ISSN 0543-5846
METABK 46 (4) 273-276 (2007)
UDC - UDK 669.15–419:621.791.4:62–229.348=111

INTRODUCTION OF EXPLOSIVE CLADDING TECHNOLOGY FOR THE MANUFACTURING OF HYDRAULIC CYLINDERS

Received - Primljeno: 2006-07-26
Accepted - Prihvaćeno: 2007-01-10
Preliminary Note - Prethodno priopćenje

The microhardness, microstructure and bond strength of the interface of a bi-metallic joint on the cross-section of the testing hydraulic cylinder were investigated. Experimental findings of related to both method of cladding obtained with metallographic and mechanical investigations of the interface between the CuSn6 bronze and the TS5 (Č.1213) steel cylinder, are given.

Key words: *explosive cladding, hydraulic cylinder, bond strength, bronze-steel interface*

Uvođenje tehnologije eksplozijskog platiranja u postupku izrade hidrauličkih cilindara. Istraživani su mikrotvrdoća, mikrostruktura i čvrstoća veze međupovršine bimetalnog spoja po poprečnom presjeku ispitivanog hidrauličnog cilindra. Na osnovi metalografskih i mehaničkih ispitivanja međupovršine između CuSn6 bronce i čeličnog cilindra TS5 (Č.1213) usporedno su prikazani odgovarajući rezultati ovih dviju tehnologija platiranja.

Ključne riječi: *eksplozijsko platiranje, hidraulički cilindar, čvrstoća veze (spoja), međupovršina bronca/čelik*

INTRODUCTION

In the manufacturing of hydraulic cylinder, bronze cladding technology is applied to form gliding pairs of various materials [1]. In this way the occurrence of cold welding of the gliding pairs during overloading in the working process (the application of the cylinder on a hydraulic press for sheet-metal bending) is prevented [2].

The hydraulic cylinder and the piston, as the gliding pair in hydraulic presses, are not exposed to a dynamic overloading that could cause an abnormal working and lead to cold welding, however, in practice there are cases of cold welding of these pairs. The causes of this welding are identified as:

- irregularry defined tolerances,
- inadequate processing quality of the gliding surfaces,
- dirt in the oil,
- bronze cladding quality, and
- bronze material quality.

Bronze cladding is a discontinuous process, which may lead to the formation of porous surfaces and hard zones and, in this way, to the impairing quality of the gliding surfaces.

We have investigated alternative gliding-pairs forming technologies from various materials, intended for hydraulic cylinders of presses for sheet-metal bending [3].

The technology of explosive cladding has been used for the production of bi-metal materials (bronze clad steel for hydraulic cylinders) featuring high physical-mechanical and service properties [4 - 7]. This technology is based on an explosive detonation, whose energy is transferred by a special medium to the material being cladding. A detailed description of the explosive technique is given in [8 - 13]. In these investigations, the experiments were performed in improvised conditions [14, 15].

PRESENT TECHNOLOGY FOR THE PRODUCTION OF HYDRAULIC CYLINDERS

The manufacturing of hydraulic cylinders (Figure 1.) is carried out according to standard technology [16]. The main operations are bronze cladding on the previously prepared inner surface of the steel hydraulic cylinder and turning. The bronze cladding is conventionally carried out as follows:

- cleaning and removing grease from the surface,
- application of dissolving material on the surface (*CASTOLIN* 18),
- cylinder pre-warming up to 300 °C, and

V. Jovišević, Faculty of Mechanical Engineering University of Banja Luka, Banja Luka, Bosnia and Herzegovina, M. Soković, Faculty of Mechanical Engineering University of Ljubljana, Ljubljana, Slovenia, B. Kosec, Faculty of Natural Sciences and Engineering University of Ljubljana, Ljubljana, Slovenia

- application (cladding) of bronze on the surface with the electrode *CASTOLIN CP* 146.

