Chemical composition (wt.%) of multi-phase steel

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Ti	B	Al	N
2	0.24	0.99	1.55	0.009	0.007	1.52	0.08	0.04	0.020	0.0025	0.021	0.005

Table 4. Mechanical properties of rail of multiphase steel

Steel	R _{p02} , MPa	R _m , MPa	A ₁₀ , %	K _{IC}	Z	HB
2	720	1255	13.0		37.6	362

Example 3

Table 5 shows chemical composition of manufactured multi-phase steel according to the invention and table 6 presents mechanical properties.

Table 5. Chemical composition (wt.%) of multi-phase steel

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Ti	B	Al	N
3	0.34	1.01	1.17	0.011	0.007	1.50	0.08	0.04	0.021	0.0020	0.007	0.006

Table 6. Mechanical properties of rails of multi-phase steel

Steel	R _{p02} , MPa	R _m , MPa	A ₁₀ , %	Z	HB
3	717	1307	14.4	29.4	387

Example 4

Table 7 shows chemical composition of manufactured multi-phase steel according to the invention and table 8 presents mechanical properties.

Table 7. Chemical composition (wt.%) of multi-phase steel

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Ti	B	Al	N
4	0.35	1.07	1.41	0.010	0.008	1.50	0.40	0.25	0.22	0.0025	0.008	0.007

Table 8. Mechanical properties of rails of multi-phase steel

Steel	R _{p02} , MPa	R _m , MPa	A ₁₀ , %	Z	HB
4	881	1393	10.7	36.1	430

Example 5

Table 9 shows chemical composition of manufactured multi-phase steel according to the invention and table 10 presents mechanical properties.

Table 9. Chemical composition (wt.%) of multiphase steel

Steel	C	Si	Mn	P	S	Cr	Ni	Mo	Ti	B	Al	N
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5	0.36	1.05	1.44	0.010	0.008	1.50	0.42	0.26	0.21	0.0031	0.39	0.007
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Table 10. Mechanical properties of rails of multiphase steel

Steel	R _{p02} , MPa	R _m , MPa	A ₁₀ , %	Z	HB
5	853	1379	11.2	30.0	415

Claims:

1. Multi-phase steel, preferably used for the production of standard gauge rail wherein the content of basic elements in the steel is not less than:

C: 0.15 wt.%;

Si: 0.60 wt.%;

Mn: 1.20 wt.%;

Cr: 1.20 wt.%;

Ni: 0.20 wt.%;

Mo: 0.10 wt.%;

and, additionally, multi-phase steel contains:

Ti: 0.01-0.25wt.% satisfying the relationship $(\% \text{ wt Mo})/(\% \text{ mas. Ti}) > 1$;

Al: 0.01-0.80 wt.%;

B: 0.001-0.003 wt.%;

H₂ ≤ 2 ppm;

N ≤ 80 ppm,

the contents of alloy elements and carbon satisfy the following relationship:

$$0.15 \leq C \leq 0.77 * CE$$

(1)

where CE is a carbon concentration at an eutectoid point, calculated using the following equation:

$$CE = 0.768 - 0.0522(\% \text{Mn}) - 0.037(\% \text{Cr}) - 0.113(\% \text{Si}) - 0.012(\% \text{Mo}) - 0.068(\% \text{Ni}) - 0.006(\% \text{Cu});$$

(2)

and contents of Al, Si, Ti, C and N satisfy the following limitations:

$$[(\text{Al}) + (\text{Si})]/C \geq 2.5$$

(3)

and

$$\frac{(\% \text{Ti})}{\left[(\% \text{C}) + \frac{12}{14} (\% \text{N}) \right]} \geq 0.03$$

4)

the amount of the individual constituents is in relation to the total weight of multi-phase steel

2. Multi-phase steel according to claim 1 wherein the temperature of bainitic transformation B_s initiation is no higher than 460°C, and temperature of martensitic transformation M_s initiation is no less than 300°C.
3. Multi-phase steel according to claim 1 wherein after the rail cooling in still air, the content of bainitic ferrite is above 70% vol. of steel, allotrimorphic ferrite below 10 % vol. of steel, self-tempered martensite below 10% vol of steel, retained austenite connected with bainitic ferrite - of carbon content min. 1.25% wt - above 10% vol. of steel, bainitic ferrite is hardened with nano-particles of TiC carbide.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/PL2016/000155

A. CLASSIFICATION OF SUBJECT MATTER C22C38/50 (2006.01), C22C38/54 (2006.01), C22C38/06 (2006.01)		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C22C38/00, C22C38/02, C22C38/04, C22C38/06, C22C38/08, C22C38/12, C22C38/14, C22C38/18, C22C38/50, C22C38/54		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data, Databases of the Polish Patent Office		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO2004048618 A1 (USINOR [FR]; BEGUINOT JEAN [FR]; BRISSON JEAN-GEORGES [FR]) 10 JUNE 2004 (2004-06-10) claims 1, 7, description p. 3-8, table 1 (sample D)	1, 3
X	EP2365103 A (USUI KOKUSAI SANGYO KK [JP]; UNIV SHINSHU [JP]) 25 SEPTEMBER 2011 (2011-09-14) claims 1-10, table 2, paragraphs [0016], [0033] – [0035], example 1, fig. 1	1-3
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search 15 March 2017		Date of mailing of the international search report 16 March 2017
Name and mailing address of the ISA/ Visegrad Patent Institute / Branch Office PL Al. Niepodległości 188, 00-950 Warsaw, Poland Facsimile No. +48 22 579 00 01		Authorized officer Krzysztof Gos Telephone No. +48 22 579 03 85

INTERNATIONAL SEARCH REPORT
Information on patent family members

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PCT/PL2016/000155

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO2004048618 A1	10-06-2004	AR042072 A1	08-06-2005
		AT388247 T	15-03-2008
		AU2003290187 A1	18-06-2004
		AU2009201117 A1	09-04-2009
		BR0315694 A	20-09-2005
		CA2506347 A1	10-06-2004
		CN1714161 A	28-12-2005
		DE60319567 T2	26-03-2006
		EP1563103 A1	17-08-2005
		ES2300636 T3	16-06-2008
		FR2847271 A1	21-05-2004
		JP2006506526 A	23-02-2006
		KR20050083912 A	26-08-2005
		PE04862004 A1	18-08-2004
		PL375541 A1	28-11-2005
		PT1563103 E	22-04-2008
		RU2005119211 A	20-02-2006
		SI1563103 T1	30-06-2008
		UA81134 C2	10-12-2007
		US2006144483 A1	06-07-2006
US2008253921 A1	16-10-2008		
ZA200504151 B	26-07-2006		
EP2365103 A	14-09-2011	CN102203310 A	28-09-2011
		JP2010106353 A	13-05-2010
		KR20110063581 A	10-06-2011
		US2011209803 A1	01-09-2011
		WO2010050619 A1	06-05-2010