

# New Results Regarding Cavitation Behavior of Polymers Modified with Anorganic Substances Coated on Bronze Surfaces

LAVINIA MADALINA MICU<sup>1</sup>, IOSIF LAZAR<sup>2\*</sup>, ADRIAN CIRCIUMARU<sup>3</sup>, ILARE BORDEASU<sup>2\*</sup>, LIVIU DANIEL PIRVULESCU<sup>2\*</sup>, MIHAI HLUSCU<sup>2\*</sup>

<sup>1</sup>University of Agricultural Sciences and Veterinary Medicine of Banat King Mihai I from Romania, 119 Calea Aradului, 300645, Timisoara, Romania

<sup>2</sup>Politehnica University of Timisoara, 1 Mihai Viteazul Blvd., 300222, Timisoara, Romania

<sup>3</sup>Dunarea de Jos University of Galati, 47 Domneasca Str., 800008, Galati, Romania

*Due to mechanical resistance characteristics, chemical corrosion and abrasive erosion resistance, the polymers are more widely used in equipments and installations that are exploited in different fluid hydrodynamic conditions. Among these applications there is the protection of surfaces of hydromechanic organs stressed by cavitation, like in hydraulic machines rotors and valves. Consequently, the research aims the extension of using these and protection of other components surfaces hardly stressed by cavitation. The research in this paper points toward the behavior of modified polymer layer, coated on surfaces of bronze used in casting the propellers of maritime and river ships. The tests were performed in standard piezoceramic crystal vibrating equipment within Cavitation Laboratory of Politehnica University of Timisoara. The damaging intensity of equipment is much greater than any cavitation vortex, created by ship propeller, hydraulic turbine or centrifugal pump. The obtained results, compared to both recorded on uncovered surfaces with polymer layer and recorded on surfaces covered with HVOF composite materials layers, show an increased resistance that implies the increased exploiting duration of those surfaces.*

**Keywords:** polymer, composite material, cavitation, film, layer, pitting, SEM and EDAX analysis

It is known that composite materials with polymeric matrices, used in protection of surfaces stressed by cavitation flows and suspension of abrasive particles [1-6] have very high mechanical properties that can even exceed the steel. [7-10]. Their application in equipments working in cavitation regime, is intense used in valves [11], rotors of hydraulic machines and ship propellers [6, 12], or less used in control equipments of hydraulic installations [13], control system in hydraulic transport installations [10] erosion damaging is very important due to long term stagnation for repairing. For this reason, the research on influence on both flow quality and increasing the exploiting duration, due to enhancing the behavior and resistance to cavitation erosion by covering the surfaces with polymeric composite materials is in great expansion [1-5, 14, 15]. The research becomes more intense due to advanced technologies [7-9], using dedicated software [16-18, ], that diversifies the structure and properties. Present research performed on a modified polymer is conducted in this direction and its results are presented and analyzed in this paper.

## Experimental part

### Polymer

For studying the behavior of modified polymers in vibrating cavitation, were used samples, figure 1 of bronze used in pallet and propellers casting. The polymers layers as films, were coated on active and cylindrical surface of samples. The bronze of samples has the following chemical composition: 81.45 % Cu, 14.58 % Sn, 0.3639 % Zn, 1.037 % Pb, 0.6471 % Fe, 0.8489 % Ni, 0.0359 % Mn, 0.077 % Si, 0.0298 % S. In order to identify and analyze the results, the samples were marked with I and II.

The polymer coated on plain surface (the one affected by cavitation) and cylindrical, figure 1, is a mixture whose composition is: 200g epoxydic resin of Epiphen RE4020 +

strengthen DE4020 [19], from Resoltech company, 4.165g BaCl<sub>2</sub>, 4.030g CuCl<sub>2</sub>, 3.258g La<sub>2</sub>O<sub>3</sub> and 200g epoxy novolac resin, diluted in stiren Sirester VE 64-M-140, from Sir Industriale SpA [20].