With turning and grinding the final dimensions of the cylinder are achieved. The technological process is limited by the following:
- porosity of the cladded bronze layer,
- heating to prevent the formation of hard zones, and
- the difficulties in cutting the groove for the gasket because of the eventual presence of hard zones on the boundary bronze steel.

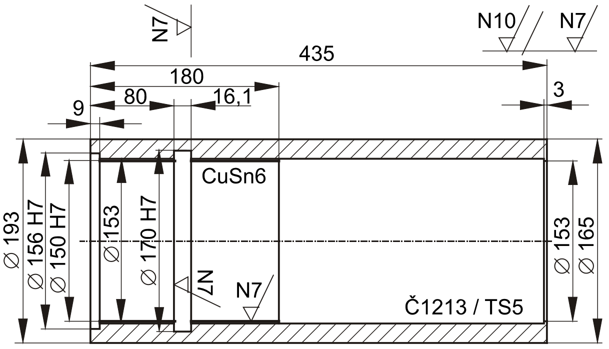

Figure 1. **Hydraulic cylinder**
Slika 1. **Hidraulički cilindar**

These limitations lead to the development of a given new technology for the manufacturing of the gliding pair's for the hydraulic cylinders.

EXPLOSIVE CLADDING TECHNOLOGY IN HYDRAULIC-CYLINDER PRODUCTION

Explosive cladding is a method of deformation processing based on the energy of explosive detonation with air, water, sand or PVC as transmission media.

The intensity of explosion and the average energy transmission are the elements defining the total energy needed for the deformation. This energy is hard to control because of the influences of unknown factors and the impossibility of development of a suited mathematical model. Thus, numerous experiments are used to determine the elements to achieve the required quality of processing. With explosive detonation, the very high pressures needed for metal shaping is obtained very rapidly. The product quality depends on:
- explosive type,
- explosive technological properties,
- the place for setting the explosion,
- the working medium in which the process is being carried out, and
- the experience in the field of explosive shaping.

The explosive cladding is used for hydraulic-cylinder manufacturing as alternative to the standard method of bronze cladding on the inner surface of the cylinder. The explosive cladding is performing according to the following procedure:
- preparation of tubes from bronze sheet metal,
- bronze tube welding along the connection line,
- placing the tube into the cylinder,
- placing the explosive inside the cylinder,
- placing the cylinder into the water, and
- explosion initiation inside the cylinder.

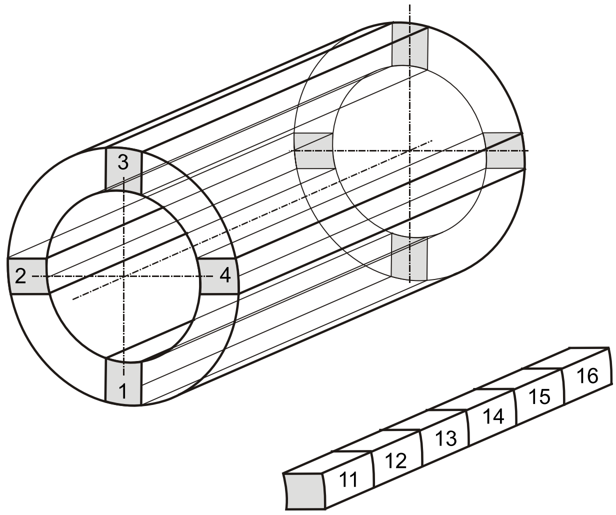

Figure 2. **Position of the investigated samples**
Slika 2. **Mjesta za uzorkovanje**

EXPERIMENTAL WORK

The possibility of explosive cladding technology rather than the present standard bronze cladding technology on the inner surface of a hydraulic cylinder was investigated

