Materials Physics and Mechanics 16 (2013) 126-134 Received: March 14, 2013

STUDY OF SHIELDING GASES FOR MAG WELDING

Irina Boiko*, Didzis Avisans

Riga Technical University, Institute of Mechanical Engineering, Ezermalas 6k, LV-1006, Riga, Latvia

*e-mail: irinaboyko@inbox.lv

Abstract. The aim of our research was to find out the influence of the composition of shielding gas on costs of the welding joint. We were looking for different mixtures of shielding gas that is used in MAG welding for non-alloyed steel. For economical estimation of welding joint following researches were executed: amount of spatter on the welded parts after welding, metallographic research of welding joint, chemical composition analysis, penetration, and calculation of the welding joint. Each composition of the shielding gas provided different results for each parameter during the investigation. This brought us to the conclusion which gas mixture provides the best quality of the welding joint. During research we found out that the choice of separate shielding gas influences the speed of welding. This parameter makes the difference in calculation of the welding joint. There is also lay-out of the components that influence the costs of the welding joint in our research work.

1. Introduction

Companies in Baltic States have developed their production becoming more and more competitive within Western and North Europe during last years. Metalworking and steel processing is one of the branches that has been developed and has been in demand. A lot of production plants of this brunch are still looking for new solutions to become more competitive, to develop processes, to reduce costs and human resources. For that reason some companies are buying new equipment that give input in productivity, some companies even change the production technologies to increase the volumes of the production output.

Welding is one of the processes that takes an important role in metalworking and also is a part of all costs. It is done by different types of welding like MMA, MIG/MAG, TIG, SMAW, plasma and laser welding, depending on the set task, type of the material, thickness and other conditions. MIG/MAG welding is the process that is commonly used in the Baltic States. Shielding gas takes a great role in MIG/MAG process [1-5]. It can influence the quality and look of the welding joint, speed of the welding as well as the costs of the process.

Nowadays, there are different types of shielding gases available since the different gas companies have started their business in the Baltic States. It makes better opportunities for production companies to choose the best shielding gas for MIG/MAG process. Gas suppliers and production plants have made the tests of the shielding gas to choose which one is better for the production. Price of the shielding gas is a criterion for the owners and gas suppliers in most of the cases. However, the theoretical foundation is usually not recovered to the customer and stays at the supplier.

The aim of our research was to find out the influence of the composition of shielding gas on costs of welding and weld metal properties in non-alloyed steel using MAG welding.

2. Experimental

2.1. Materials. In the Baltic States one of the commonly used materials welded by

MAG welding is structural steel S°235 [6]. The S°235 steel plates 150°mm x 75°mm with thickness 5°mm were used for the experiments. Chemical compositions of the workpiece and of the welding wire Autrod 12.51 (ESAB Company) are presented in the Table°1.

Table 1. Chemical composition of steel S235 and welding wire Autrod 12.51.

	Content of chemical elements, %								
	Fe	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*
Wire	97.25	0.09	0.83	1.45	0.011	0.010	0.03	<0.01	0.02
	Al	*Co*	*Cu*	*Nb*	*Ti*	*V*	*W*	*Pb*	*Zr*
	<0.01	-	0.09	-	<0.01	0.01	-	-	<0.01
Steel	*Fe*	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Mo*	*Ni*
	99	0.106	0.186	0.381	0.008	0.009	0.024	0.01	0.039
	Al	*Co*	*Cu*	*Nb*	*Ti*	*V*	*W*	*Pb*	*Zr*
	0.037	0.01	0.084	0.012	<0.01	<0.01	<0.007	<0.002	0.002

Five different shielding gases were used in our experiments:

