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Research on Weld Cladding of Valves Used in the Petroleum Industry

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Abstract

This paper presents the technology and the equipment designed for internal cladding of a 4 $^1/_{16}$ inch petroleum valve subjected to severe corrosion and erosion, by using the Metal Inert Gas (MIG) procedure. The welding technology and the layer characteristics were analyzed by metallographic research, hardness measurements and corrosion and wear behavior of the cladding.

Keywords: *weld cladding, Metal Inert Gas (MIG) procedure*

Foreword

The media flowing through a valve destined for petroleum industry are strongly abrasive and corrosive. As a result, processes as wear of seat-obturator and corrosion of the inside body of the valve occurs, leading to loss of tightness and need of premature replacement of valves, with important technical, economic and ecological consequences.

To avoid the inside corrosion of the valve's body, the following cladding procedures are used:
- molding the valve body using a metal core from the cladding material;
- cladding by Hot Isostatic Pressure (HIP);
- cladding by welding.

Choosing the right procedure for cladding depends of parts shape and dimensions, basic material type, cladding material and also economical conditions of the applied technology.

This paper presents the results of the research on cladding equipment and technology for internal cladding of a 4 1/16 inch valve, by using the MIG procedure, as well as the behaviour of the coated surface to corrosion and wear.

The Equipment and Charging Technology Used for Cladding

Welding procedures applicable to cladding the internal surface of valves

Cladding the inside of valves by using welding technology is a difficult procedure due to the folowing factors:

- there is a limited space (the inner diameter of the valve) that does not allow easy handling of welding heads, nor observing the cladding procedure;
- the welding process generates intense heating of the welding torch.

Nowodays the Wolfram Inert Gas (WIG) technology start to be used extensively. This technique uses an automatic programming system for the welding head movement and wire supply, wich allows the interior cladding, however this technique is costly and nonproductive.

The results obtained by using the MIG cladding technology, as presented in this research are proving that by manufacturing an equipment and implementing the Metal Inert Gas (MIG) procedure would be achieved a more productive technology for weld cladding with Stellite.

Equipment and materials used for weld cladding based on MIG procedure

Equipment used in this research for weld cladding using the MIG procedure is composed of ESAB MIG C420W welding source, Aristo Feed 3000 feeder, positioning table and shielding gas supply (88% argon 12% CO_2).

To realise the inner cladding of valve bodies, a welding new head that can be introduced inside the valve has been designed. This head also withstand highest temperatures due to water cooling, can be easy handled by the welder and could be easily adapted for automated aplications.

Due to the fact that the original parts of an original MIG torch do not allow for easy acces at the interior of the valve, a „hibrid” welding torch has been developed. Instead of the MIG torch gas diffuser, collet and current nozzle, a 1.6 mm diameter collet body with a gas lens was used from a WIG torch. Instead of the MIG torch gas nozzle, a ceramic shielding gas nozzle was used, wich can be fitted directly to the collet body. An intermediary part has been developed wich permits mounting the gas lens collet to the MIG torch body. Thus, a new welding torch was obtained, having the shape and components that can be seen in figures 1 and 2.

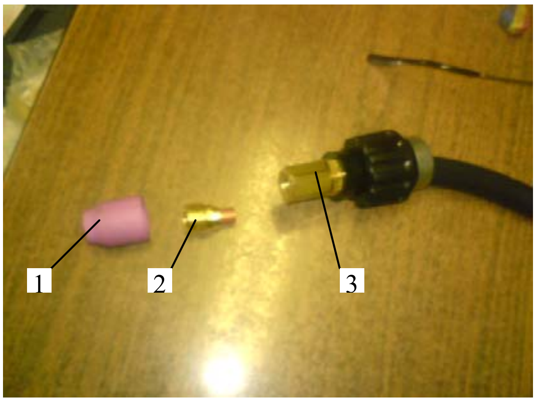


Fig. 1. MIG welding torch components: 1. ceramic gas nozzle; 2. collet body-gaz lens; 3. swan neck