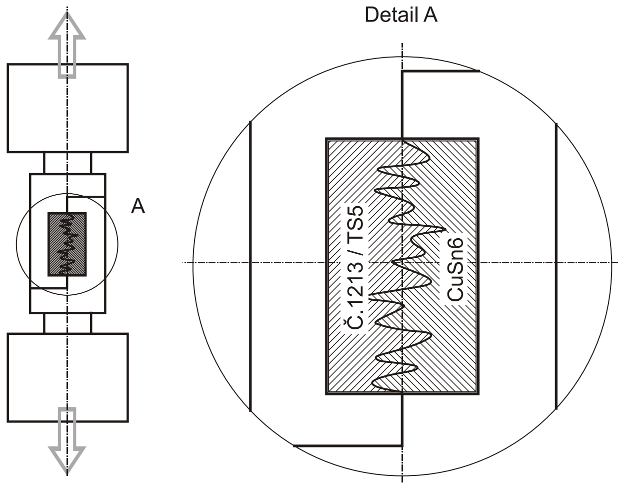

Figure 3. **Testing samples allowing the parallel action of shear forces in relation to the joint**
Slika 3. **Ispitivani uzorci koji omogućavaju usporedno djelovanje smicajnih sila u odnosu na spoj**

with metallographic analyses and mechanical tests of the joint of the bimetal layer (TS5 steel cylinder clad with CuSn6 bronze). The investigations were carried out on the samples taken from a hydraulic cylinder with standard bronze cladding and a cylinder with explosive cladding according to Figure 2.

For testing the maximum shearing stresses at the bronze/steel joint interface special shaped test was used, permitting the parallel action of shearing forces in relation to the connection (Figure 3.).

Samples of standard bronze cladding

The microstructure at the interface between the bronze and the inner surface of the steel cylinder in the standard electrode cladding is shown in Figure 4. It consists of three zones: bronze, steel and joint interface.

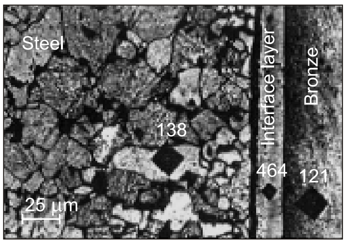

Figure 4. **Joint region whit marks of HV0,01 microhardness tests (samples after standard bronze cladding)**
Slika 4. **Područje spoja i otisci ispitivanja mikrotvrdoće HV0,01 (uzorci nakon standardnog platiranja broncom)**

The microstructure of the bronze and the steel is separated by parallel layer joining the two basic materials. Because of its flat configuration, this joint layer does not guarantee a very strong binding force, especially at stretching, shearing stressing.

The results of shear-strength measurements in the joint interface of the different samples of electrode cladding, are variable (198,8 ± 50,5 MPa), and depend on the bronze-welding quality, reflecting the quality of the welder's work. The microstructure of the sheared surface of electrode cladding is shown in Figure 5. The fracture due to shearing stresses occurs on the interface layer of great hardness.

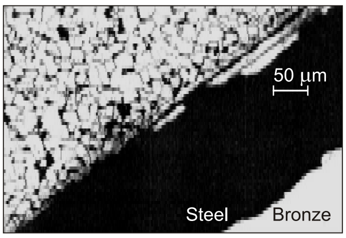

Figure 5. **Fracture surface due to shearing stresses (standard bronze cladding)**
Slika 5. **Lomna površina zbog smicajnih naprezanja (standardni postupak platiranja broncom)**

Samples of explosive cladding

The microstructure at the bronze/steel interface of explosive cladding is shown in Figure 6. The great and specific explosion pressure changed the microstructure in the narrow contact zone of both materials, and the shape of the joining surface bronze - steel. The wavy shape of the contact layer shown in Figure 7. is characteristic for this type of joint increases strongly the strength of the bonding microhardness of the different cladding areas are shown in Figure 8.