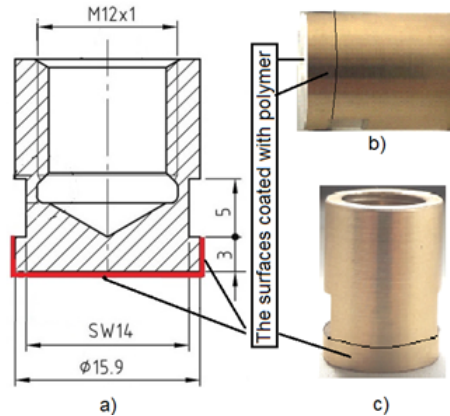


Fig. 1  
Cavitation sample  
- indication to the  
surfaces coated  
with polymer  
films  
a) - section  
through sample;  
b) and c) - real  
sample

For an increased adhesion, especially on active surface exposed to cavitation, in order to avoid exfoliation due to repetitive impacts and intense shocks created by microjets and waves generated by cavitation, the metallic parts were oxidated with citric acid, washed with distilled water, cleaned with ethanol and polished with sand paper. The mixture was coated in three stages.

In the first stage was made the mixture of epoxydic resin with strengthen and salts BaCl<sub>2</sub> and CuCl<sub>2</sub>, at a temperature of 50°C and rotation speed of 600 rot/min, using magnetic stirrer.

In the second stage, for the same temperature and speed La<sub>2</sub>O<sub>3</sub> was added.

In last stage 200 g polyvinyl was added.

The duration of every stage, with continuous stirring, was 7 days, after every stage the obtained layer was coated on surfaces of two samples used in experiment (marked

\* email: iosif.lazar@upt.ro; office@ducodan.ro; ilarica59@gmail.com, ilare.bordeasu@upt.ro, Phone: 0723650248;

liviu-daniel.pirvulescu@upt.ro; mihai\_hluscuc@yahoo.com

as I and II), previously heated at 90°C and maintained for 24 h. The obtained layer was a film thinner than 0.1 mm.

The morphological analysis of polymer films is performed based on pictures in figure 2-5.

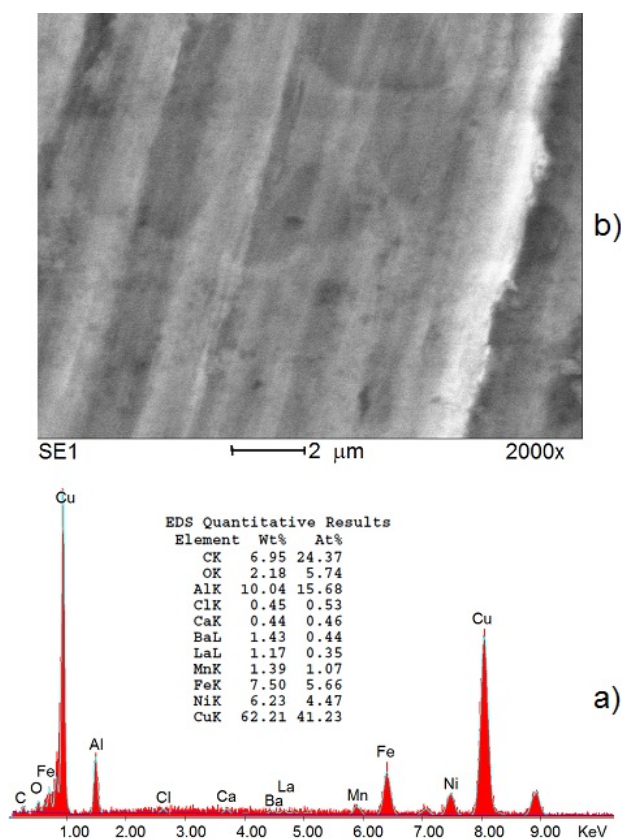


Fig.2. SEM and EDAX analyzes of thin films in the sample I  
a) EDAX image; b) SEM image

