RESEARCH ON THE CAVITATION EROSION RESISTANCE OF THE X3CRNI13-4 STAINLESS STEEL USED TO MANUFACTURE THE RUNNER BLADES OF KAPLAN TURBINES

Marian-Dumitru NEDELONI, Eftimie Murgu University of Resita, ROMANIA
Cornel HAŢIEGAN, Eftimie Murgu University of Resita, ROMANIA
Lidia (Filip) NEDELONI, Eftimie Murgu University of Resita, ROMANIA
Luminiţa (Barboni) HAŢIEGAN, Eftimie Murgu University of Resita, ROMANIA
Eugen BIRTĂRESCU, Eftimie Murgu University of Resita, ROMANIA
Aurel BĂRA, Eftimie Murgu University of Resita, ROMANIA
Adrian PELLAC, Eftimie Murgu University of Resita, ROMANIA

ABSTRACT: This paper presents beside the theoretical concepts about the Kaplan hydraulic turbines, also the experimental results of cavitation erosion research regarding the resistance of the X3CrNi13-4 stainless steel that can be used to manufacture the runner blades of Kaplan hydraulic turbines. So, the cavitation erosion researches involve four different tests of 180 minutes on 2 samples of the same batch of X3CrNi13-4 stainless steel, so 3 hour for each test or a total time of 12 hours. These results are in tabular form, through charts and pictures, presented in this paper.

KEY WORDS: Cavitation erosion resistance, X3CrNi13-4 stainless steel, Kaplan turbines.

1. INTRODUCTION

Today, different metallic materials are tested to see their cavitation erosion resistance, erosion produced especially in the hydraulic machines such as hydraulic turbines through cavitation phenomenon [1] - [8].

Many experimental stands may be particularly the vibratory apparatus because the short time and good results [9] - [13].

The most short time can be done through the direct cavitation method [14].

In this paper, all the experimental tests are made on a cavitation stand (vibratory apparatus) by the indirect cavitation method respecting certain standards [15] and [16].

For this X3CrNi13-4 stainless steel, the same collective of authors, presented some results [17], [18] and [19], but from other batches of the X3CrNi13-4. For this batch of X3CrNi13-4, the chemical composition is shown in Table 1.

Table 1. Chemical composition [%]

C	Si	Mn	P	S
0.06	0.43	0.42	0.015	0.009
Cu	Ni	Cr	Mo	Fe
0.07	3.81	12.5	0.32	82.36

2. KAPLAN TURBINES

According to citation [20], the Kaplan hydraulic turbine is an axial turbine, with double regulating (adjustable runner blades and adjustable guide vanes).

The Kaplan turbine runner has a reduced number of profiled blades (3 blades in for small falls of 6 m to 8 blades for large falls of more than 50 m) [20].

For a clearer image of the Kaplan hydraulic turbine components, also for more details on cavitation phenomenon and

cavitation erosion at the Kaplan hydraulic turbines runners [21], [22] and [23], Figure 1, 2 and 3 are shows.

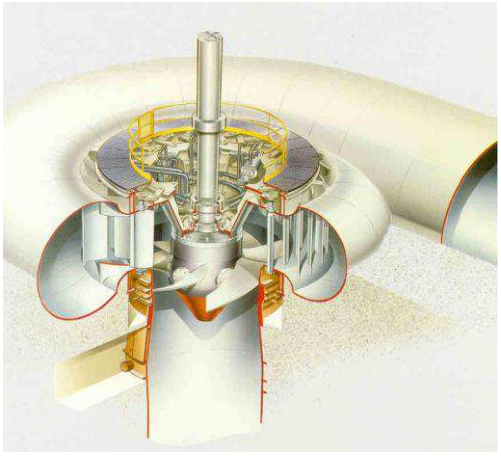


Figure 1. View of a Kaplan turbine

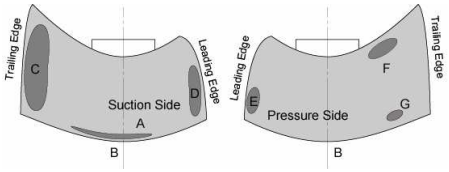


Figure 2. Typical areas of cavitation erosion for blades of a Kaplan turbine

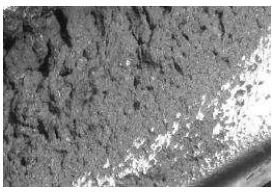


Figure 3. Cavitation erosion for a blade of a Kaplan turbine

The runner and the runner blades are the most exposed to cavitation erosion [20].

