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# PROCEEDINGS

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# Contents

# Repair of Damaged Surfaces of Components of Turbine and Hydromechanical Equipment through the use of Cold Metallization

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**Abstract:** Cold metallization includes the powder or wire application on the cold surface of components by electric arc, gas, plasma, supersonic, gas-detonation method. It could be applied on all metals except on pure copper, but not on glass and non-metallic materials. Thickness of the layer which is being deposited ranges from 0.05 to 5 mm. Porosity of the layer is 3-15 %. Temperature of the parent material does not exceed 250°C, and therefore it sustains its mechanical properties. Taking into account the above mentioned, for the repair of damaged surfaces of components of turbine and hydromechanical equipment, the methodology of the electric arc technique was developed. At first, research regarding the possibility of application of cold metallization at damaged samples of metal sheets and pipes made of structural steel was carried out, and afterwards the same methodology was performed and confirmed during the repair of damaged surfaces of the flange at the horizontal Kaplan turbine with nominal power of 28 MW (Djerdap 2). Functional role of the flange, made of steel X5CrNi18-10, is to prevent the water from entering the enclosed space of the turbine shaft.

**Keywords:** Kaplan turbine, Flange, Repair, Cold metallization

## 1. Introduction

Two hundred metallization techniques were developed since today, which are being distinguished among themselves taking into account the metallization equipment, type of material and type of burning gases. Basically, these techniques can be grouped into cold and hot metallization techniques. Devices for cold metallization techniques, with respect to the geometry of the component or structure, use the filler material in the form of wire or powder, while devices for hot metallization use nothing but powder as filler material.

While selecting the metallization technique, the properties of device and significance of components or structures (device and tools, geometry of components, dimensions, purpose), type of damage (corrosion, surface cracks), parent material (type, quality, melting point, hardness), filler material (type, purpose, quality), machinability, quality of the machined surface and measures of safety while handling the appropriate device have to be taken into account.

Cold metallization (CM) includes the application of powder or wire on the cold surface of components by electric arc, gas, plasma, supersonic, gas-detonation method. It can be applied on most metals, but not on pure copper, glass and non-metallic materials. Thickness of the layer which is being deposited ranges from 0.05 to 5 mm. Porosity of the layer is 3-15 %. Temperature of parent material does not exceed 250°C, and therefore it sustains its mechanical properties.

Difference between electric arc technique and other techniques of metallization is that the burning gases are not being used when it comes to electric arc technique, unlike other cold metallization techniques, but electric energy, compressed air and 2 wires during the application. Electric arc technique is used when it is necessary to deposit thick layers at large surfaces in a short period of time. The velocity of particles during the deposition is around 200 m/sec. The velocity of layer deposition is 5-50 kg/h, depending on the type and dimensions of filler material. The width of weld metal could be fixed at 50-280 mm. Layer porosity with this technique is around 15%, while thickness of applied layers can vary from 0.30-30 mm, depending on the use of the component or structure and type of the wire. Connection with the basis is established through adhesion and mechanical incarceration.

Taking into account the above mentioned, for the repair of damaged surfaces of components of turbine and hydromechanical equipment, the methodology of the electric arc technique was developed. At first, the research regarding the possibility of application of cold metallization at damaged samples of metal sheets and pipes made of structural steel was carried out, and afterwards the same methodology was performed and confirmed during the repair of damaged surfaces of the flange at the horizontal Kaplan turbine with nominal power of 28 MW (Djerdap 2). Functional role of the flange, made of steel X5CrNi18-10, is to prevent the water from entering the enclosed space of the turbine shaft.

