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CHARACTERISTIC OF MAG WELDED JOINTS OF 22MnB5 STEEL GRADE FOR AUTOMOTIVE INDUSTRY

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S u m m a r y

Results of investigation of MAG 22MnB5 steel welds have been presented. The influence of welding condition on mechanical properties and microstructural characteristic of pipe joints ∅90x3,6 have been presented. The tensile strength of welded joints are slightly lower than that of the base material. The maximum hardness in the heat affected zone (HAZ) without preheating exceed 380HV10, simultaneously preheating up to 350°C caused decrease in the hardness to 266HV10. The microstructure of the weld is mainly composed of bainite and ferrite. In the HAZ bainite, ferrite and martensite are present. The results of technological welding trials and destructive examination of welds indicate that the MAG welding is a useful technology to join 22MnB5 pipes.

Keywords: 22MnB5 steel, arc welding, mechanical properties, microstructure

Charakterystyka złączy stali typu 22MnB5 dla przemysłu motoryzacyjnego spawanych metodą MAG

S t r e s z c z e n i e

W pracy przedstawiono analizę wyników badań mikrostruktury i właściwości mechanicznych złączy spawanych metodą MAG wykonanych ze stali 22MnB5. Określono wpływ warunków procesu spawania na właściwości mechaniczne i mikrostrukturę spoin wykonanych z rur ∅90x3,6. Ustalono, że wytrzymałość na rozciąganie badanych złączy spoin jest mniejsza od materiału podstawowego. Maksymalna twardość przekroczyła wartości 380HV10 w SWC dla złączy spawanych bez nagrzewania wstępnego oraz 266HV10 po nagrzewaniu wstępnym. Jednoczesne nagrzewanie wstępne spowodowało obniżenie twardości do poziomu 266HV10 w SWC. W mikrostrukturze spoiny występuje bainit i ferryt, natomiast SWC z bainitu, ferrytu i martenzytu. Analiza wyników próby technologicznej oraz badań niszczących pozwala stwierdzić, że spawanie metodą MAG jest w pełni przydatne do spawania rur ze stali 22MnB5.

Słowa kluczowe: 22MnB5, spawanie łukowe, mikrostruktura spoiny, właściwości mechaniczne i technologiczne

1. Introduction

Due to the high demand for reduced vehicle weight, improved safety, and crashworthiness qualities, the need to manufacture automobile structural

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components of ultra-high strength steels is apparent. Thus importance of 22MnB5 is rising due to its lightweight construction potential. The possibility of reaching high strength by a press hardening treatment allows decreasing wall thicknesses. Additionally, press hardening leads to increased fabrication process efficiency by cycle time reduction [1-3]. Hot stamped components are composed of safety and crash-relevant structural components of the car body, including the front and rear bumper beams, door reinforcements, windscreen upright reinforcements, B-pillar reinforcements, floor and roof reinforcements, roof and dash panel cross members [4-5]. Hot stamping is a non-isothermal high-temperature forming process, in which complex ultra-high strength parts are produced with the goal of no springback. In hot stamping process, the blanks are austenitized and subsequently formed and quenched in the die. The 22MnB5 steel has a ferritic-pearlitic microstructure with a tensile strength of approximately 600 MPa at a delivery condition. During quenching, the austenitic microstructure transforms into a martensitic one because of rapid cooling. The martensite evolution during quenching causes an increased tensile strength up to 1500 MPa [6-8]. Figure 1 illustrates an overview of the hot-stamping process sequence.