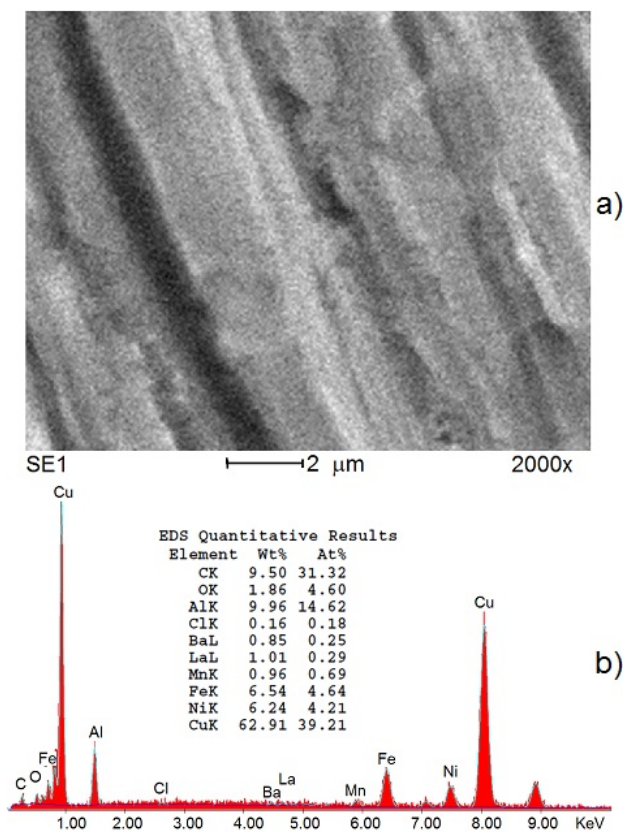


Fig.3. SEM and EDAX analyzes of thin films in the sample II  
a) EDAX image; b) SEM image

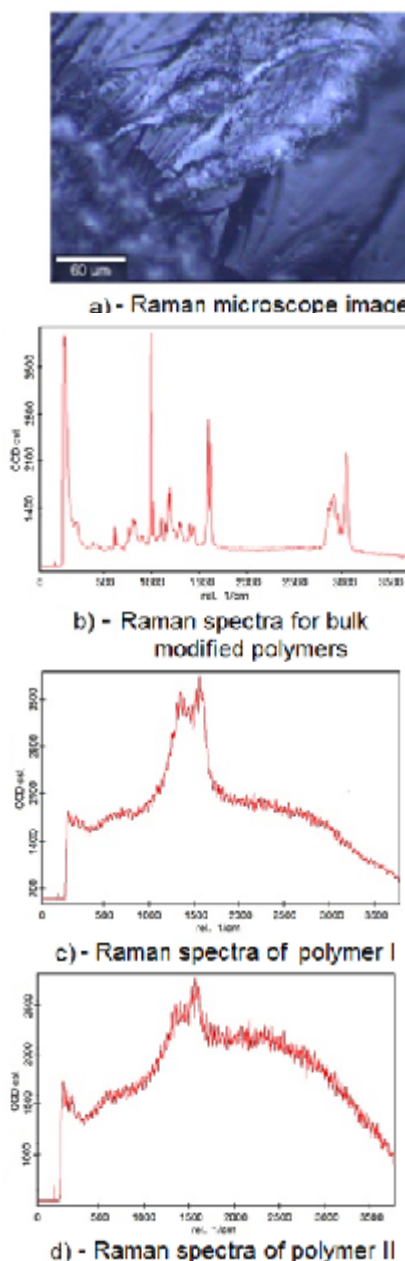


Fig. 4. Raman microscope images and Raman spectra

We can conclude:

-SEM analysis figure 2b si 3b and EDAX do not emphasize significant differences between two samples, butt EDAX analyse highlights anorganic elements inside polymer figure 2a si 3a;.

-SEM pictures from figure 4a reveals main direction of mechanical processing (first line of every sample), while the second line reveals small points that can not be explained as effect of processing tool and can be associated with complex anorganic nanoparticles.

-EDAX analysis, figure 2a si 3a shows massive presence of copper (main component of metallic alloy), rather increased concentrations of iron, manganese, nickel and aluminium, very low presence of barium that comes not from alloy but from polymer film.