## 2. Experimental researches regarding the practicability of cold metallization for the repair of damaged surfaces of components and structures of turbine and hydromechanical equipment

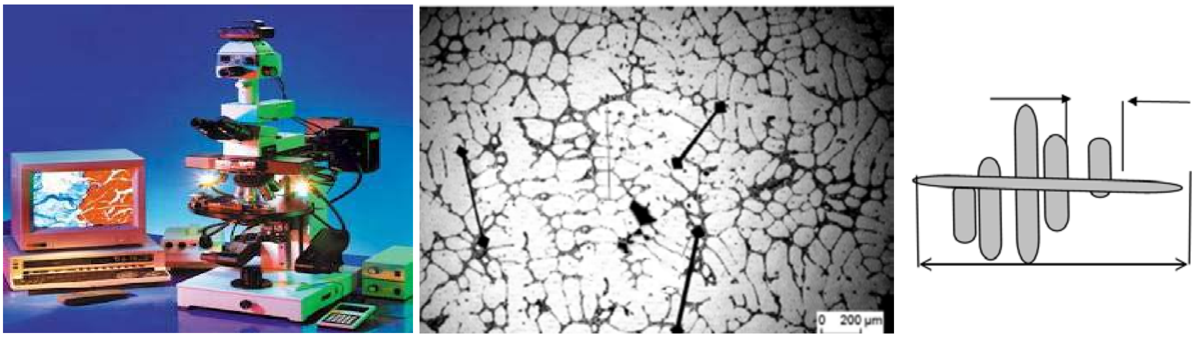
Researches were carried out at damaged samples of 3 mm and 12 mm thick metal sheets and 6 mm thick pipes made of structural steel in order to determine the practicability of cold metallization for the repair of damaged surfaces of components and structures of turbine and hydromechanical equipment.

Austenitic Cr-Ni steel wire, with hardness of 290-340 HV, was used during the process of metallization. Applied filler material is resistant to atmospheric corrosion and can be deposited in thick layers at internal and external surfaces. Thickness of deposited layers ranges from 0.5-1 mm at metal sheets and 0.2-0.3 mm at pipes. Device for metallization and test samples are presented in figure 1.Visual check regarding the adhesion was carried out by grinding (which can be seen at the left side of the metal sheet and at the internal side of the pipe) and hammer blows (which can be seen at the right side of the metal sheet and at the external side of the pipe).

*a) Device for metallization* *b) Appearance of the 12 mm thick metal sheet* *c) Appearance of the Ø200x6 mm pipe*

*Figure 1. Appearance of the device for metallization and samples at which cold metallization was performed*

Thickness of deposited layers on samples is measured by standard measuring instruments and recently developed methodology for analysis of metallographic image of the transversal cross-section of the metalized surface, figure 2 [2]. Method was checked and confirmed for measurement of dimensions of microstructural components.




*a) Device for measurement by image analysis b) Metallographic image measurement c) Example - length measurement*

*Figure 2. Appearance of the device for metallization and samples at which cold metallization was performed*

## 3. Repair of damaged surfaces of the flange at the horizontal tubular Kaplan turbine

Ten horizontal tubular Kaplan turbines, with nominal power of 28 MW, were installed at hydro power plant Djerdap 2. Turbine and flange on which the repair of damaged surfaces was performed are presented at figure 3, device for metallization and process of repair by cold metallization are shown in figure 4, while the appearance of damaged surfaces of the flange before and after the repair can be seen in figure 5. Functional role of the flange, made of steel X5CrNi18-10, is to prevent the water from entering the enclosed space of the turbine shaft. Chemical composition and mechanical properties of the flange material are presented in tables 1 and 2 [3]. Repair by cold metallization was performed through the use of the alloy wire (Fe-Ni-Cr-Si-Mn) EuTronic® Arc 579, with diameter 1,6 mm and hardness of approximately 230 HV, produced by Castolin Eutectic. After the repair, damaged surfaces were grinded by special sandpaper and polished.

