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Initial assessment of the weldability of modern power engineering steel PB2

Abstract: The article contains information concerning a new generation steel designated as PB2 (X13CrMoCoVNbNB9-2-1) intended for the operation in power boilers of fresh steam supercritical parameters. The article presents the results of tests on the effect of welding thermal cycles on the structure, toughness and hardness of the simulated HAZ of modern power engineering PB2 steel as well as the susceptibility of this steel to hot cracking. The tests involved the use of a simulator of thermal-strain cycles. The publication also contains the results of the tests of similar butt joints of PB2 steel pipes subjected to the post-weld heat treatment.

Keywords: PB2 steel, welding thermal cycle, simulated heat-affected zone, hot cracking, simulator of thermal-strain cycles, properties of welded joints

Introduction

The development of steels intended for operation at higher temperatures is caused by the power industry's constant pursuit of reducing air pollution emissions and power generation costs. In Poland, electric energy is generated using mainly carbon and brown coals, the resources of which will definitely be the basic source of energy for the decades to come. Burning coal in power boilers is accompanied by emissions of considerable amounts of such pollutants as carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and various kinds of dusts. Directive 2001/80/WE of the European Parliament and of the Council of 23 October 2001 on the limitation of emission of certain pollutants into the air from large combustion plants set permissible limits for these pollutions. This directive refers to the whole national power sector in which 97% of energy is generated using solid fuels. The emission of SO_2, NO_x and dusts by electric energy and heat sources such as power plants, heat and power stations as well as heat generating plants has to be limited following a strictly specified schedule (Fig. 1). The costs related to the construction of flue gas purification systems and

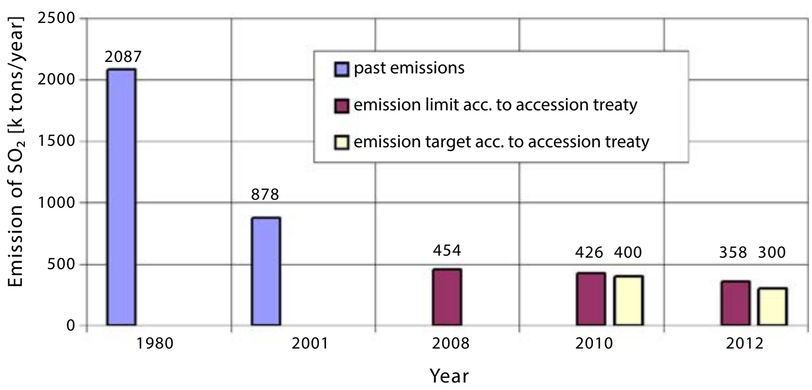

Fig. 1. Emission of SO2 into the air from big national combustion systems [3]

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those related to the restoration of power generation capability of sources which need to be replaced will be twice as high as the investments made so far [2,3,4,6].

Pursuits of reducing pollutant emissions into the air are related to the use of supercritical steam parameters which can increase the efficiency of power units up to 45%. The achievement of higher parameters is possible through the constant search for structural materials characterised by greater creep strength and heat resistance yet not compromising their formability, weldability and the ease of heat treatment. The use of flue gas purification plants and better solid fuel combustion conditions make it also possible to significantly reduce the emission of pollutants into the air [6].

The key issue connected with the selection of modern steels for power industry constructions is the assessment of steel weldability based on the analysis of structural transformations taking place in the Heat Affected Zone of steel as well as on the analysis of susceptibility to various types of cracking caused by welding thermal cycles. Structural transformations are usually accompanied by stresses and strains generated during cooling, resulting from the local heating of a material and the impossibility of the unrestrained deformation of an element being welded due to the restraint of the parts of a joint. The stresses mentioned above are one of the main reasons for the generation of cracks. The reproduction of a structure and of stresses and strains in the HAZ enabling the accurate determination of steel susceptibility to cracking is possible by means of specialist devices, i.e. simulators of thermal-strain cycles, enabling the heating of samples using any thermal cycle with the simultaneous strains of the samples at any temperature of a cooling cycle.

The article presents the results of testing the effect of welding thermal cycles on the structure, toughness and hardness of a simulated Heat Affected Zone of modern power engineering steel PB2 (X13CrMoCoVNbNB9-2-1), its susceptibility to the generation of hot cracks in a welded joint during cracking, using a simulator of thermal-strain cycles. The study also presents the properties of a butt joint manually welded on a pipe $\phi 219 \times 31$ mm made of PB2 steel [11].