- CO_2 – cheapest shielding gas in the market. Recently, gas takes less roll in the production. It is more used in small workshops and household.
- Ar 92 % + CO_2 8 % - this is most expensive gas between the participants. Mostly used for robot welding and for thick materials. Gas supports welding with short arc and spray arc, increasing the productivity of the welding process.
- Ar 82 % (80 %) + CO_2 18 % (20 %) – mostly used as mixtures as well as 18%, as 20% in Baltic market. Gases are used with rather similar parameters. Mostly used in production as well as in household and small workshops where the look of the welding joint is important but the productivity is not themost important issue. This is one of the gases that is suggested from the welding equipment suppliers.
- Ar 75 % + CO_2 25 % - is not very reputed gas. Very good shielding gas at very low welding parameters supports short arc. Neither, shielding gas is good for welding the covered steel with zinc. Next step changing shielding gas from CO_2.
- Ar 90 % + CO_2 5 % + O_2 5 % - is not wide spread shielding gas between participants in Baltic States. Gas supports short arc as well as spray arc.

Previously mentioned gases are in the range of different gas suppliers. AGA Company is one of the suppliers that have all of these shielding gases in the product range and it is the biggest gas supplier in the Baltic States. The names and more precise content of the gases are shown in the Table°2.

Table 2. Chemical composition and names of shielding gases, supplied by AGA Company and used in these study.

No	Name	Content, %				Label
		Ar	*CO_2*	*O_2*	*NO*	
1	MISON®18	82	18	-	0,03	M18
2	MISON®25	75	25	-	0,03	M25
3	CORGON®3	90	5	5	-	C3
4	MISON®8	92	8	-	0,03	M8
5	CO_2	100	-	-	-	CO_2

2.2. Experimental procedure. S°235 samples were welded as T-joint in PB position in direction from right to left side. The view of welded joint is shown in Fig. 1. The criterion for welder was to set the parameters that afford wavelet of the welding joint between 4…5 mm.

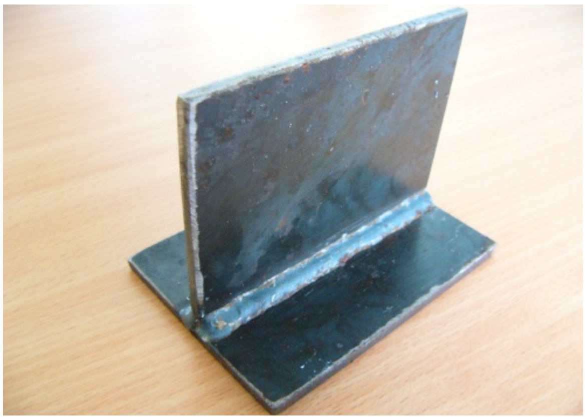

Fig. 1. View of S°235 welded T-joint.

Welding parameters of the experiments are given in the Table°3. When the parameters were set for each sample separately, the times of the each welding procedure were recorded.

Table 3. MAG welding parameters, using different shielding gases.

Parameters	M18	M25	C3	M8	CO_2
Current (A)	161	158	158	171	215
Voltage (V)	22.1	21.9	21.9	23	25.9
Welding wire speed (m/min)	9	8	8	10	10.3
Shielding gas consumption (l/min)	15	15	15	15	15
Welding joint length	150 mm				
Welding time (sec)	9,8	11,3	11,3	8,5	12
Welding speed (mm/min)	920	800	800	1060	750

2.3. Testing of welded samples. Different types of tests were done with the samples after the end of welding:

- Visual test – test on spatter after welding;
- Chemical test – chemical analyses of the welding joint after welding;
- Penetration test – penetration performance for each sample;
- Microscopic test – test of the welding joint structure (x200).

Visual test was shown, that the surface with most spatter on the sample were made by welding with CO_2 as shielding gas. All of the other shielding gases showed a good performance and all the samples were clean. It means that there is no need for additional cleaning of the metal parts after welding. It reduces the costs of the end product.

Chemical analyses of the welding joint were made by using the optical spectrometer PMI-MASTER PRO. After penetration test (macroscopic test) the microscopic test was executed. All samples were cut into small pieces and grinded until there were no scratches on them. By using the digital microscope and the program NEXSYSS Image EXPERT we were able to get the pictures of the welding joint structure with x 200 (times) enlargement.