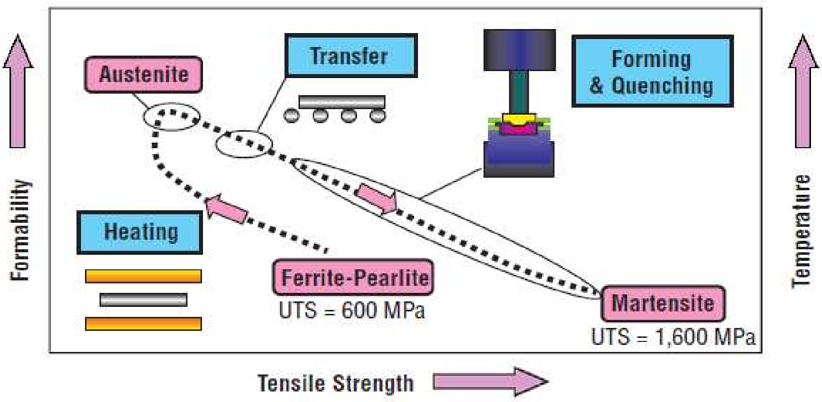

Fig. 1. Tensile strength and microstructure change during hot stamping (based on [9])

Very often 22MnB5 steel has an aluminum-silicon pre-coating that was developed to protect the metal from oxidation (scale) and decarburization during hot stamping. The pre-coating is applied to the coils in a continuous process and offers excellent resistance to hot stamping heat treatment; final parts using this forming technology have improved corrosion resistance after painting, eliminating the need for anticorrosion post treatment. The additional advantages of 22MnB5 are [10]:

- elimination of the shot blasting step required for conventional uncoated hot forming steels (no scale),
- very good final part geometric tolerance (no shot blasting, hence no deformation),
- excellent final part corrosion resistance,
- no decarburization,
- simplified process and cost savings (no shot blasting, no inert atmosphere in ovens).

According to the steel manufacturer [10] the product has a wide welding range and the mechanical (tensile, shear) performance of the joints complies with automotive manufacturer requirements and with standards. Thanks to the alloy layer obtained after hot stamping, welding electrode life is considered exceptional (several thousand spots without deterioration) compared to that of conventional metal coatings. MAG/MIG and conventional metal welding techniques, including brazing, can readily be applied.

Despite the fact that during welding the harmful effects (e.g. splinters, slag, gases and radiation) affect a human organism, along with the industrial development and particularly with the implementation of advanced electronics in machines, new welding technologies as well as devices fully or partially automating the welding process have been developed [11, 12]. The aim of continuous development of the welding process is not only joining and cutting [13], but also selective melting [14].

In the this paper, the quenchable boron steel 22MnB5 made by Arcelor Mittal was selected and technological welding tests were performed using MAG welding. During tests three different filler metal were used and for each wire the joint was made with and without preheating. The main goal of this work was to determine the relationship between welding conditions and properties of the welded joints. The samples were subjected to microstructural and mechanical testing, including macro and microscopic, tensile and hardness tests. The obtained results can be useful for the automotive industry.

2. Experimental procedure

The chemical composition of the 22MnB5 ϕ 90 is as follows C = 0.2, Mn = 1.0, Si = 0.02, P < 0.03, S < 0.01, Cr = 0.2 and B = 0.003% and mechanical properties are as follows: Rm = 675,7 MPa, Re = 607.8 MPa and A5 = 19.1%.

The experiments were carried out on a robotic welding stand (Fig. 2) which was composed of the welding machine PRO 5200 Evolution (Kemppi), the robot ROMAT 310 (CLOOS company) and the clamping system used to hold the welded pipes during arc welding. The welding parameters are given in Table 1. The mechanical properties of filler metals are given in Table 2.

Fig. 2. The robotic welding stand with clamping system

Table 1. Welding parameters of 22MnB5 ϕ 90 x 3,6 mm

No	Filler metal, standard	Welding current, A	Arc voltage, V	Preheating, °C
1.	(Böhler X70 IG) PN-EN ISO 16834 G 69 5 Mn3 NiCrMo	200	20.5	350
2.				20
3.	ESAB OK Autrod 12.51 PN-EN ISO 14341-A-G3Si1	200	20.5	350
4.				20
5.	ESABOK Tubrod 14.13 PN-EN ISO 17632-A T 42 2 M M 2 H5	220	20.1	350
6.				20
Remarks: welding wire diameter 1.2 mm, welding speed 40 cm/min, shielding gas argon with 18 % CO_2, flow rate 14 l/min., welding position PA				