New generation of power engineering steels

An increase in the power of power units requires the use of high steam parameters, i.e. temperature and pressure. For this reason low-alloy steels used in the construction of power generating machines had to be sufficiently thick in order to provide required mechanical properties. This, however, resulted in an economically unjustified increase in the mass of such devices. That is why various research centres and laboratories across Europe, Japan and USA have been constantly involved in research, the purpose of which has been to develop modern steel grades intended for operation at higher temperatures. These steels should meet strict requirements resulting from operation in modern boilers characterised by supercritical parameters and small dimensions and thicknesses of elements used in the construction of the boilers [1]. Figure 2 presents a net increase in the efficiency of coal-fired power units in Germany in the function of the development of steels used in the production of power units. Special attention should be given to the use of nickel alloys in the production of power units characterised by ultrasupercritical parameters and net efficiency exceeding 50%.

Depending on a working temperature, power engineering system elements are made of ferritic creep resisting steels, martensitic steels as well as austenitic steels. Figure 3 presents the development of creep resisting steels containing approximately 2Cr%, 9Cr% and 12Cr% [8]. The group of steels containing 9-12% Cr meets strict operational requirements set for steels including high temperature creep resistance with adequate resistance to oxidation.

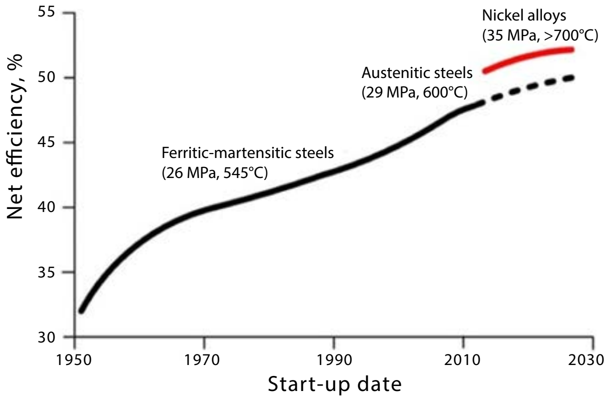


Fig. 2. Development of coal-fired power units in Germany [5]

The modification of a chemical composition through providing appropriate amounts of alloying additions such as vanadium, tungsten, nickel, copper, cobalt and the microadditions of nitrogen, boron and niobium with simultaneously reducing carbon and molybdenum contents has given rise to (except for a group of steels containing approximately 2.25% Cr) two major trends of steel development [7], i.e. the production of steels with an approximate 9% Cr content with Mo addition (introducing V and W additions as well as N, B and Nb microadditions has resulted in developing P/T91, P/T92, E911 and PB2 steels) and the production of steels with an approximate 12% Cr content with Mo and V additions (introducing W, Ni, Cu or Co additions as well as N, B and Nb microadditions has led to the development of new steels NF12, TB12M, HCM12A AND VM12).

The materials of the groups referred to above (Fig. 3) can be used in the production of supercritical elements operating at 620°C and under a pressure of approximately 30MPa (e.g. the superheaters of high-pressure boilers) owing to good mechanical, creeping, plastic and technological properties such as weldability, bendability or high-temperature creep resistance [7]. However, it should be noted that the technological processes of new generation materials for power industry require the strict observance of very narrowly ranging welding parameters.