3. Results and discussion

3.1. Chemical composition and microstructure. The results of the chemical analyses of the material of the welding joint after welding are shown in the Table°4. In general, the chemical composition of the weld metal was dependent of used shielding gas. For most elements the variations were not very significant, but for elements such as C, Si, Mn, P and S these variations are considerable (Table°4). You can find that CO_2 as a shielding gas shows the worst result between all gases in relation to the composition of weld metal. A lot of important micro alloying elements was burned out from the weld metal. It can influence the strength of the welded parts during the exploitation [1, 2, 5].

Table 4. Chemical composition of material of the welded joint (fragment).

Gases	Content of chemical elements, %									
	Fe	*C*	*Si*	*Mn*	*P*	*S*	*Cr*	*Ni*	*Ti*	*V*
M18	95,8	0,637	1,41	1,50	<0,005	0,007	0,0773	0,0406	0,0178	0,0125
M25	92,7	0,488	>2,25	>2,5	>0,125	0,236	0,0499	0,0383	0,0204	0,0150
C3	95,3	1,00	1,35	1,00	0,0339	0,0494	0,0268	0,0209	0,0245	<0,002
M8	93,8	1,15	1,28	1,45	>0,125	>0,4	0,0932	0,0433	0,0176	0,0147
CO_2	98,5	0,366	0,485	0,533	<0,005	<0,005	<0,005	<0,005	0,028	<0,002

There were made tests with rather similar shielding gases by Mr. I. Uygur and Mr. B. Gulenc in their research work „The effect of shielding gas compositions for MIG welding process on mechanical behavior of low carbons steel" [7]. Graph in the Fig. 2 displays that the yield stress for the joint with CO_2 is the lowest between all shielding gases. Also it is becoming lower as the Oxygen is used in the shielding gas mixture. The content of the manganese is lower for Ar + CO_2 + O_2 then for other mixtures of Ar + CO_2. Oxygen that is taking place in the mixture is supporting the burning of the micro alloying elements in the welding pool. This explains why, for example, manganese is less content in the welding joint that can cause the weaker strength of the joint.

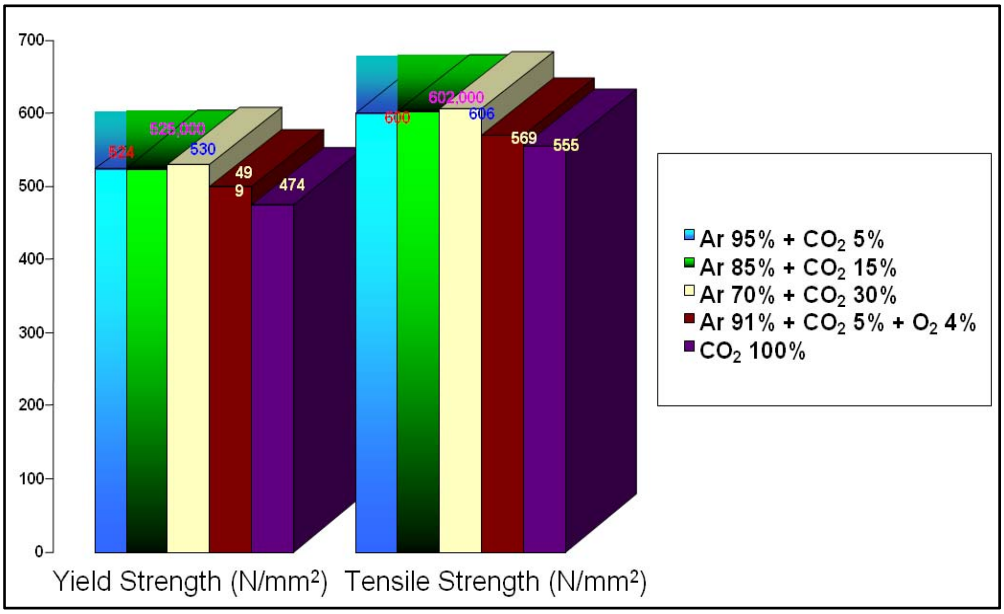

Fig. 2. Yield and tensile strength of the welding joint [7].