To determine the influence of the welding process on properties of welded joints, the tensile and hardness tests as well as metallographic examination were carried out. Tensile testing transverse to the weld was executed on a 600 kN mechanical Instron 4210 universal testing machine at the room temperature, in accordance with PN-EN 895. All presented test data are mean values of three tensile sample results. The microstructure of the base material and welded joints was observed using the light microscope (LM) Eclipse MA 200 (Nikon). The samples were etched by the Nital reagent. Vickers hardness measurement of the welded sheet was performed along the line 1 mm below the surface of the material under the load of 90.98 N (HV10) acc. to PN-EN 1043-2:2000 by using the GNEHM Digital Brickers 220 hardness tester.

Table 2. Mechanical properties of filler metal (deposited metal) (based on [16-18])

Mechanical properties	**Filler metal**		
	Böhler X70 IG	**ESAB OK Autrod 12.51**	**ESAB OK Tubrod 14.13**
R_m, MPa	800	560	480
R_e, MPa	900	640	640
A_5, %	19	26	22

3. Results and discussion

The main goal of this investigation was to verify whether the MAG welding can be used for welding of 22MnB5 steel pipes. Technological trials, metallographic examination and mechanical tests were carried out. As the first step of the presented investigation, technological trials of MAG welding on 22MnB5 pipe ϕ 90 x 3,6 mm was conducted. The tests were performed on the experimental stand at the welding parameters (Table 1). The achieved results indicate, that for all welding parameters, welded joints with good properties can be obtained.

Before heat treatment, the microstructure of 22MnB5 steel is composed of ferrite and perlite (Fig. 3).

In order to clarify the influences of the welding process on the microstructure transformation of 22MnB5 steel, the continuous cooling transformation (CCT) diagram is shown in Figure 4. This diagram was determined by dilatometry tests, metallographic investigations and hardness measurement. In Figure 4 the ferrite start point A_{c3} reaches about 870°C, the

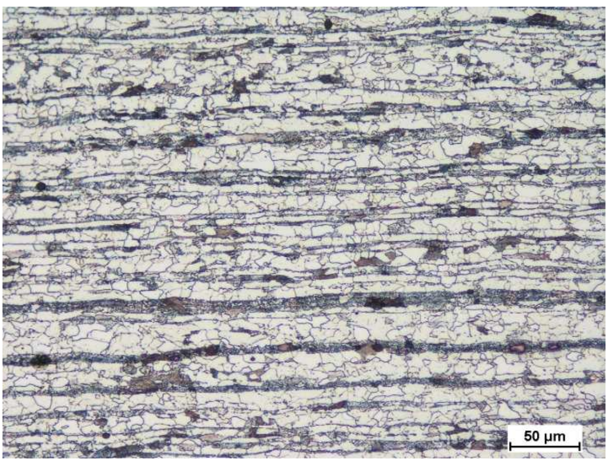

Fig. 3. The microstructure of 22MnB5 steel before heat treatment

eutectoid reaction temperature point A_{c1} amounts to 722°C, the martensite start point M lies at 410°C and the martensite finish M_f is 230°C [19]. As shown in Figure 4 cooling curves shift to the left and cooling rate decrease from e.g. 100 to 30°C/s which can suppress the ferrite, perlite and bainite transformation and increase hardenability. The homogeneous martensitic microstructure can be obtained at low cooling rate in 22MnB5. Figure 5 shows the typical HAZ (Heat Affected Zone) in the welded joint microstructure of 22MnB5 steel at different preheating temperature (20 and 350°C). The volume fraction of martensite increases with decreasing cooling rate (without preheating), then the ferrite and bainite phase fractions are gradually reduced. The preheating of the 22MnB5 steel before welding causes also the increase of the grain sizes (Fig. 5).