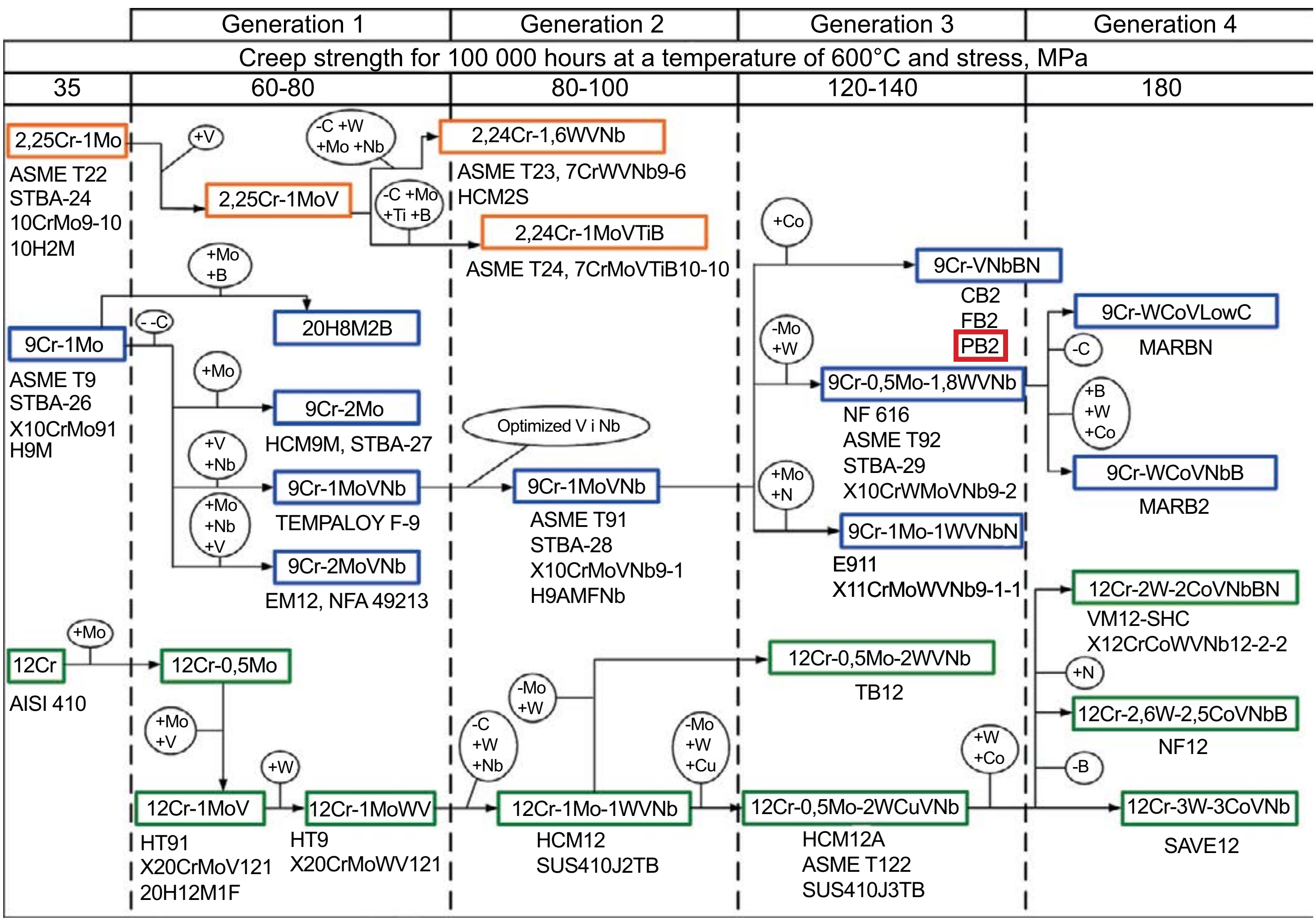


Fig. 3. Development of ferritic creep resisting steels [5,8]

One of the most promising steels as regards its practical application in the production of the power boiler critical elements is the steel designated as PB2 (X13CrMoCoVNbNB 9-2-1), with the approximate chemical composition of 9%Cr-1.5%Mo-1.3%Co-0.2%V,Nb,B,N. This steel is produced in the form of pipes or forgings used to produce the critical elements of industrial fixtures. The steel designation of PB2 has been adopted and used throughout the article.

PB2 weldability tests

The subject of the authors' own research-related tests was a pipe ϕ 219.1x31 mm made of PB2 by the Italian company Tenaris Dalmine. The steel used in the tests was the third generation steel having a martensitic structure and was intended for the production of the critical elements of power generation fixtures. The chemical composition of PB2 steel is presented in Table 1. Figure 4 presents a diagram of PB2 steel impact energy in the function of impact temperature and heat treatment conditions, whereas Figure 5 presents the change of the mechanical properties (yield point and tensile strength) in higher temperatures and in various heat treatment states. The mechanical properties of PB2 steel in the state of delivery are presented in Table 2. The diagram of austenite decomposition in welding conditions indicates that within the range of cooling time characteristics of commonly used welding methods and described as $t_{8/5} \leq 60$ sec. in the HAZ of PB2 steel the dominant structure is martensitic (diagram not published, made within the confines of project no. N N508 623540 financed from NCN funds).

Structure and properties of simulated HAZ

In order to test the effect of welding thermal cycles and heat treatment on the structure, hardness and toughness of the simulated HAZ and the susceptibility of PB2 steel to hot cracking the steel was subjected to the following simulated thermal-strain cycles:

- simple welding thermal cycles having the following parameters: T_{max} = 1250°C, cooling time $t_{8/5}$ = 2-3, 4, 6, 12, 24, 60, 120 and 300 s;

Table 1. Chemical composition of PB2 steel declared by the producer [9]

Steel	Chemical element content [%]									
PB2	C	Mn	Si	P	S	Cr	Ni	Cu	Al	Ti
	0.135	0.31	0.076	0.0058	0.001	9.28	0.15	0.031	0.07	0.001
	B	Nb	Mo	V	Co	As	Sb	Sn	N	
	0.0091	0.053	1.51	0.19	1.33	0.002	0.005	0.004	0.026	