3. THE CAVITATION STAND (VIBRATORY APPARATUS)

The cavitation stand (Figure 4 [24]), operates under the following conditions: natural frequency: 20000 ±500 Hz; amplitude value: 50 μm; temperature of the liquid: 25 ± 2 °C and the distance between the ultrasonic horn and the sample is 0.6 mm.

Figure 4. The cavitation stand

4. SAMPLES DETAILS AND THE RESEARCH RESULTS

The two samples from a batch of X3CrNi13-4 stainless steel with the dimensions Ø16 x 10 mm, will be subjected to a cavitational attack for a period of 5 and 10 minutes and for 11 periods of 15 minutes (Tables 2 ÷ 5).

The four testing surfaces will be noted as: Sample 1-Face 1, Sample 1-Face 2, Sample 2-Face 1 and Sample 2-Face 2.

Table 2. The results for Sample 1-Face 1

Accum. time	Period time	Specimen mass	Accum. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/min]
0	0	15637.7	0	0.0000
5	5	15637.56	0.14	0.0257
15	10	15637.35	0.35	0.0145
30	15	15637.28	0.42	0.0057
45	15	15637.18	0.52	0.0093
60	15	15637	0.7	0.0117
75	15	15636.83	0.87	0.0157
90	15	15636.53	1.17	0.0240
105	15	15636.11	1.59	0.0303
120	15	15635.62	2.08	0.0377
135	15	15634.98	2.72	0.0417
150	15	15634.37	3.33	0.0443
165	15	15633.65	4.05	0.0527
180	15	15632.79	4.91	0.0620

Table 3. The results for Sample 1-Face 2

Accum. time	Period time	Specimen mass	Accum. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/min]
0	0	15632.79	0	0.0000

5	5	15632.71	0.08	0.0110
15	10	15632.7	0.09	0.0009
30	15	15632.69	0.1	0.0037
45	15	15632.59	0.2	0.0077
60	15	15632.46	0.33	0.0107
75	15	15632.27	0.52	0.0140
90	15	15632.04	0.75	0.0183
105	15	15631.72	1.07	0.0230
120	15	15631.35	1.44	0.0227
135	15	15631.04	1.75	0.0293
150	15	15630.47	2.32	0.0370
165	15	15629.93	2.86	0.0383
180	15	15629.32	3.47	0.0430

Table 4. The results for Sample 2-Face 1

Accum. time	Period time	Specimen mass	Accum. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/min]
0	0	14896.55	0	0.0000
5	5	14896.43	0.12	0.0167
15	10	14896.41	0.14	0.0031
30	15	14896.34	0.21	0.0043
45	15	14896.28	0.27	0.0077
60	15	14896.11	0.44	0.0117
75	15	14895.93	0.62	0.0140
90	15	14895.69	0.86	0.0163
105	15	14895.44	1.11	0.0173
120	15	14895.17	1.38	0.0187
135	15	14894.88	1.67	0.0217
150	15	14894.52	2.03	0.0247
165	15	14894.14	2.41	0.0243
180	15	14893.79	2.76	0.0223

Table 5. The results for Sample 2-Face 2

Accum. time	Period time	Specimen mass	Accum. eroded mass	Cavitation erosion rate
t [min]	t [min]	m [mg]	mc [mg]	vec [mg/min]
0	0	14903.21	0	0.0000
5	5	14903.12	0.09	0.0143
15	10	14903.05	0.16	0.0066
30	15	14902.96	0.25	0.0123
45	15	14902.68	0.53	0.0240
60	15	14902.24	0.97	0.0310
75	15	14901.75	1.46	0.0340
90	15	14901.22	1.99	0.0357
105	15	14900.68	2.53	0.0383
120	15	14900.07	3.14	0.0470
135	15	14899.27	3.94	0.0527
150	15	14898.49	4.72	0.0550
165	15	14897.62	5.59	0.0683
180	15	14896.44	6.77	0.0890

Next, the material loss and cavitation erosion rates curves will be presented.