-Raman analysis, figure 4, do not show chemical modifications, even it could be possible because of low concentration of collagen compounds or anorganic. In this figure is shown also a picture of Raman spectra for bulk modified polymer, figure 4b that were captured by Raman microscope. Meanwhile, it can be seen that both spectra have the same profile wit multiple peak centered on 1500  $\text{cm}^{-1}$ , situation that can be associated with Raman metallic footprint, or the presence of anorganic particles



of nanometric size that establish a stronger link between polymer and metallic surface. Anyway, for increasing certainty, the investigations must be continued.

## Results and discussions

### Cavitation Behavior

Experimental research program occurred on vibrating equipment with piezoceramic crystals within the Cavitation Laboratory of Politehnica University of Timisoara [1, 11, 13, 14] that, from functional point of view, accomplishes with ASTM G32-2010 regulations [21].

The stages followed during experiments fulfill the internal laboratory regulations, regarding samples preparation, liquid environment used and temperature during tests, functional parameter values of equipment needed for producing the vibrating cavitation and analysis of damaged surfaces. The internal rules are described in [1, 11, 13].

Considering the expelling of polymer layers, within 35-40 minutes of expose to vibrating cavitation, the evaluation of behavior is performed exclusively based on photographic images taken after every testing stage. The use of curves and specific parameters, as usually done for resistance evaluation to cavitation erosion, is not possible due to short testing duration. The duration of cavitation testing in our laboratory, for making the specific curves and determinating the values of characteristic parameters using the relations established in laboratory [22], is minimum 165 min.

In some situations, for elucidation, the surface exposed to cavitation was studied with optical microscopes.

The pictures in figure 5-7 show a behavior approximately identical for both samples. In the first 30 min, the behavior of polymer layer in vibrating cavitation, coated on two samples I and II can be seen in figure 5 and figure 6.

So:

- in first 5 min of stress in vibrating cavitation, the layer is very adherent but starts a light detach in periferal zones, but without ripping. From this reason, between polymer layer and metallic surface of sample, due to oscillations, the water penetrated as cavitation bubbles;

- after 15 min of exposure to cavitation, due to very high pressures caused by repeatedly impact with microjets and

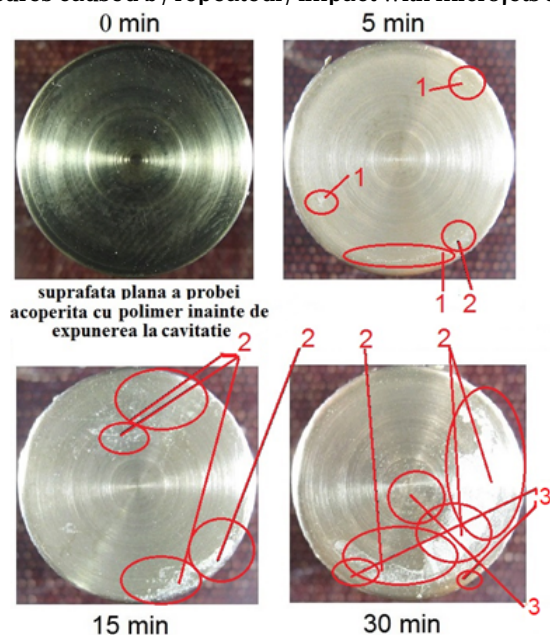


Fig.5 The cavitation behavior of the layers of polymer I  
1. perforations in the polymer film; 2. water and bubbles between the polymer film and the metal surface of the sample; 3. cracks/pittings



Fig.6 The cavitation behavior of the layers of polymer II  
1. water and bubbles between the polymer film and the metal surface of the sample; 2. the remaining polymer film fixed on the metal surface; 3. expelled polymer film (despoiled surface); 4. cracks/pittings

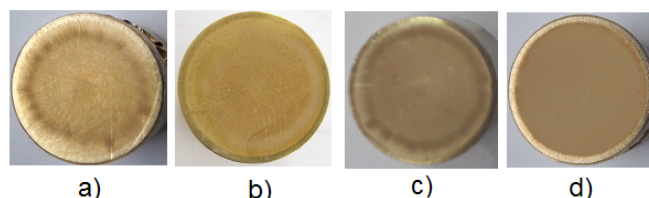


Fig.7 Images of the surface of the sample cavitated  
a) after removal of polymer I film and 45 min of the cavitation exposure; b) after removal of polymer II film and 45 min of the cavitation exposure; c) after 15 min of the cavitation exposure of the bronze surface; d) after 45 min of the cavitation exposure of the bronze surface

shock waves, generated during bubbles implosion from cavitation cloud created through vibration [15, 12], within the layer surface appear perforations, the detached area is increased and the water and bubble quantity pervaded between polymer layer and metal base is increased too;

- after 30 min of cavitation, the detached area increased significantly, the adherence is much decreased, due to typical fatigue tensions. In some areas the layer is ripped and this allowed erosion, through small caverns in metallic surface.