Table 2. Mechanical properties of steel PB2 according to the producer [9]

PB2 steel properties in function of heat treatment conditions	Steel properties:			
	R_e ($R_{0,2}$) [MPa]	R_m [MPa]	A_5 [%]	HV10
1070+780°C	601	754	19	253
1100+780°C	610	763	21,5	258

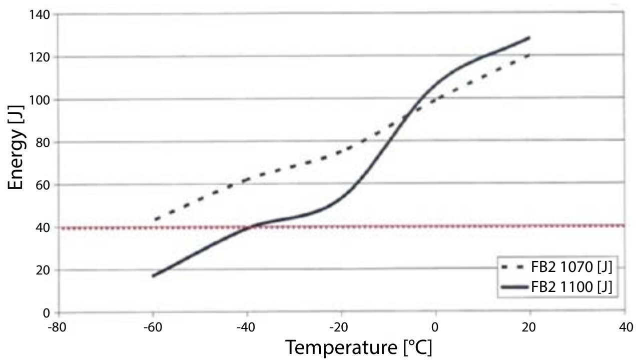


Fig. 4. Curves of transition into a brittle state after heating FB2 steel to various values of austenitisation temperature [9]

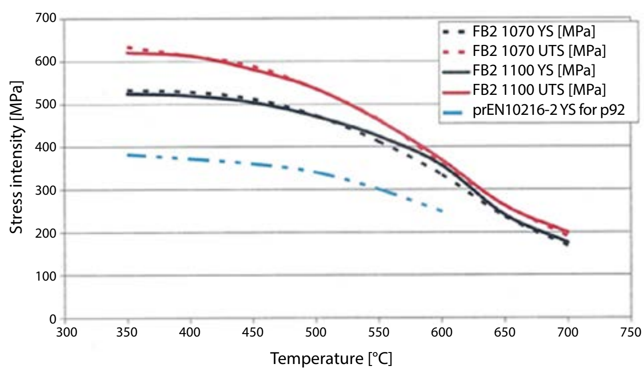


Fig. 5. Change of yield point and tensile strength in function of temperature after heating FB2 steel to austenitisation temperature 1070 and 1100°C [9]

- complex welding thermal cycles (composed of simple welding thermal cycles and classic post-weld heat treatment) having the following parameters: T_{max}=1250°C, $t_{8/5}$=4, 12, 60 and 120 [s] + T_{max}=780°C/2h (treatment in furnace).

The tests were also focused on the influence of the maximum temperature of thermal cycles (400, 550, 750, 900 and 1100°C, with a constant cooling time $t_{8/5}$ of 12 seconds) on the structure, hardness and toughness of the simulated HAZ area. The classical heat treatment was carried out at a temperature 780°C/2 hours, at a material heating and cooling rate of 250°C/h.

In the middle of the simulated HAZ ISO Charpy V notches of impact samples were made. The results of KCV impact strength tests and of HV5 hardness tests of the samples subjected to the simulated thermal cycle are presented in Table 3 containing the average value and extended measurement uncertainty. The figures below present the influence of heat treatment on the toughness (Fig. 6) and hardness (Fig. 7) of the simulated HAZ of PB2 steel.

Table 3. Results of KCV impact strength tests and HV5 hardness tests of samples subjected to simulated thermal cycle

Thermal cycle parameters		Measurement results		Structure type
T_{max} [°C]	$t_{8/5}$ [s]	$KV_{śr}$ [J/cm²]	$HV5_{śr.}$	
Simple single thermal cycle				
1250	2.5	13.3±2.9	477.5±8.8	Martensite
	4	13.3±1.4	469.0±16.7	
	6	13.3±1.4	479.1±5.8	
	12	15.8±1.4	485.3±5.0	
	24	27.5±2.5	455.8±21.7	
	60	24.2±5.2	441.9±23.1	
	120	38.1±6.6	446.6 ±9.7	
	300	29.4±8.8	432.0±7.9	
Thermal cycle of various maximum temperature				
400	12	225.5	243.9±4.0	Tempered martensite
550		200	246.9±4.9	
750		215	250.9±7.4	
900		180	395.1±13.2	
1100		20	482.6±7.4	Martensite
Simple single thermal cycle with post-weld heat treatment at 780°C/2h				
1250	4	235.8±10.1	250.3±5.6	Tempered martensite
	12	243.3±18.4	257.9±6.8	
	60	219.2±23.2	252±11.5	
	120	216.7±8.8	248.4±4.3	
Base metal				
—	—	209.2±3.8	230.8±4.3	Tempered martensite