As we can see from Fig. 3 the shielding gas influence on microstructure of material of welding joint too. The most homogeneous structure is received, using shielding gas MISON®8 (Fig. 3 d). It is evident that an increase in CO_2 content in the shielding gas as well as applying of O_2 in the mixture of gases (Fig. 3 c) increases the grain size due to the higher heat input.

Degree of oxidation is high for pure CO_2 and increases with higher quantities of CO_2 and or O_2 in the shielding gas. The presence of a very high volume fraction of inclusions may initiate premature ductile fracture [8].

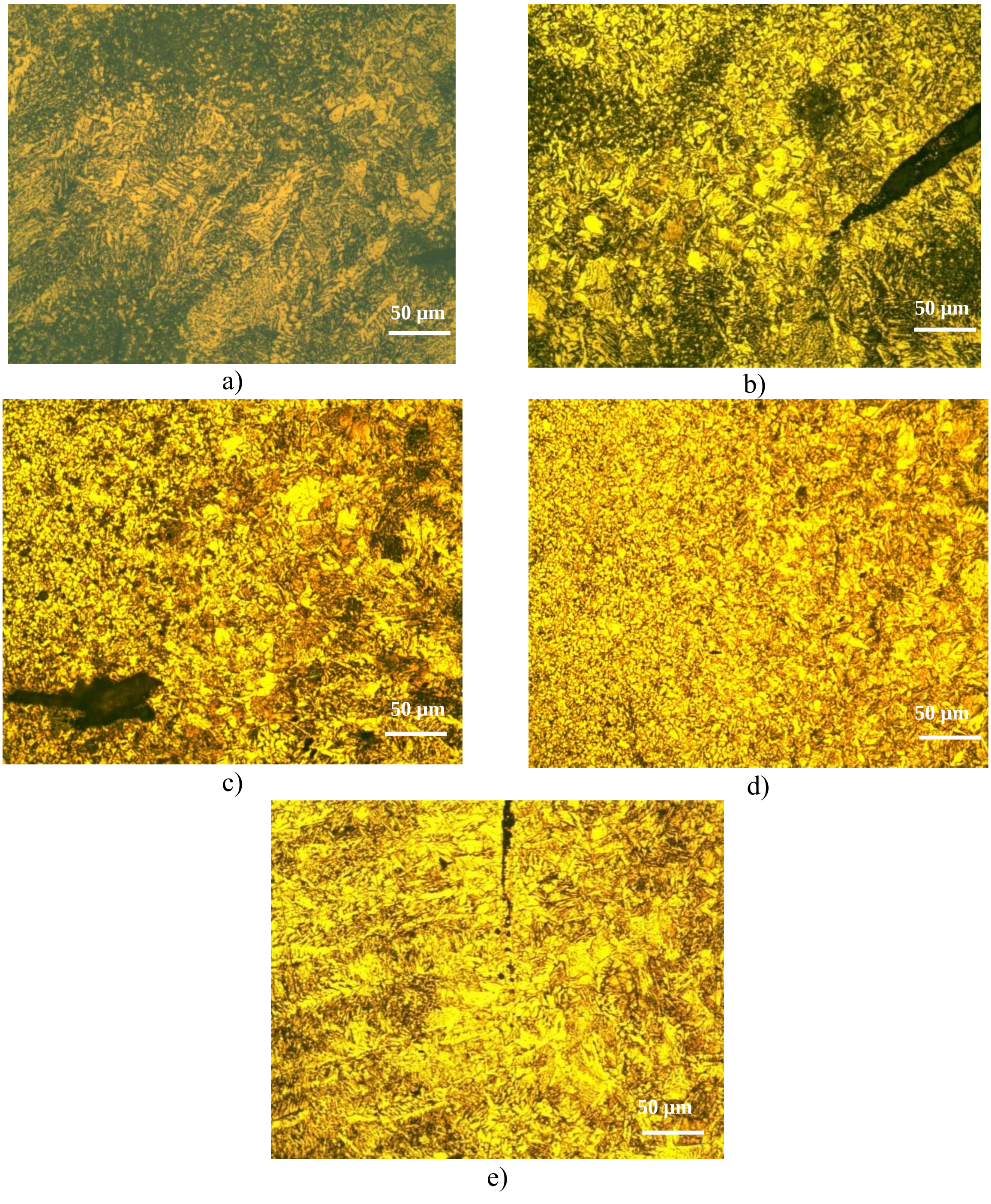

Fig. 3. Microstructure of the weld metal using different shielding gases: a)MISON®18; b) MISON®25; c) CORGON®3; d) MISON®8; e) CO_2.

3.2. Penetration level. The next step of the experiments was to find out the quality of the welding joint from the penetration point of view. The degree of penetration and side wall fusion, size and position of the welds are important factors, because they all reflect the quality of the weld. We cut samples into pieces and then grinded them until the structure of the penetration was recovered. The macrostructure of the welded samples is presented in Fig. 4.