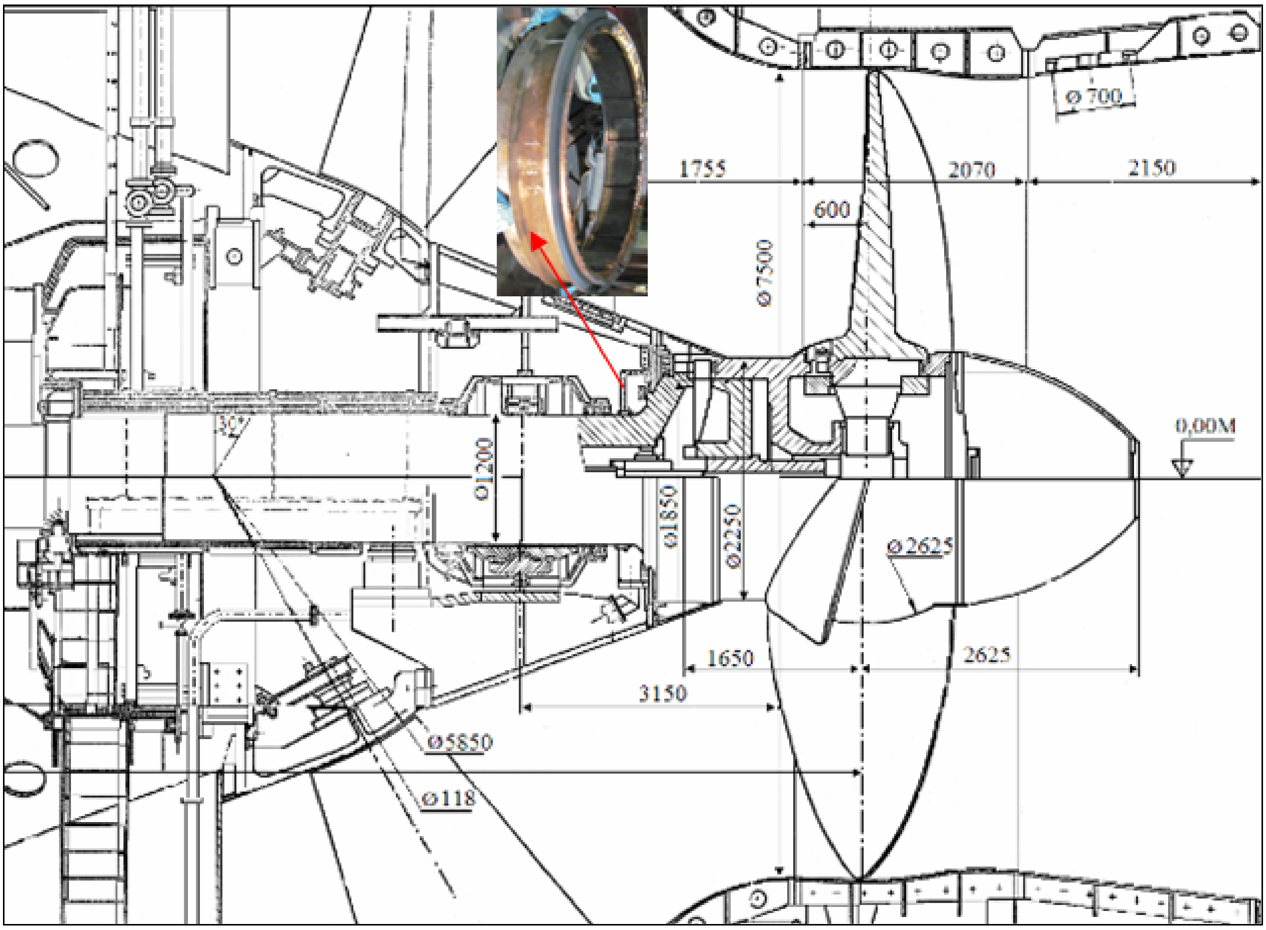


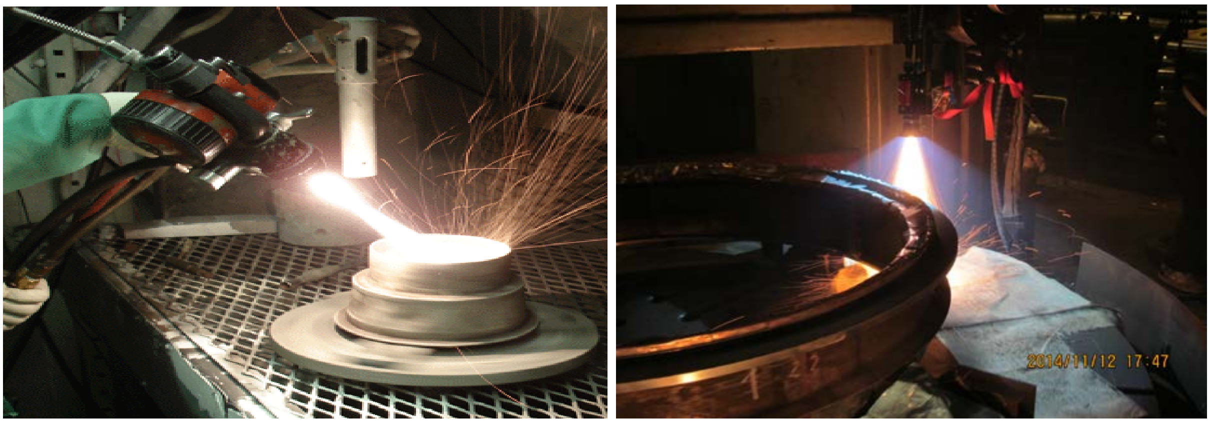

*Figure 3. Appearance of the flange at the horizontal Kaplan turbine, with nominal power of 28 MW*

*Table 1. Chemical composition according to [3], values in %*

| Steel | C | Si | Mn | Cr | Ni | N | S | P |
|---|---|---|---|---|---|---|---|---|
| X5CrNi18-10 | max 0.07 | max 1 | max 2 | 17.5-19.5 | 8-10.5 | max 0.11 | max 0.015 | max 0.045 |

*Table 2. Mechanical properties of steel in annealed condition, according to [3]*

| Steel | Yield stress $R_{0.2}$ [N/mm$^2$] | Tensile strength $R_m$ [N/mm$^2$] | Elongation A5 [%] | Impact energy KV [J] | Hardness [HB] |
|---|---|---|---|---|---|
| X5CrNi18-10 | 190-235 | 500-750 | Min 45 | Min 60 | 200-215 |




*a) Appearance of the device for cold metallization* *b) Repair process of damaged surfaces of the flange*

*Figure 4. Appearance of the device and repair process of the flange through the use of cold metallization*

*a) Appearance of the flange before the repair* *b) Appearance of the flange after the repair by cold metallization*

*Figure 5. Appearance of the flange before and after the repair by cold metallization*

## 4. Results and discussion

After the repair of damaged surfaces of the flange, non-destructive tests were performed. By visual testing (performed in accordance with the standard EN 970:1997 [4]) and penetrant testing (performed in accordance with the standard EN 571-1:2005 [5]) it was determined that it is possible to perform the repair of damaged surfaces of the flange by cold metallization.

## 4. Conclusion

Successfulness of the methodology carried out in order to repair damaged surfaces of the flange through the application of cold metallization at hydro power plant ’Djerdap 2’ was confirmed by the manufacturer ’Power Machines’ from Saint Petersburg, because they gave the guarantee for the further use of the flange until planned rehabilitation of the turbine.

It should also be mentioned that significant financial effect was achieved, because the manufacture of the new flange would cost approximately 30000 €, without taking into account the period of time needed for that, which is in direct connection with the amount of hydro energy that would be produced by a hydroelectric generating set during that period.

Presented methodology for the repair of damaged surfaces of the flange through the application of cold metallization could be used for the repair of other components and structures of turbine and hydromechanical equipment exposed to various causes of degradation while in service.

## Acknowledgements

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