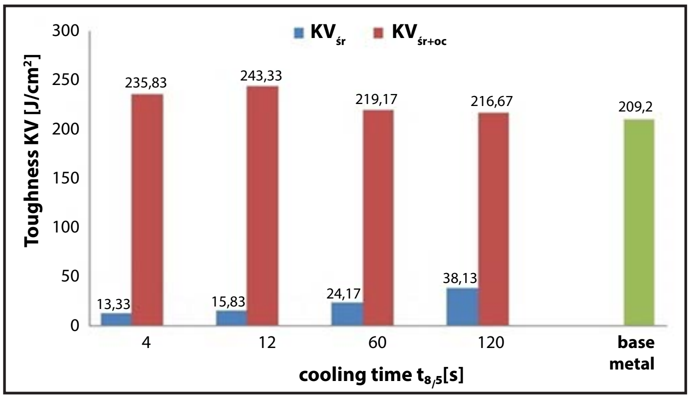


Fig. 6. Toughness of simulated HAZ of PB2 steel before ($KV_{śr}$) and after heat treatment ($KV_{śr+oc}$)
$KV_{śr}$ – toughness of samples simulated with simple welding thermal cycle, $KV_{śr+oc}$ – toughness of samples simulated with simple welding thermal cycle and after heat treatment at 780°C/2h

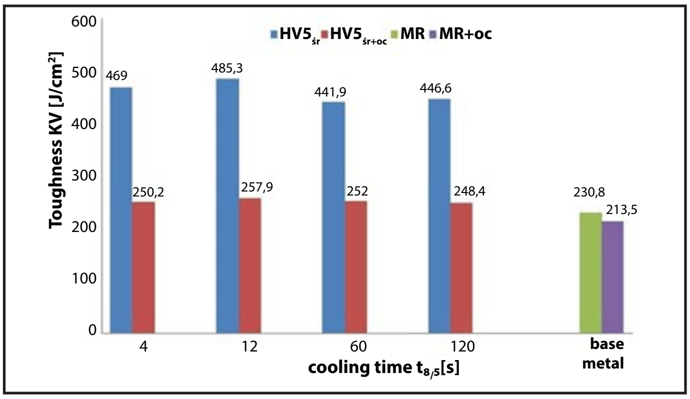
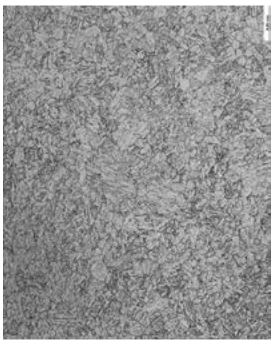


Fig. 7. Influence of heat treatment on hardness of simulated HAZ of PB2 steel
$HV5_{śr}$ – toughness of samples simulated with simple welding thermal cycle, $HV5_{śr+oc}$ - toughness of samples simulated with simple welding thermal cycle and after heat treatment at 780°C/2h

The microscopic metallographic tests of the simulated HAZ areas were carried out using a Leica-manufactured optical microscope at a magnification of 200x. The selected microstructures before and after the heat treatment (for cooling thermal cycles $t_{8/5} = 12$ and 120 seconds) are presented in Table 4.

The fractographic tests of the fractures of the samples simulated with welding thermal cycles T_{max}=1250°C, $t_{8/5} = 2,5$; 12 and 120 [s] were carried out with a Zeiss-made SUPRA 35 scanning electron microscope using the secondary electron observation technique (SE). The tests of the fractures (Table 5) revealed trans-crystalline fissile fractures (toughness 15.8±1.4 [J/cm²]). For a cooling time $t_{8/5} = 120$ [s] the fracture is characterised by a fissile crack with plastic deformation traces (toughness 38.1±6.6 [J/cm²]).

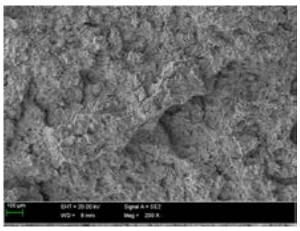
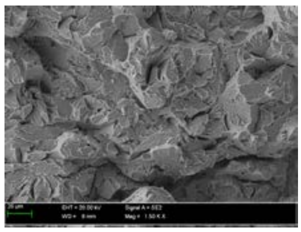
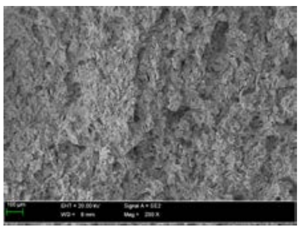
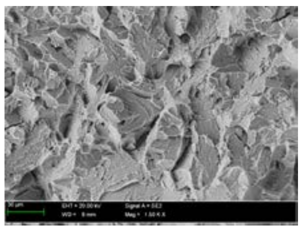
Table 4. Microstructure of base metal and of simulated HAZ for cooling times $t_{8/5} = 12$ and 120 s of samples before and after heat treatment