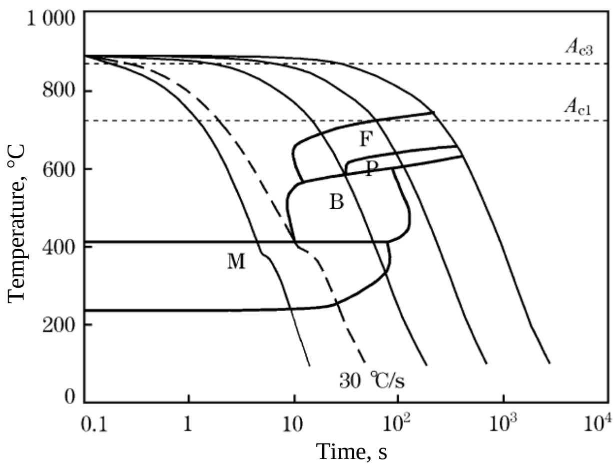

Fig. 4. CCT diagram of 22MnB5 steel (based on [19])

The results of hardness distribution in the welded joints are presented in Figure 5. The results of tensile tests of welded joints are given in Table 3. The achieved results have indicated that the preheating causes decrease in the hardness values especially in the HAZ for all specimens No 2, 3 and 5 (Fig. 6). Moreover the hardness profiles have provided the information that for all filler metals the welds have a little bit higher hardness than raw material, 187HV10 and 234HV10 (max value with preheating for specimen No 6), respectively. When the welding trials were carried out without preheating the hardness in the welds increased up to 305HV10 (max value for specimen No 2). This phenomenon is in accordance with CCT diagram presented in Figure 4.

a) b)

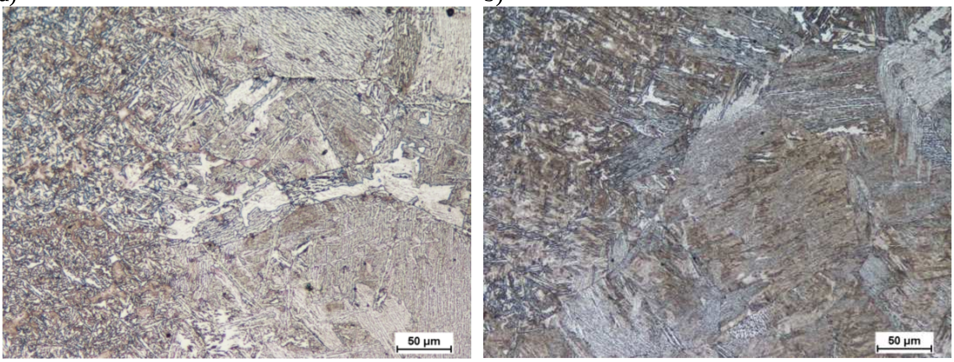

Fig. 5. Microstructure of HAZ of 22MnB5 steel: a) preheating temperature 350°C, b) without preheating, filler metal Böhler X70 IG, welding current 200A, arc voltage 20,5 V

Table 3. Tensile strength of welded joints

No of welded joint from Table 1	**Tensile strength R_m, MPa**	
	Value	**Mean value**
1	612.9	619.9
	622.6	
	624.3	
2	626.4	624.1
	618.2	
	627.8	
3	648.5	651.1
	644.3	
	660.4	
4	699.3	689.4
	681.9	
	686.9	
5	613.0	612.4
	611.9	
	–	
6	623.3	623.8
	624.3	
	–	

The results of tensile tests indicated that the for one specimen the tensile strength of welded joints is higher than the tensile strength of the raw material, 689.4 and 675.7 (without preheating for specimen No 4), respectively. It can be caused by the slightly higher strength of the raw material of specimen No 4. The preheating procedure caused decreasing of the maximum tensile strength down to 651.1 for specimen No 3.