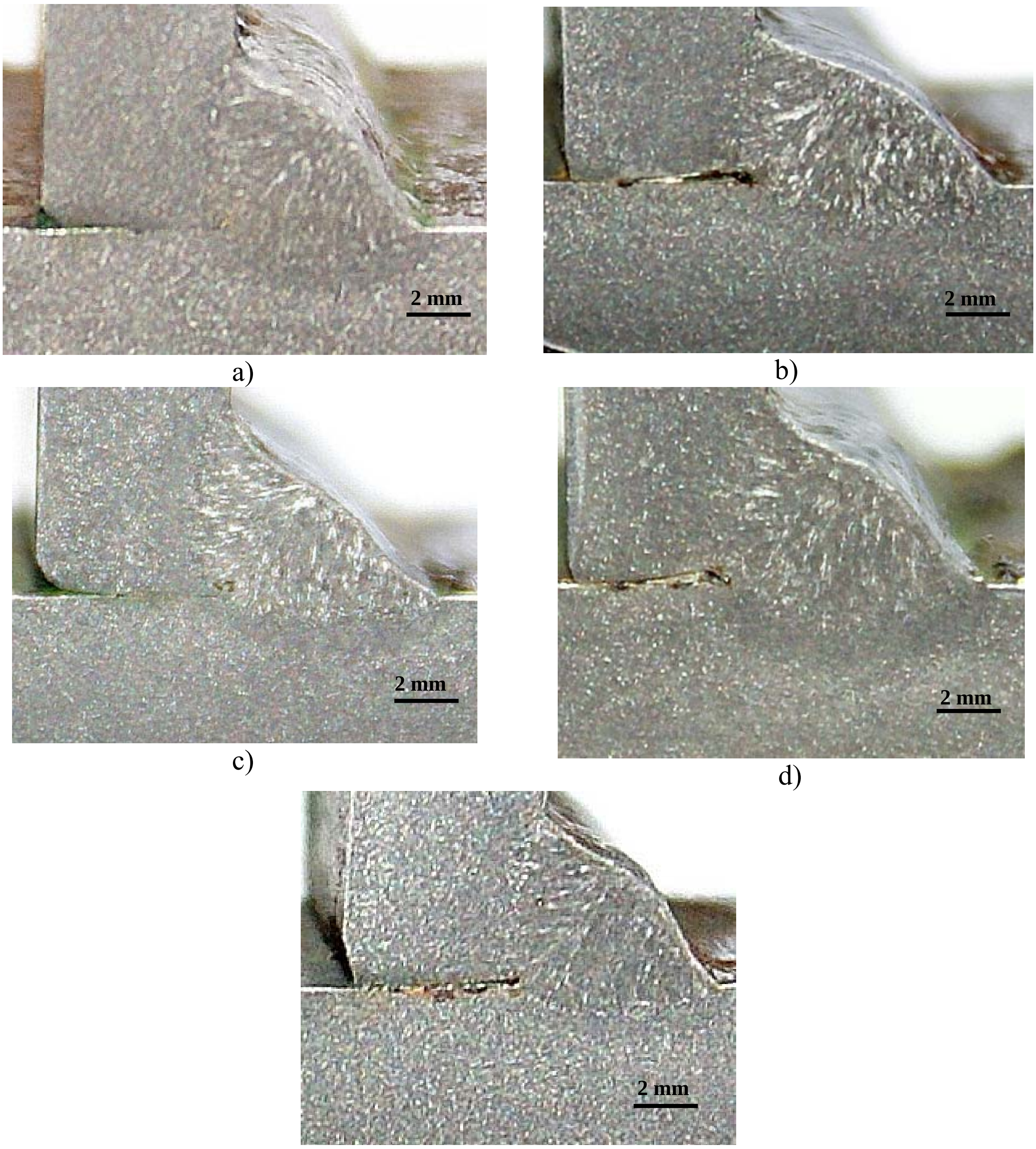

Fig. 4. Penetration view of the weld using different shielding gases:
a) MISON®18; b) MISON®25; c) CORGON®3; d) MISON®8; e) CO_2.

It is shown that the penetration is the best for the CO_2 shielding gas. This might be described with the short circuit that forms when the welding wire is melt in the welding pool. This is also the reason where the spatters after welding with CO_2 come from. The same time this short arc also melts the base material and it forms a wide and good penetration.

The worth penetration was performed by the shielding gases with Ar + CO_2 + O_2. Shielding gas with O_2 content might have rather interesting influence on the welding pool. Oxygen is working in two ways during the whole arc process:

• First, it rises the temperature in the welding pool as the melted material becomes more viscous and stays on the top of the welding pool;

• Second, oxygen creates an oxide layer on the bottom of the welding pool so that the arc cannot burn it when the next drop of the welding wire reaches the welding pool [9].

Spatters do not appear a lot during the welding process because of the high temperature and very good melted metal in the welding pool.

Shielding gas mixtures with different content of CO_2 performs a good penetration. Depending on the quantity of CO_2 we can see how deep the penetration is and how fast welding process should be done to create a good and nice looking welding joint. Smaller or bigger drops of the melted welding wire falls into the welding pool during the welding. The size of the droplets depends on the chosen welding parameters and shielding gas. The higher the parameters and less CO_2 content in Ar the droplets are getting smaller. This is why the spatters during welding do not appear so much in welding with mixture where CO_2 is 8 % in Ar.

3.3. Cost of the welding joint. The welding time was set during the experiments for each sample as it's described previously. This step was done with an aim to find out the influence of the shielding gas on the costs of the welding process. We can easily calculate the welding speed of the process as we know the length of the sample and the arc time. Nevertheless, we can also calculate the volume of shielding gas and amount of the welding wire used as these parameters are displayed on the gauge and welding equipment. American scientists in their article "7 effects of shielding gas" [10] wrote that shielding gas takes only 5 % of whole welding process costs. The greatest part of the costs takes the salary for the welder.

Taking into account previously mentioned we can understand that the costs depend on the time spent for welding. As faster you weld as cheaper the labour force and welding costs are. Important roll of the welding takes the spatters that stay on the welding peace. Spatter is the welding wire that is melted but hasn't stayed in the welding pool. It means that only a part of the fed welding wire is used in the welding joint. Some companies have calculated the coefficient of efficiency of the welding wire depending on the shielding gas. From 80 to 90 % of welding wire stays in the welding joint by using the CO_2 as the shielding gas.