- after 45 min of exposure to cavitation, figure 7a and b, can be observed that polymer layers were completely expeled, and metallic surface, under repetitive impact of cavitation microjets, had suffered extensive erosions, more significant on peripheral areas (ring zones dark coloured). Analysis on optical microscope shows the presence of pinches, pitting type, specific for degradation through this type of strain [1].

The comparison with metallic surface degradation evolution without protective layers, figure 7c,d, shows the beneficial effect of polymer layers, that makes, after 45 min of cavitation stress, the coated surface to have less damages (fig.7a, b) than uncovered surfaces after 15 min (fig.7.c) and much more reduced after 45 min (fig.7.d).

The comparison with some composite materials layers HVOF coated on carbon steel 270-480 W Sr ISO 13755:1995 ( powder formed of 47.08 %Cu, 28.83 % Zn, 16.2 % Ni, 6.64 % Cr, 0.32 % Ti, 0.27 % PT, 0.27 % Co, 0.22 % Fe, 0.17 % Mo [15]) and stainless steel duplex X2CrNiMoN22-5-3 (ceramic powder Thermico WC-9Co-5Cr-1Ni [12]), figure 8 with important erosions yet from

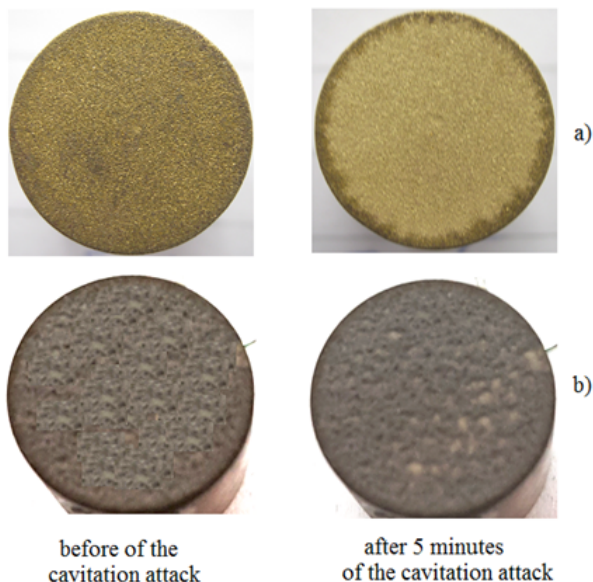


Fig. 8. Comparison of vibratory cavitation behavior between polymer layers and composite material layers HVOF deposited on metallic surfaces . a) composite material with copper base [15] ; b) The Thermico WC-9Co-5Cr-1Ni Ceramic Powder [12]

first 5 minutes of cavitation, it can be stated that modified polymer layers have a superior resistance. As it turns out, the damage is different: composite layers are degraded according to the technique of cavern generation, while in polymer layers, perforations are delayed due to elasticity, but in time, the adherence is decreased and the layer is peeled. These differences represent premises for continuing the research in order to increase the adherence to metallic surface.

## Conclusions

The behavior in cavitation of modified polymer layers is dependent on the adherence to protected metallic surface.

The way the polymer layer behaved in vibrating cavitation, by peeling from metallic surface without braking, proves that used technology confers mechanical resistance and elasticity characteristics able to increase the service life of bronze surface, in intense cavitation.

The comparison with coated composite materials layers HVOF, figure 8 and with degrading way of unprotected metallic surface, figure 5 and figure 7, suggests the continuing of research in order to create new modified polymers, to lead towards increasing the duration of stress to cavitation such that can be used successfully to coat the surfaces that work in high cavitation intensity currents.

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