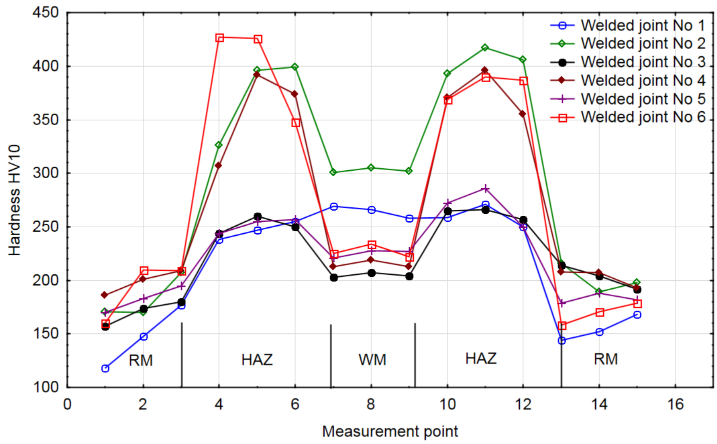

Fig. 6. Hardness distribution in the welded joints: RM – raw material, HAZ – Heat Affected Zone, WM – weld metal, Number of welded joints acc. to Table 1

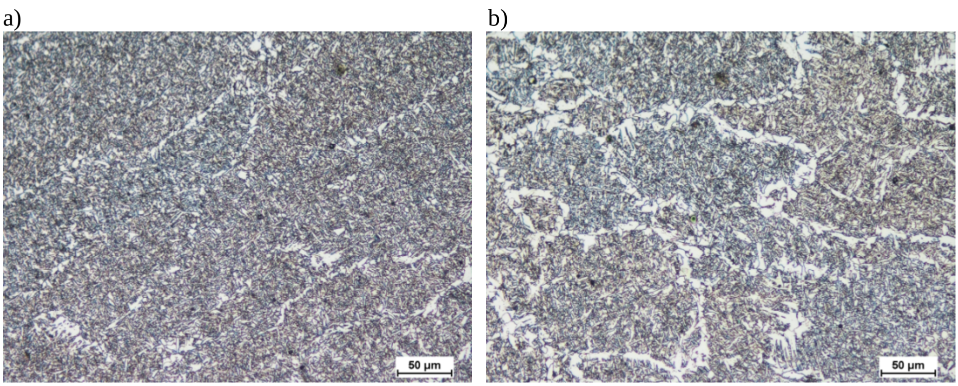

Fig. 7. The microstructure of welds in the welded joints a) specimen No 4 and b) specimen No 3, LM

The welding technological trials indicated that the best results, taking into account the tensile strength R_m (Table 3), were gained for the combination of the following welding parameters: welding current 200 A, arc voltage 20.5 V, welding speed 40 cm/min and ESAB OK Autrod 12.51 as a filler metal. Figure 5a presents the results of metallographic LM examination of the HAZ of welded joint, which was prepared at the room temperature (specimen prepared at the parameter No 4 in Table 1). Figure 5b shows the results for specimen No 3 (at the preheating 350°C). The HAZ consists of ferrite, bainite and martensite. The results of hardness test are presented in Fig. 6. The maximum hardness exceed 380 HV (the recommended value of hardness acc. to EU standard EN 15614-1 [20]) for specimen No 4 (398HV10 max value). Meanwhile the preheating decreased the hardness down to 266HV10 (max value). The weld in these welded joints is composed of bainite and ferrite mixture (215 HV10 and 205HV10 mean value for sample No 4 and 3, respectively), (Fig. 7). In the tensile test, all specimens fractured in the HAZ of a base metal. Based on the results of tensile and hardness tests, and metallographic examination, the joint performed at the I = 200 A, U = 20.5 V and preheating temperature 350°C was chosen as the best one. It should be noted, that despite using the filler metal Böhler X70 IG the tensile strength is lower than 700 MPa. This is caused by dilution of the base metal in the weld metal.

Conclusions

The properties of arc welded 22MnB5 steel joints were investigated in respect of hardness, microstructure and tensile strength. The following results were found:

- before heat treatment the microstructure of base metal is composed of ferrite and perlite mixture,
- the microstructure of the welded joint, estimated as the best one, consisted of bainite and ferrite mixture in the weld metal and ferrite, bainite and martensite mixture in the HAZ,
- the maximum hardness amounts to 398 HV without preheating, and 266HV with preheating up to 350°C,
- the maximum tensile strength R_m of the welded joint is about 689 MPa without preheating and 651 MPa with preheating up to 350°C,
- the MAG welding can be used for joining of quenchable boron 22MnB5 steel pipes with filler metal.

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