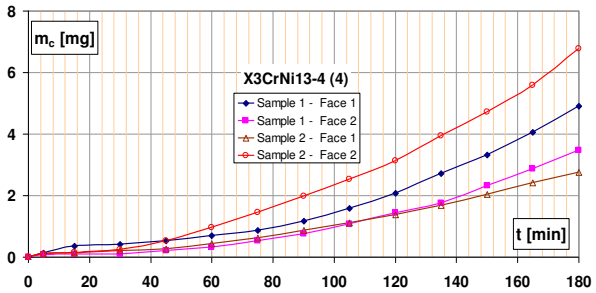


Figure 5. Material loss curve

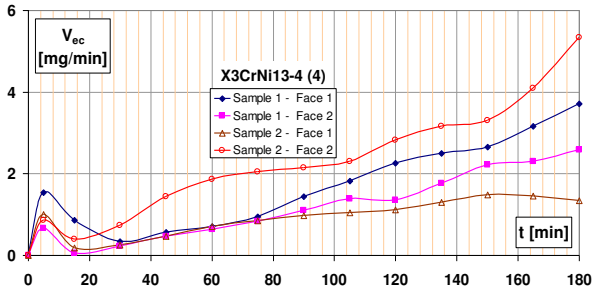
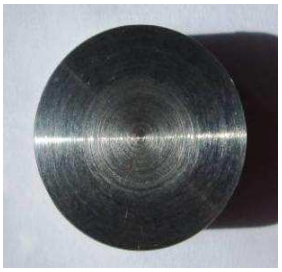
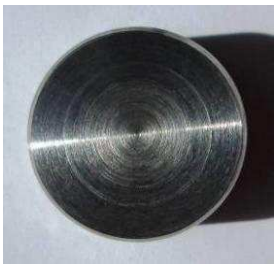


Figure 6. Cavitation erosion rate curve

Figures 7 ÷ 10 show photos before and after the cavitation of the two samples of X3CrNi13-4 stainless steel.