Fig. 2. MIG welding torch shape

Usually, materials used for cladding of petroleum valves are Stellite type alloys and are composed of 45-65% Co, 15-35% Cr, 1-2.5%C, W and Mo. Although Stellite type alloys are high resistant to abrasive wear and corrosion, but offer a poor cutting machinability, as they are used in cast state or in the form of metal deposition. In turn, it is possible to grind or polish Stellites with an abrasive material, by using cooling systems to prevent local overheating wich can produce internal stresses, deformations or cracks. There it is a large variety of Stellite type alloys, however for this particular application, the 1.2mm diameter Stellite 1 type welding wire was used. The chemical composition of this alloy is presented in the table 1.

Table 1. Chemical composition of welding wire

Added material	**Chemical composition [%]**					
	Co	C	Cr	W	Mo	Si
Stellite 1 type wire with 1.2 mm diameter	45.5	2.1	30	17	2.5	0.8

The valve to be claded has the chemical composition presented in table 2, according to the international industrial valve manufacturing standards.

Table 2. Chemical composition of valve material

Type	**Product chemical analysis**							
AISI 4130/75K	Fe, %	C, %	Si, %	Mn, %	P, %	S, %	Cr, %	Mo, %
	85.7	0.228	0.159	0.123	0.028	0.027	12.19	0.096
	Ni, %	Al, %	Co, %	Cu, %	Pb, %	Ti, %	V, %	W, %
	0.208	0.006	0.165	0.255	0.002	0.006	0.055	57

Cladding technology

The technological steps are:

- Positioning and fixing the valve to the workbench;
- Preheating the sample to 190^{o}C;
- Verifying the preheating temperature;
- Applying first layer of Stellite (welding parameters: tension - 28V, current 197A, speed - 5m/min);
- Measuring the temperature of the valve and waiting until the temperature is 190 ^{o}C;
- Aplying the second layer of Stellite;
- Measuring the temperature of the valve and waiting until the temperature is 190 ^{o}C;
- Aplying the third layer of Stellite;
- Grinding the valve.

Research Regarding the Cladded Layer's Behaviour to Wear and Corrosion

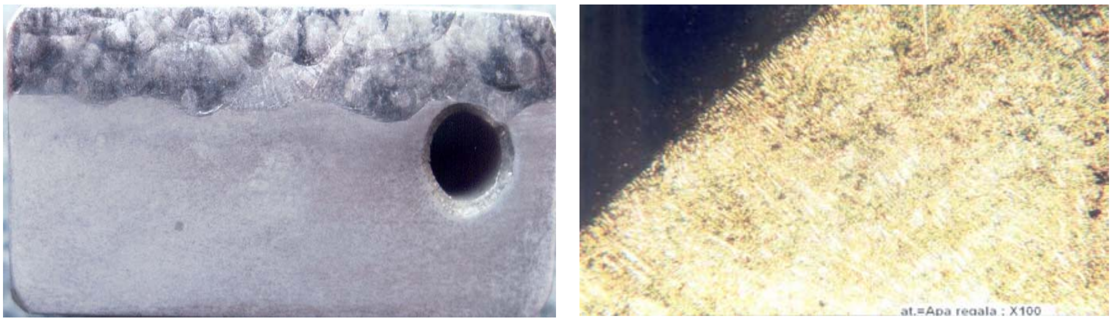
After cooling the valve the sample cooled down, cylindrical and rectangular samples were cut from it and then subjected to experimental tests according to the programme presented in table 3. Stellite layer thickness after samples processing was approx. 4,5 mm.

Sample's macro and microstructural analysis

The visual examination, shows no visible defects (cracks, concavities). The sample's microstructure was examined at 100 x zoom using a metallographic microscope after a specific reactive attack (royal water). Photographs taken include the base material as well as the deposition. Images of the studied areas are presented in figure 3.