	Magnification 200x (scale 1:1, etchant $FeCl_3$)	
Base metal	 Tempered martensite 230.8±4.3HV5	
$T_{max} = 1250°C$, $t_{8/5} = 12$ s	Before heat treatment	After heat treatment
	 Martensite 485.3±5.0 HV5	 Tempered martensite 257.9±6.8HV5
$T_{max} = 1250°C$, $t_{8/5} = 120$ s	Before heat treatment	After heat treatment
	 Martensite + bainite + delta ferrite traces 446.6±9.7 HV5	 Tempered martensite +bainite 248.4±4.3 HV5

Testing susceptibility to hot cracking

The determination of PB2 steel susceptibility to hot cracking involved the use of a method developed by the Belgian Welding Institute. The method consisted in subjecting samples having a measurement diameter of 6 mm to a simulated thermal cycle having an austenitisation temperature of 1250°C and a cooling time $t_{8/5}$=12 [s] as well as subjecting the samples (in the simulator of thermal-strain cycles) during cooling to a constant tensile force in assumed points of the thermal cycle TR until the rupture of the sample. The test included the recording of stress in the sample and, in order to determine

Table 5. Results of fractographic tests of simulated HAZ areas of PB2 steel carried out with a scanning microscope [12]

	Magnification 200x	Magnification 1500x
$T_{max} = 1250°C$, $t_{8/5} = 12$ s		
	Fracture description: trans-crystalline fissile fracture	
$T_{max} = 1250°C$, $t_{8/5} = 120$ s		
	Fracture description: trans-crystalline fissile fracture with traces of plastic deformation	

the area reduction of the sample (Z), the measurement of the sample diameter at the rupture point. Due to the limited amount of test material, the hot cracking test was limited to one measurement.

The temperature at which the sample area reduction Z amounted to 0% was designated as TND, whereas the temperature at which the stress intensity amounted to 0 MPa was designated as T_{NS}. The adopted assessment criterion of hot cracking susceptibility was the value $\Delta T = T_{NS} - T_{ND}$. The assessment of hot cracking resistance involved the adoption of the cracking susceptibility classification according to the publication [10].

The results of the PB steel hot cracking resistance test are presented in Table 6 showing the cross-section of the samples subjected to tension at temperatures of 1150 and 1190°C. Figure 8 presents the dependence of the sample area reduction Z in the function of the sample tension temperature as well as the dependence between the stress intensity during rupture σ and the sample tension temperature.

Making and testing the test joint

The data provided below refer to the results obtained on the basis of the publication [11]. The test joint was made at Instytut Spawalnictwa in Gliwice. The test involved a similar butt joint (welding position: PF, U-bevelling) made on a PB2 steel pipe ϕ 219×31 mm in a conventional way (welding + post-weld stress relief annealing at 770°C/3h). The root run of the joint was

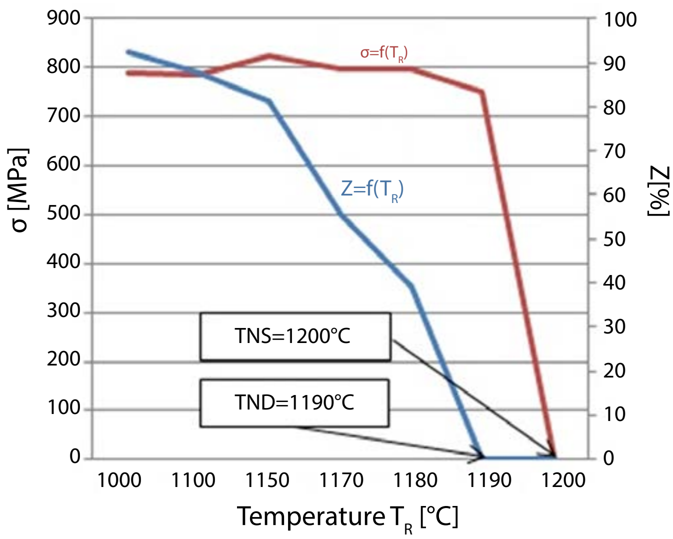


Fig. 8. Dependences between stress intensity during rupture σ and sample area reduction Z and sample tension temperature TR [13]

Table 6. Results of PB2 hot cracking susceptibility tests[13]

No.	Sample design.	T_R [°C]	Sample diameter before test	Sample diameter after test	Sample area reduction Z [%]	Stress intensity on rupture σ [MPa]	Temp. determin.	Sample fracture type
1	A1200	1200	5.88	5.88	0	4	T_{NS}	hot
2	A1190	1190	5.98	5.98	0	750	T_{ND}	hot
3	A1180	1180	6.04	4.71	39.2	798	—	plastic
4	A1170	1170	6.01	4.01	55.5	796	—	plastic
5	A1150	1150	5.99	2.58	81.4	822	—	plastic
6	A1100	1100	6.00	2.12	87.5	786	—	plastic
7	A1000	1000	6.00	1.65	92.4	789	—	plastic

T_{NS} – temperature at which stress intensity σ in sample amounts to ≌0 MPa,
T_{ND} – temperature at which sample area reduction Z amounts to 0%,
T_R – tension temperature during sample cooling cycle.