Sample 1 - Face 1

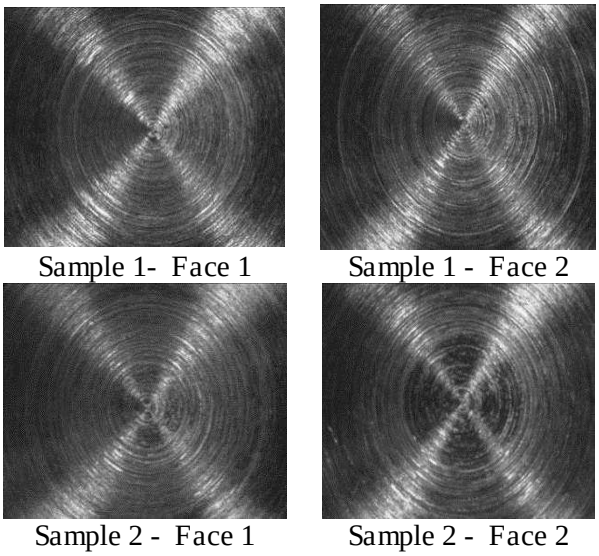


Sample 1 - Face 2

Sample 2 - Face 1

Sample 2 - Face 2

Figure 7. Images of the samples before the cavitation



Sample 1- Face 1 Sample 1 - Face 2

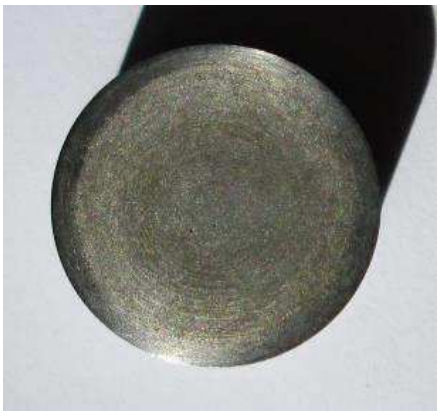
Sample 2 - Face 1 Sample 2 - Face 2

Figure 8. Macrostructures of the samples before the cavitation

Sample 1 - Face 1

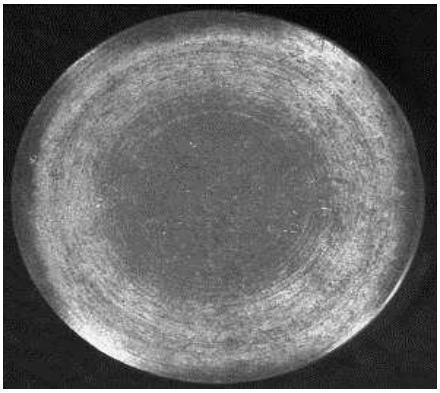
Sample 1 - Face 2

Sample 2 - Face 1

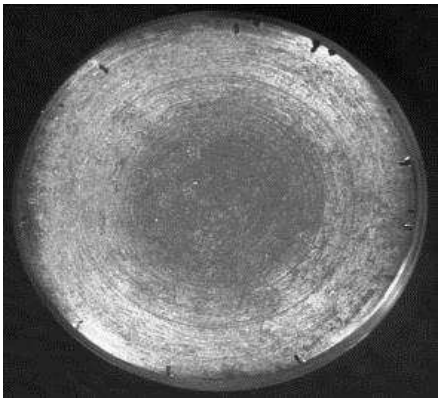


Sample 2 - Face 2

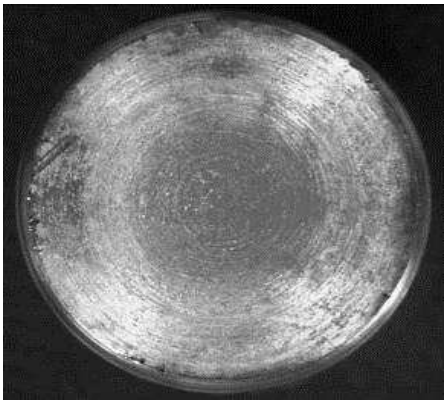
Figure 9. Images of the samples after the cavitation



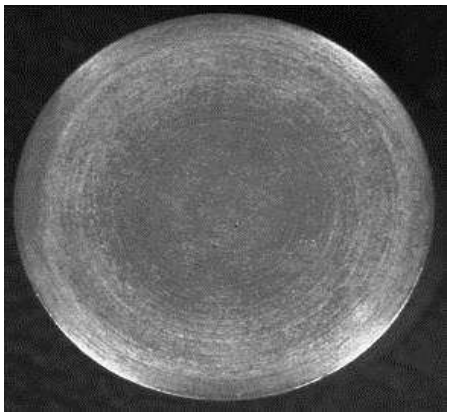
Sample 1 - Face 1



Sample 1 - Face 2



Sample 2 - Face 1



Sample 2 - Face 2

Figure 10. Macrostructures of the samples after the cavitation

5. CONCLUSION

It notes that areas 1 and 2 of the sample 1 respectively surfaces 1 and 2 of samples 2 have lost each of mass as following: 4.91, 3.47, 2.76 and 6.77 mg. The surface with a good cavitation erosion resistance is surface from Sample 2 - Face 1.

Of the 4 surfaces, the greatest amount the mass loss for a testing period, it was as follows: 0.86 mg (S1-F1); 0.61 mg (S1-F2); 0.38 mg (S2-F1) şi 1.18 mg (S2-F2);

The images after the cavitation had shown a clear view of the erosion, but for this batch of the X3CrNi13-4 stainless steel it can be concluded that assume a good cavitation erosion resistance.

REFERENCES

[1] Lupinca, C.-I., Nedeloni, M.-D., Nedelcu, D. Gray Cast Iron Behaviour in Cavitation Erosion, Materials Science Forum, Vol. 782, 2014.

[2] Mânzână, M. E., Ghiban, B., Ghiban, N., Bordeaşu, I., Miculescu, F., Marin, M. Different Aspects of Cavitation Damages in Some Stainless Steels, Analele Universităţii Eftimie Murgu, anul XVIII, nr. 1, 2011.

[3] Lupinca, C. I., Nedeloni, M.D. Comparative study regarding the cavitation erosion behavior of Cu and Al alloys, International Journal of Latest Research in Science and Technology, Volume 3 (2), 2014.

[4] Nedeloni, M.D., Cojocaru, V., Nedelcu, D., Ciubotariu, R. Cavitation Erosion Tests Performed by Indirect Vibratory Method on Stainless Steel Welded Samples with Hardened Surface, Analele Universităţii Eftimie Murgu, Vol. 19, 2012.

[5] Lupinca, C. I., Nedeloni, M.D. The Study of Bronze Behaviour During Cavitation Erosion, Indian Journal Of Applied Research, Volume 4 (5), 2014.

[6] Cojocaru, V., Câmpian, C.V., Frunzaverde, D., Ion, I., Cuzmos, A., Dumbrava, C. Laboratory tests concerning the influence of surface hardening on the cavitation erosion resistance, Proceedings of 3rd WSEAS International Conference On Engineering Mechanics, Structures, Engineering Geology (EMESEG '10), 2010.

[7] Chirus, D., Nedeloni M.D. Cavitation Erosion Research for AlSi12 alloy tested at different time periods, Analele Universităţii "Eftimie Murgu", Vol. 20, Nr. 1, 2013.

[8] Ianici, S., Ianici, D. Design of mechanical systems, Eftimie Murgu Publisher, Resita, 2010.