Table 3. Experimental tests programme

Sample	Trial run	Equipment used
Stellite cladded sample using the MIG procedure	1. Sample's macro and micro-structural analysis	Metallographic microscope
	2. Hardness test	Krautkramer MIC 10, MC 205 hardness measurement device , 10N force
	3. Corrosion behavior analysis	Water solution + HCl Crude oil solution + NaCl
	4. Wear behavior analysis	C.S.M. Instruments tribometer



Macroscopic view of the deposited layer The microstructure of deposited layer

Fig. 3. Images of the samples cladded using the MIG procedure

Hardness test

The hardness test was performed on samples containing the cross section of the Stellite layer. Hardeness measurement locations were placed according to figure 4, both in the deposited material and the base material. Results are presented in table 4.

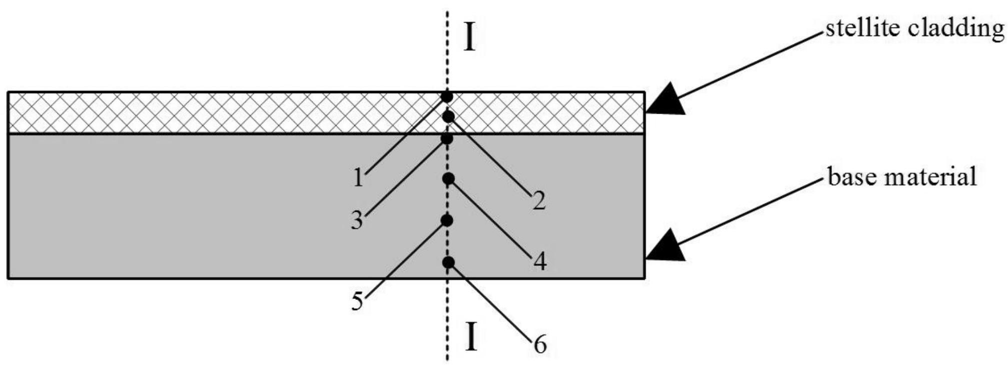


Fig. 4. Hardness measurement locations on the samples cladded using the MIG procedure

Table 4. Hardness test results

Type of test	Print number	HB hardness		
		Base metal	ZIT	Deposited metal
Samples cladded with Stellite using the MIG procedure	1	-	-	442
	2	-	-	422
	3	-	382	-
	4	226	-	-
	5	218	-	-
	6	212	-	-

Note that the deposited layer's hardness is greater than that of the base material and corresponds to the valve manufacturing standards.

Corrosion behavior analysis

Tests were performed in real petroleum industry environments. Rectangular samples were kept in these environments: crude oil + 0,05 NaCl, well water + 0.35% HCl and 0.8% HCl for 240 hours at 20°C. The test results are presented in table 5. To determine the corrosion rate the gravimetric method was used:

$$v = \frac{\Delta m}{A \cdot t} \qquad (1)$$

where: Δm - mass lost in the corrosion process; A - surface area subjected to corrosion; t - exposure time in corrosive environment.

Table 5. Corrosion test results

Test	Environment	Surface area subject to corrosion (cm^2)	Mass lost in the corrosion process (mg)	Corrosion rate (mg/cm^2x hours)	Penetration (mm/year)	Note
Samples cladded with the MIG procedure	Crude oil + 0.05% NaCl	19.4564	0.0005	0.107×10^{-3}	1.19×10^{-4}	Highly resistant
	Water + 0.35%HCl	19.4564	0.0334	7.15×10^{-3}	7.97×10^{-3}	Highly resistant
	Water + 0.8% HCl	19.4564	0.0340	7.28×10^{-3}	8.12×10^{-3}	Highly resistant

Note that the water attack was more intense than the crude oil attack.