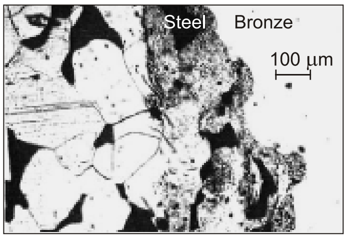

Figure 6. **Microstructure of the bronze/steel joint (explosive cladding)**
Slika 6. **Mikrostruktura spoja bronca/čelik (eksplozijsko platiranje)**

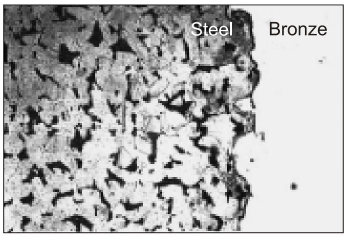

Figure 7. **Characteristic wave shaped of contact layer (explosive cladding)**
Slika 7. **Karakteristični valni oblik kontaktne površine (eksplozijsko platiranje)**

The shear stress of samples of explosive cladding is greater and more uniform (382,1 ± 11,5 MPa) in comparison to that obtained for specimens of electrode cladding.

The amplitude of the wavy shape interface for four groups of samples are given in Table 1. The amplitude of a = 0,18 mm, enables a high strength of bronze/steel joint (Figure 9.).

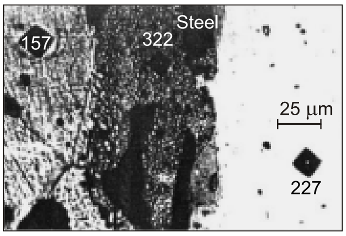

Figure 8. **Joint region and HV0,01 microhardness (explosive cladding)**
Slika 8. **Područje spoja i mikrotvrdoća HV0,01 (eksplozijsko platiranje)**

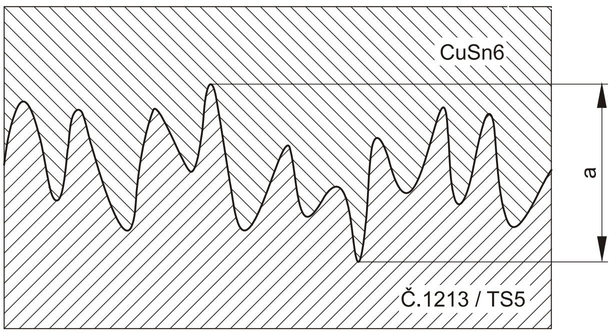

Figure 9. **Characteristic wavy shape of interface layer obtained with explosive cladding**
Slika 9. **Karakteristični valni oblik međupovršinskog sloja eksplozijskim platiranjem**

Table 1. **Amplitude of the wavy-shaped interface (a) on the different explosive clad samples**
Tablica 1. **Dubina valovitosti penetriranih slojeva (a) za različite eksplozijski platirane uzorke**

Sample number	*a* / mm	Sample number	*a* / mm	Sample number	*a* / mm	Sample number	*a* / mm
11	0,12	21	0,14	31	0,12	41	0,12
12	0,24	22	0,18	32	0,14	42	0,10
13	0,40	23	0,18	33	0,12	43	0,18
14	0,30	24	0,18	34	0,16	44	0,24
15	0,28	25	0,18	35	0,16	45	0,20
16	0,26	26	0,18	36	0,18	46	0,16

DISCUSSION

The interface layer between the bronze and the steel for samples of standard bronze cladding is hard. Its flat configuration does not guarantee a great shearing strength and good contact between the two materials.

The hardness of the interface layer is smaller on samples of explosive cladding, and more suited for turning processes (Table 2.).

Table 2. **Microhardness of the joint of (bronze/steel) bi-metal samples for different claddings**
Tablica 2. **Usporedba mikrotvrdoća u spoju bronca / čelik na uzorcima kod različitih načina platiranja**

Joint surface zones	Microhardness / $HV_{0.01}$	
	Electrode cladding	Explosive cladding
Bronze	121	227
Interface layer	464	322
Steel	138	157

The shearing stresses of the samples of standard electrode cladding are lower and very variable (198,8 ± 50,5 MPa), increase of the variable bronze-welding quality. After explosive cladding the shearing stress is greater and more uniform (382,1 ± 11,5 MPa).