A1190

A1150

made using the TIG method with a linear energy of ~18 kJ/cm, whereas filling layers were made by means of covered electrodes using a linear energy of ~11-12 kJ/cm and materials used for welding P92 steel.

The scope of the joint tests was consistent with standard PN-EN ISO 15614-1:2008/A2:2012E [14] and included a static tensile test, side bend test, impact strength tests (notch cut in the weld and HAZ), microscopic metallographic tests and hardness measurements. The tests were carried out in accordance with valid standards PN-EN [15-19]. The results of the joint-related tests are presented in Table 7.

In the tests the following assessment criteria of joint properties were adopted:

1. brittle cracking resistance (determined using standard samples with Charpy V notch) for a level of min. 27 J at the ambient temperature,
2. maximum hardness in the HAZ not exceeding 350 HV10 (data for 6th material group after a heat treatment according to the publication [14]),
3. angle in a side bend test of 180°,
4. structure of tempered martensite in PB2 steel HAZ.

Summary

The impact strength tests of the simulated HAZ areas have revealed the following:

a) for the simple thermal cycle having T_{max} = 1250°C an increase in cooling time $t_{8/5}$ is accompanied by a slight increase in toughness from 13.3 J/cm² for the thermal cycle $t_{8/5}$=2.5 s to 38.1 J/cm² for the cycle $t_{8/5}$=120 s (Fig. 6). The toughness of the simulated HAZ for the whole range of time $t_{8/5}$ tested is approximately 10 times lower than the toughness of the base metal (209 J/cm²). The fractures of the samples are brittle in the whole range of time $t_{8/5}$.

b) during the simulations with the simple thermal cycles having the maximum temperature T_{max}=1250°C and cooling times $t_{8/5}$=4, 12, 60 and 120 s with post-weld heat treatment at 780°C with 2-hour annealing, the toughness of the simulated HAZ for all the cooling times $t_{8/5}$ is higher than that of the base metal (being 209.2±3,8 J/cm²) and changes from 216.7 J/cm² for the cooling time $t_{8/5}$=120 s to 235.8 J/cm² for the time $t_{8/5}$=4 s. The fractures of the samples are brittle in the whole range of time $t_{8/5}$.

c) in the case of the simulation with the thermal cycle having the maximum temperature of 400, 550, 750, 900 and 1100°C as well as the constant cooling time $t_{8/5}$=12 s the toughness adopts values close to that the base metal and the fractures of the samples are plastic. The cycles which do not follow this tendency are those with the maximum temperatures of 1100 and 1250°C, where the toughness of the simulated HAZ falls to the value 15.8÷20 J/cm² and with the fractures of the samples being brittle. The reason for such a situation is the austenitisation of the simulated HAZ at a temperature above the temperature A_{C3}.

The hardness measurements of the simulated HAZ areas have revealed the following:

a) welding thermal cycle causes a significant hardness increase from 231 HV5 to 477.5 HV5 for the cycle $t_{8/5}$=2.5 s,

Table 7. List of properties of PB2 steel welded joints [11]

Average tensile strength Rm [MPa]	Average impact energy KV [J]				Max. hardness HV10 in HAZ	Bend angle [°] on samples for side bending (D=60 mm)
	HAZ from weld face side	Weld from face side	HAZ from weld root side	Weld from root side		
703.6 – rupture outside weld	137.3	49.3	194.7	46.7	270	180 – without scratches and cracks

b) extending a cooling time from $t_{8/5}$=2.5 s to $t_{8/5}$=300 s leads to a decrease in hardness from z 477.5 to 432 HV5 respectively,
c) classical heat treatment cycle in a furnace at 780°C for 2 hours results in the hardness of the simulated HAZ for cooling times $t_{8/5}$=4, 12, 60 and 120 s being in the range 248÷258 HV5; the effect of the heat treatment temperature on the hardness of simulated HAZ is presented in Figure 7,
d) for welding thermal cycles of various maximum temperatures and the constant cooling time $t_{8/5}$=12 s it is possible to observe an increase in hardness which for the maximum temperatures 400, 550 and 750°C amounts to 244, 247 and 251 HV5 respectively, whereas for T_{max}=900, 1100 and 1250°C amounts to 395, 483 and 485 HV5 respectively.