[9] Cojocaru, V., Câmpian, C.V, Frunzaverde, D., Miclosina, C.O. Residual Stresses Analysis of Weld Overlays Coatings Used for

the Repairs at Kaplan Turbine Runner Blades Areas Damaged by Cavitation Erosion, „Recent Researches in Environment, Energy Planning and Pollution", Proceedings of the 5th WSEAS International Conference on Renewable Energy Sources (RES '11), 2011.
[10] Cojocaru, V., Câmpian, C.V., Miclosina, C.O. Experimental Analysis of Residual Stresses in Samples of Austenitic Stainless Steel Welded on Martensitic Stainless Steel Used for Kaplan Blades Repairs, Lucrarile conferintei "Systems & Structures" (SysStruc '11), 16-17 September 2011, Resita, „Analele Universitatii "Eftimie Murgu" Resita, Anul XVIII, nr.1, 2011).
[11] Frunzaverde, D., Câmpian, C.V., Cojocaru, V., Marginean, G., Baran, M., Ciubotariu R. Influence of welded layers thickness on the cavitation erosion resistance, Proceedings of 6th WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD '10), 2010.
[12] Cojocaru, V., Câmpian, V. C., Balint, D. Numerical Analysis of Flow in Kaplan Turbine Runner Blades Anticavitation Lip with Modified Hydrodynamic Profile, Analele Universităţii Eftimie Murgu, anul XVIII, nr. 1, Reşiţa, 2011.
[13] Ciubotariu, R., Şerban, V. A., Frunzăverde, D. Mărginean, G., Câmpian, V. Comparative study regarding the repair techniques for protection against cavitation, Scientific Bulletin of the "Politehnica" University of Timisoara Transactions on Mechanics, vol. 55 (69), Timişoara, 2010.
[14] Nedeloni, M.D. Cercetări privind eroziunea cavitaţională pe materiale utilizate la fabricaţia componentelor de turbine hidraulice (Research regarding the cavitation erosion on materials used to manufacture the components of hydraulic turbines), PhD Thesis, Eftimie Murgu University, Reşiţa, 2012.
[15] *** ASTM Standard G32-92 (1992), Standard Method of Vibratory Cavitation Erosion Test. Annual Book of ASTM Standards, Philadelphia, 1992.
[16] *** ASTM G32–10, Standard Test Method for Cavitation Erosion Using Vibratory Apparatus, ASTM International, 2010.
[17] Nedelcu, D., Nedeloni, M.-D., Lupinca, C.-I. Cavitation Erosion Research on the X3CrNi13-4 Stainless Steel, Materials Science Forum, Vol. 782, 2014.
[18] Nedeloni, M.D., Nedelcu, D., Campian, V.C., Chirus, D., Avasiloaie, R.C., Danut, F. Research regarding the cavitation erosion resistance of the stainless steel with the 13% Cr and 4% Ni used to manufacture the components of Kaplan, Francis and Pelton hydraulic turbines, Constanta Maritime University Annals, Vol. 14, No. 19, 2013.
[19] Chirus, D., Nedeloni, M.D., Campian, V.C. Cavitation erosion research on X3CrNi13-4 stainless steel samples with cubic/cylindric shape and 3D design for new brackets used for the cavitation experimental stand, Constanta Maritime University Annals, Vol. 14, Nr. 20, 2013.
[20] Georgescu, A.M., Georgescu S.C. Hidraulica reţelelor de conducte şi maşini hidraulice, Editura PRINTECH, Bucureşti, 2007.
[21] Câmpian, V. C. Turbine hidraulice de mică putere şi microturbine. Principii de funcţionare. Soluţii constructive, Editura Orizonturi Universitare, Timişoara, 2003.
[22] Avellan, F., Introduction to cavitation in hydraulic machinery, Scientific Bulletin of the "Politehnica" University of Timisoara, Special issue - The 6th International Conference on Hydraulic Machinery and Hydrodynamics, Timişoara, 2004.
[23] Frunzăverde, D., Câmpian, V., Mărginean G., Metallographic Investigations on Anti-Cavitation Lips of Kaplan Blades, 23rd IAHR SYMPOSIUM on Hydraulic Machinery and Systems, Yokohama, Japan, 2006.
[24] Hamat, C.O., Nedeloni, M.D., Haţiegan, C., Ciubotariu, R.C., Pădureanu, I., Cavitation erosion research on C45 carbon steel. Part I: Multiple tests of 180 minutes, Annals of „Constantin Brâncuşi" University of Târgu Jiu, No. 3, 2015.