To make the calculation more objective we decided to take the average welder salary in Latvia. We asked 10 steel processing companies for the information about the salary level for the best welders in their companies. It gave us possibility to adopt these figures to our calculation. The price for the welding wire was given by ESAB Company and price for the shielding gas was supplied by gas supplier AGA Company.

Methodology of calculation of the total cost of the welded joint is presented in the author's paper [11]. Prices of welding materials and calculated costs for the examined samples are collected in the Table°5 and shown as a graph in the Fig. 5 below. First of all it proves that American scientists [10] were correct regarding influence of shielding is 5 % but only in the case of CO_2.

However, shielding gas takes more roll in welding costs when the Ar mixtures are used. Labour force costs are similar in both applications – CO_2 and Ar mixtures. It is also interesting to see that the influence of the welding wire that stays in the welding pool gives the influence on welding costs. It's taking more share in the joint made by CO_2 with even more then 10 % difference against that joint made by Ar mixture MISON®8.

Table 5. Results of calculation of the cost of the welded joint (EUR).

	MISON®18	MISON®25	CORGON®3	MISON®8	CO_2
$Price_{w.w.}$ *Welding wire*	1.90	1.90	1.90	1.90	1.90
$Price_{sh.g.}$ *Shielding gas*	6.27	5.90	6.80	7.13	1.07
$Costs_{w.w.}$ *Welding wire*	0.11	0.11	0.11	0.11	0.18
$Costs_{sh.g.}$ *Shielding gas*	0.10	0.12	0.13	0.10	0.03
$Costs_{lab.}$ *Labour*	0.25	0.28	0,29	0,21	0,29
$Costs_{tot.}$ *Welding process*	0.46	0.51	0.53	0.42	0.50
$Costs_{w.j.}$ *Welding joint*	0.070	0.077	0.078	0.064	0.074