The microstructure and the sliding surface at the bronze/steel interface using electrode cladding are shown in Figure 5. The fracture during shearing stresses occurs along the joint layer of great hardness. The microstructure and the shape of the sliding surface in the bronze/steel interface after explosive cladding are shown in Figure 10. The sliding fracture occurred along the bronze zone, this indicates that the joining layer, formed according to the technology of explosive cladding, has a greater hardness and shearing strength.

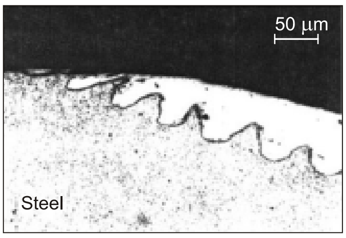

Figure 10. **Shape of the sliding surface in the bronze/steel interface on explosively clad samples**
Slika 10. **Oblik klizne površine bronca/čelik kod eksplozijsko platiranih uzorka**

CONCLUSIONS

The results of our investigations show that hydraulic cylinders prepared with explosive cladding technology have better structural and mechanical properties at the bronze/steel interface compared to hydraulic cylinders prepared with standard bronze cladding.

According to the results of the explosive cladding tests, it can be concluded that the explosive cladding can be successfully applied for the manufacturing of hydraulic cylinders and better results than with the present technology can be expected in the exploitation of the cylinders. The application of explosive cladding is limited for the following reasons:

1. The gliding properties of the bronze sheet metal that is intended for explosive cladding should be checked by chemical analysis.
2. There is no processing method for the control of energy dissipation during the explosion.
3. Quality of the cladding must be in real conditions with hydraulic press operation.

REFERENCES

[1] V. Jovišević: Results of metallographic and mechanical testing of bronze/steel joining in hydraulic cylinder, Project report, Steel foundry Jelšingrad, Banja Luka, 1999.
[2] V. Jovišević, M. Soković, Journal of Mechanical Engineering 51 (2005) 4, 193 - 203.
[3] V. Jovišević, M. Soković, B. Kosec Metalurgija 46 (2006) 3, 218.
[4] B. Crossland: Explosive welding of metals and its applications, Oxford University Press, New York, 1982.
[5] L. A. Dobrzanski, Technical and Economical Issues of Materials Selection, Selesian Technical University, Gliwice, 1997.
[6] S. Petrović: Fizika eksplozije, Mašinski fakultet Univerziteta u Sarajevu, Sarajevo, 1988.
[7] H. Dyja, A. Maranda, R. Trebinski: Explosive techniques in the materials engineering, Series Metallurgy No. 20, TU Czestochowa, Czestochowa, 2002.
[8] B. Kosec, L. Kosec, G. Cevnik, P. Fajfar, M. Gojić, I. Anžel, Metalurgija 43 (2004) 2, 83 - 86.
[9] B. Kosec, L. Kosec, S. Petrović, V. Gontarev, G. Kosec, M. Gojić, P. Škraba, Metalurgija 42 (2003) 3, 147 - 151.
[10] V. Jovišević: Development of design and optimisation model of technological process for metal forming system production, based on group technology and data base, Doctoral dissertation, University of Belgrade, Faculty of Mechanical Engineering, Beograd, 1997.
[11] L. A. Dobrzanski, Journal of Achievements in Materials and Manufacturing Engineering 15 (2006) 1-2, 9 - 20.
[12] M. Acarer, B. Gulenc, F. Findik, Materials and Design 24 (2003), 659 - 664.
[13] H. Dyja, S. Mroz, Z. Stradomski, Metalurgija 42 (2003) 3, 185 - 191.
[14] J. F. Lancester, Metallurgy of Welding, Chapman and Hall, London, 1993.
[15] B. Kosec, Z. Kampuš, L. Kosec, F. Kosel, Journal of Achievements in Materials and Manufacturing Engineering 15 (2006) 1-2, 114 - 119.
[16] G. H. Majozoobi, A. Ghomi, Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 1-2, 124 - 131.