The metallographic tests of the simulated HAZ areas have revealed that:

a) base metal structure is that of tempered martensite (Table 4),
b) for simple thermal cycles of cooling times $t_{8/5}$ = 2.5, 4, 6, 12 and 24 s from the maximum temperature T_{max}=1250°C the simulated HAZ of PB2 steel has a typical martensitic structure (Table 4),
c) for cooling times $t_{8/5}$ = 60, 120, 300 s from the maximum temperature T_{max}=1250°C the simulated HAZ of PB2 steel contains the mixture of martensite and bainite with probable slight traces of ferrite δ,
d) for the cooling time $t_{8/5}$ of 12 seconds and the maximum temperature T_{max}=400, 550 and 750°C the material has the structure of tempered martensite, in turn in the case of maximum temperature T_{max} ≥ 900°C the structure of the material is martensitic,
e) samples after the heat treatment 780°C/2h for the cooling time $t_{8/5}$ = 4 and 12 s have the structure of tempered martensite, whereas the samples of the time $t_{8/5}$ = 60 and 120 s contain the structure of tempered martensite with the traces of bainite.

The fractographic tests of selected impact strength test samples carried out using a Zeiss-made scanning microscope revealed brittle fissile trans-crystalline fractures (toughness in the range 13.3±1.4 to 29.4±8,8 J/cm²). For the cooling time $t_{8/5}$=120 s the fracture is characterised by a fissile crack with the plastic strain traces (toughness 38.1±6.6 J/cm²).

The tests of hot cracking susceptibility carried out according to a methodology developed by the Belgian Welding Institute consisting in the tension of samples at the specified points of a thermal cycle have revealed that at 1200°C the sample area reduction Z amounts to 0%, destructive stress intensity amounts to 4 MPa and the fracture has a character typical of hot cracking. For a temperature equal to and lower than 1180°C the sample fracture is plastic and the sample area reduction Z changes from 39.2% for T=1180°C to 92.4% for T=1000°C. The temperature TNS at which the stress intensity σ is close to 0 amounts to 1200°C, whereas the temperature TND at which the sample area reduction is 0 amounts to 1190°C. The difference between the temperature TNS and the temperature TND for PB2 steel amounts to 10°C, which corresponds to hot cracking susceptibility class "0". Class "0" indicates that PB2 steel is resistant to hot cracking after being subjected to the simulated thermal cycle having the maximum temperature of 1250°C and the cooling time $t_{8/5}$ = 12 s.

The mechanical tests (tensile tests, bend tests, impact strength tests and hardness measurements) carried out on the test joint have revealed that the conventionally welded joint (combination of 141/111 methods) meets the criteria referred to in standard PN-EN ISO 15614-1:2008/A2:2012E and standards harmonised with Pressure Equipment Directive 97/23/WE. The metallographic tests of the test joint have revealed the typical structure of the joint and confirmed that conventionally welded PB2 steel is characterised by the structure of tempered martensite obtained after stress relief annealing.

Conclusions

1. PB2 steel belongs to the group of martensitic steels having the hardness of approximately 231 HV and the toughness of approximately 209 J/cm².

2. The HAZ of the samples subjected to the simulated thermal cycle of the thermal cycle maximum temperature T_{max}=1250°C and cooling times $t_{8/5}$ from the range 2.5÷300 [s] is characterised by the martensitic structure of the hardness from the range 432÷479 HV5 and the toughness from the range 13.3÷38.1 J/cm².

3. The use of the heat treatment following the welding thermal cycle (annealing at 780°C for 2 hours) leads to a multiple toughness increase in the HAZ to the value above 200 J/cm² and a very significant hardness decrease to the value of approximately 250 HV5.

4. PB2 steel does not reveal any hot cracking susceptibility.

5. The conventionally made butt joint of the pipe is characterised by high quality meeting the requirements of standard PN-EN ISO 15614-1:2008/A2:2012E.

6. The initial assessment of PB2 steel weldability determined on the basis of brittle cracking and hot cracking tests have revealed the limited weldability of PB2 steel as after welding this steel must be strictly subjected to heat treatment.

7. The positive results of the mechanical tests of the test joint provide reasons for trial application of PB2 steel in the production of power generation system elements (piping and/or fixtures) operating in supercritical conditions.

However, the comprehensive weldability assessment requires carrying out further weldability tests such as the determination of creep resistance, annealing crack resistance and resistance to cold cracking.

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