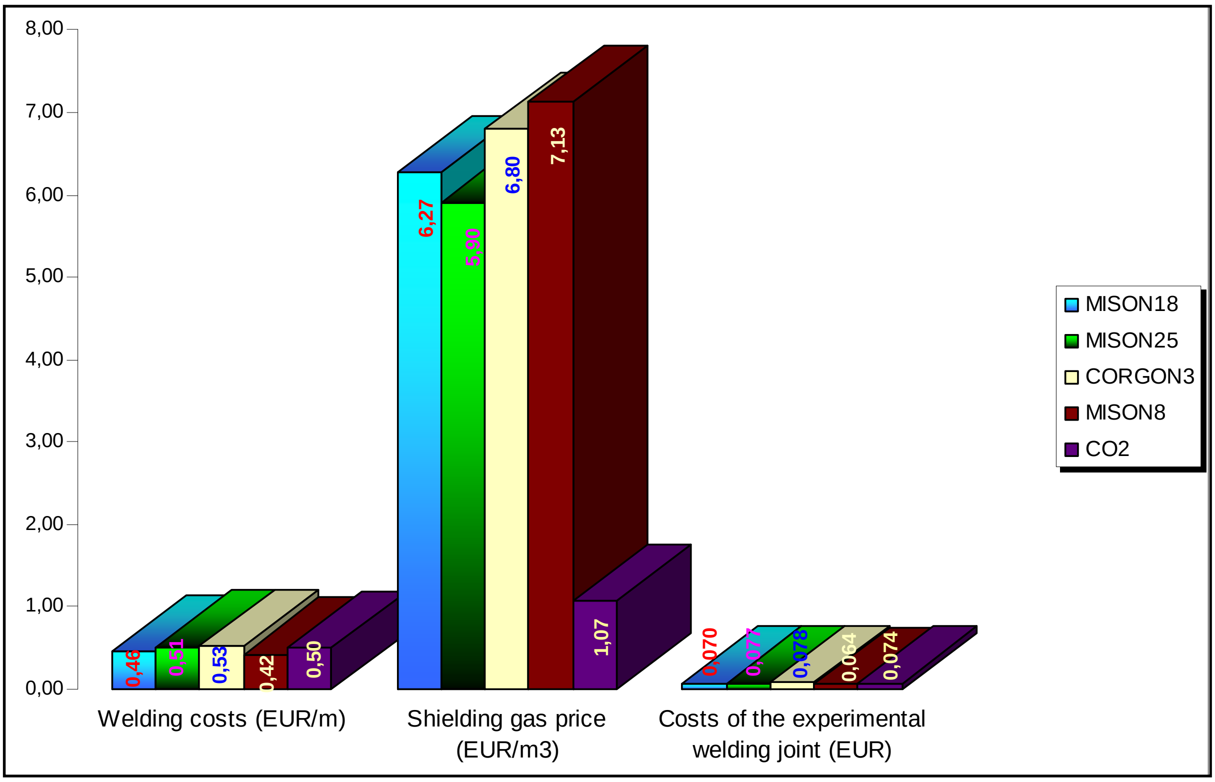

Fig. 5. Graph of calculation of the cost of the welded joint.

4. Conclusions

During investigation it was revealed, that different shielding gas gives different influence on welding process, welding joint quality and also on the welding costs. Some of the most important conclusions are displayed below:

- The chemical composition and microstructure in S°235 weld metals, as well as weld penetration and Yield and tensile strength of the welding joint are influenced by CO_2 and O_2 content in the shielding gas.

- It was clearly discovered that the carbon dioxide is not the best choice for the shielding gas. It showed the worth results during the welding process, more spatter, and lower welding speed. Pure CO_2 performs the worth result between all gases in relation to the composition of weld metal. A lot of important micro alloying elements was burned out from the weld metal and it's makes the welding joint weaker.
- Better results were performed using Argon mixtures with CO_2 and or O_2 – good welding performance, not much spatters, good welding speed. In general, the content of micro alloying elements in the welding joint is less when the oxygen is involved in shielding gas and with increasing carbon dioxide content in the shielding gas.
- Despite the cheapest price of the shielding gas, CO_2 do not perform the cheapest welding costs. Shielding gas MISON®8 (Ar 92 % + CO_2 8 %) shows the opposite results – shielding gas is the most expensive one, but the speed is the highest and costs of the welding joint are cheaper than the costs with other gases. Taking into account that other characteristics of weld metal are the best, it can be concluded, that Ar mixture with 8 % CO_2 is the best choice for S°235 steel MAG welding.

Acknowledgement

This work has been supported by the Riga Technical University within the research project ZP-2012/12 "Study on Shielding Gases for MAG Welding".

References

[1] S. Mukhopadhyay, T.K. Pal // *Manufacturing Technology* **29** (2006) 262.
[2] R. Kacar, K. Kokemly // *Materials and Design* **26** (2005) 508.
[3] S. Zielińska, F. Valensi, N. Pellerin, S. Pellerin, K. Musioł, Ch. de Izarra, F. Briand // *Journal of Materials Processing Technology* **209** (2009) 3581.
[4] I. Pires, L. Quintino // *Materials and Design* **28** (2007) 1623.
[5] Ehsan Gharibshahiyan, Abbas Honarbakhsh Raouf, Nader Parvin, Mehdi Rahimian // *Materials and Design* **32** (2011) 2042.
[6] A. Filipov, I. Boiko // *Welder*, Ukraine, **6** (2007) 36. (in Russian)
[7] I. Uygur, B. Gulenc // *Metalurgija* **43 (1)** (2004) 35.
[8] R.A. Farrar // *Weld Metals Fabrication* **44 (8)** (1976) 578.
[9] M.I. Onsoeien, S. Liu, D.L. Olson // *Welding Journal* **75 (7)** (1996) 216.
[10] W.F. Garth Stapon, K.A. Lyttle, *7 Effects of Shielding Gas* (http://www.thefabricator.com).
[11] D. Avisans, I. Boiko, In: *Proceedings of 7th International Symposium „Surface Engineering. New Powder Composition Materials. Welding"*, 2nd Part, March 2011 (Minsk, Belarus, 2011), p. 226.