Wear behavior analysis

Wear behavior of the layer deposited with the MIG procedure has been analyzed by determining the friction coefficient and wear rate. The device used was the C.S.M. Instruments (Swiss

Confederation) tribometer housed at the Gas-Petroleum University in Ploiesti. The C.S.M. tribometer determines friction coefficient, friction force, dynamic penetration, wear rate and pure sliding conditioned electrical contact resistance for first class friction couple (sphere on a plane), fourth class (plane on plane) and rolling slide in dry or lubricated conditions. Fig. 5 shows the tribometer, while fig. 6 presents its main active features.

Fig. 5. The C.S.M. tribometer

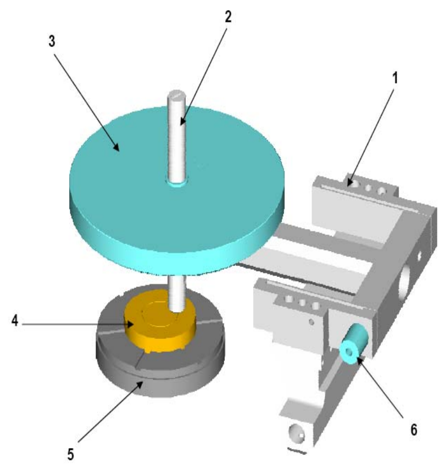


Fig. 6. The principle scheme of the tribometer's active parts:
1. Elastic slide; 2. Ball support, tip or planar test-piece; 3. Weights; 4. Disk test-piece chuck clamp; 5. Tangential force sensor; 6. Penetration sensor.

The working parameters were:

- workload 1N, 2N;
- slide speed 0.418m/s;
- working environment: dry, 25^{o}C;
- relative air humidity RH=30%;
- 100Cr6 steel ball Ø = 6mm;
- 200m friction distance
- disk test-piece (Ø = 30mm and height = 14mm) AISI 4130 Stellite cladded steel.

Preparing the test-pieces consists of degreasing all surfaces by immersion in methyl-ethyl-ketone (MEC), followed by air drying. It is recommended that after mounting the test-pieces, all active surfaces should be re-wiped.

The wear lane width on the disk and wear on the ball have been measured using a metallographic microscope equipped with a scaled eye-piece. For calculating the area of the wear mark cross-section on the disk test-pieces a special software written in Pascal language was used. The resulting area value was then uploaded to the tribometer's INSTRUMX software to calculate the wear rate. Results are shown in fig. 8, 9 and table 6.

By analyzing the values obtained for both friction coefficient and the wear rate, it is observed that the samples cladded with Stellite have better wear resistance than the samples of AISI 4130, material used to manufacture the valve body.

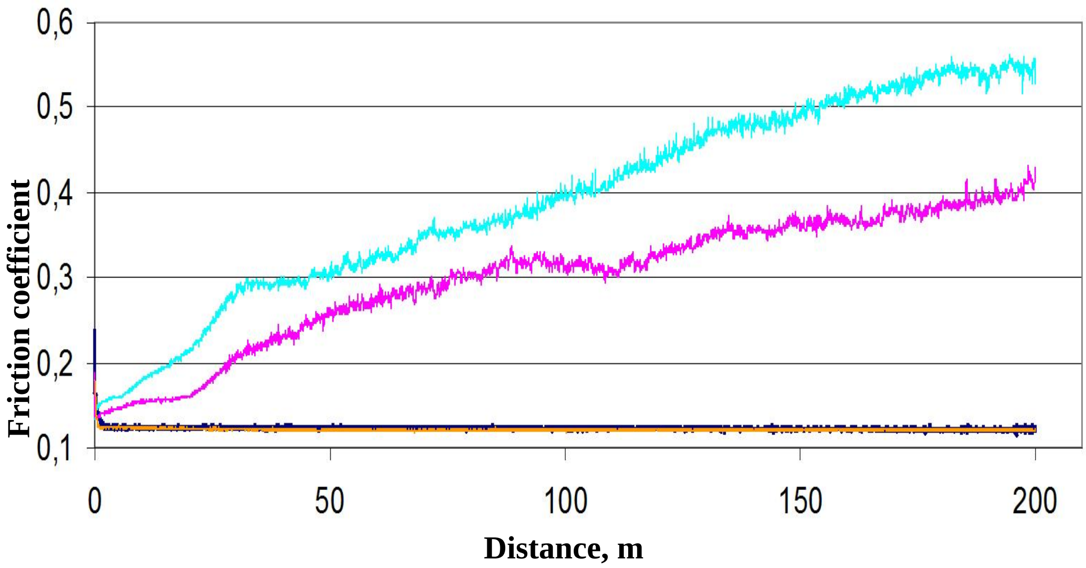


Fig. 8. Friction coefficient variation, depending on distance for loads of 1N and 2N

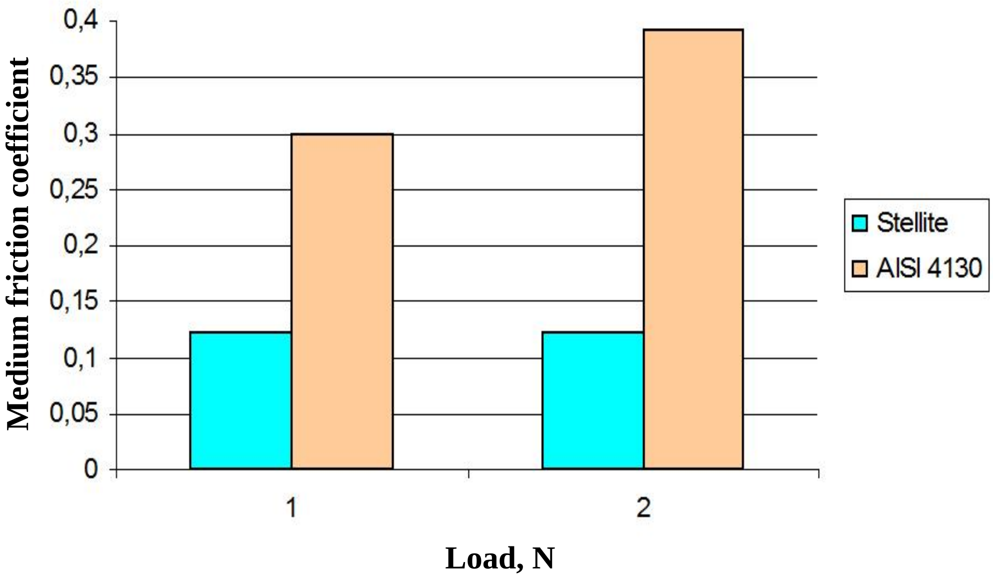


Fig. 9. Schematic representation of the average friction coefficient, depending on load

Table 6. Wear behavior results

Test	Load (N)	Average friction coefficient	Wear rate (mm^3/N/m)
AISI 4130	1	0.300	302×10^{-6}
	2	0.391	303×10^{-6}
Stellite	1	0.123	0.9657×10^{-6}
	2	0.122	0.959×10^{-6}

Conclusions

The equipment designed for inner cladding by welding of valves using the MIG procedure is effective and works properly.

The new procedure would provide a much better effectiveness in the production of reliable valves to be used in petroleum industry.

Cladding the valves with Stellite type materials in multiple layers led to a surface highly resistant to corrosion and wear.

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Cercetări privind placarea prin sudare a robinetelor utilizate în industria petrolieră

Rezumat

În lucrare se prezintă rezultatele cercetării echipamentului şi tehnologiei de placare prin sudare a corpului şi a suprafeţelor de etanşare ale unui robinet 4 $^{1}/_{16}$ inch utilizând procedeul Metal Inert Gas (MIG). Tehnologia de sudare şi caracteristicile stratului placat s-au evaluat prin cercetări metalografice, măsurători de duritate, determinarea comportării la coroziune şi la uzare.