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D9.1 Database of papers and journals related to coatings March 2016

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3	Version 3	



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Executive Summary

The purpose of this document is to present the state-of-the art regarding the coatings developed for corrosion protection of condensing economizers. The corrosion environment within a condensing economizer is rather harsh, because of the coexistence of sulfuric acid, nitric acid and water condensates, high relative humidity, the temperature variations below and over the pertaining dew points, and the saturated gas flows. All these constitute a highly corrosive ambient. The design and development of novel coatings improving the corrosion protection in these structures is highly appreciable, since will lead to longer service life, and lower operational and maintenance costs.

Based on the bibliographic review there are only few studies treating this problem, with results far from encouraging. This suggests that novel approaches shall be designed and tested.

1 Introduction

Corrosive acids (e.g. H₂SO₄, HNO₃ etc) with low pH values and high concentrations form when the exhaust streams condense at temperatures below the respective acid and water vapor dew points. Heat exchangers made from low-cost materials, e.g. carbon steels, aluminum, stainless steels, or even nickel-base alloys, cannot withstand at such corrosive environments. Expensive and elegantly alloyed exotic metals may provide improved corrosion protection. However, the return-on-investment of such metals is discouraging low. Therefore there is a need for coatings with low cost and high corrosion protection properties. The state-of-the-art of materials and methods to this end, have been included in this database.

2 Database presentation

In the following Table we summarize the documents of this database.

Table 1. Summary of documents related to coatings for corrosion protection of condensing economizers.

Nr.	Title	Year	Authors	Citation	Type of document
1	Electrochemical Behavior and Compositions of Passive Films of Amorphous Ni - P Coating in Acidic Environment	2016	Zhao, Guanlin, et al	Int. J. Electrochem. Sci 11 (2016): 140-153	Journal Article
2	Comparison of the corrosion behaviour of laser-annealed Ni-P and Ni-Mo-P deposits in H ₂ SO ₄ and NaCl solutions	2016	Liu, H., Wang, P., Liu, Z. Harission, G., Thompson, G.E.	The International Journal of Surface Engineering and Coatings, in press	Journal Article
3	The Corrosion Behaviors of Amorphous, Nanocrystalline and Crystalline Ni-W Alloys Coating	2015	Liu, Xiangyong, et al	Int. J. Electrochem. Sci 10 (2015): 9042-9048	Journal Article
4	Fluoropolymer composite coating for condensing heat exchangers: Characterization of the	2015	He, Youliang, Dan Walsh, and Chao Shi	Applied Thermal Engineering 91 (2015) 387e398	Journal Article

	mechanical, tribological and thermal properties				
5	Performance testing of iron based thermally sprayed HVOF coatings in a biomass-fired fluidised bed boiler	2015	Oksa, Maria, Tommi Varis, and Kimmo Ruusuvoori	Surface & Coatings Technology 251 (2014) 191–200	Journal Article
6	Characteristics of Sulfuric Acid Condensation on Cylinder Liners of Large Two-Stroke Marine Engines	2014	Cordtz, Rasmus Faurkov; Mayer, Stefan; Schramm, Jesper; Eskildsen, Svend S.	Paper presented at 3. Rostocker Großmotorentagung, Rostock, Germany	Conference Proceedings
7	Impact of sulphuric acid on cylinder lubrication for large 2-stroke marine diesel engines: contact angle, interfacial tension and chemical interaction	2013	Sautermeister, F. A., et al.	Tribology International 59 (2013) 47-56	Journal Article
8	Recovery of water from boiler flue gas using condensing heat exchangers	2011	Levy, Edward, Bilirgen, Harun and DuPont, John	Energy Research Center	Technical Report
9	Corrosion behavior of electroless deposited Ni–Cu–P coating in flue gas condensate	2010	Liu, Guichang, et al	Surface & Coatings Technology 204 (2010) 3382–3386	Journal Article
10	Evaluation of surface coatings for heat exchangers		Kukulka, David J., and Paul Leising	Chemical Engineering Transactions 18 (2009) 339-344	Journal Article
11	Solving heat exchanger tube problem with thin film thermally conductive coating applications	2009	Curran, E.L.	Proceedings of the International Conference on Heat Exchanger Fouling and Cleaning VIII	Conference Proceedings
12	Components Susceptible to Dew-Point Corrosion	2006	Cox, William, Huijbregts, Wally	ASM Handbook, Volume 13C, Corrosion: Environments and Industries	Handbook chapter
13	Electroless Ni–Cu–P–PTFE composite coatings and their anticorrosion properties	2005	Zhao, Q., and Y. Liu	Surface & Coatings Technology 200 (2005) 2510– 2514	Journal Article
14	Carbonaceous materials for gas phase desulfurization: role of surface heterogeneity	2004	Bagreev, Andrey, Bandosz, Teresa	Prepr. Pap.-Am. Chem. Soc., Div. Fuel Chem. 2004, 49(2), 817	Conference Proceedings
15	Graded Ni–P–PTFE coatings and their potential applications	2002	Zhao, Qi, et al	Surface and Coatings Technology 155 (2002) 279–284	Journal Article


16	Research Strategies Relevant to Heating Fuel Oil Specifications: Fuel Sulphur Aspects Literature Review	2002	Vladimir V. Razbin, S. Win Lee, Frank D. Friedrich	Environment Canada Air Pollution Prevention Directorate Oil, Gas and Energy Branch	Technical Report
17	Corrosion resistance of ternary Ni/P based alloys in sulfuric acid solutions	2002	Lu, Guojin, and Giovanni Zangari	Electrochimica Acta 47 (2002) 2969/2979	Journal Article
18	High activity magnesia use for SCR related SO ₃ problems	2002	Schmidtchen, Paul A., et al	Proceedings of 2002 Conference on Selective Catalytic Reduction (SCR) and Selective Non-catalytic Reduction (SNCR) for NO _x Control.	Conference Proceedings
19	Corrosion in flue gas desulfurization plants and other low temperature equipment	1992	Dahl, L.	Materials and Corrosion 4.1, 298-304 (1992)	Journal Article
20	The corrosion resistance of Nickel containing alloy in Sulphuric acid and related compounds	1983		The International Nickel Company	Technical Report

3 Conclusions

The document summarizes the database of papers and journals related to coatings. Twenty in total journal articles, conference proceedings and technical papers have been gleaned and uploaded in the Project website for use by the consortium.

The research regarding the coatings suitable for protection of metallic structures within condensing economizers is far from plentiful, due to the rather harsh corrosion environment. Ni coatings doped with P, Cu, Mo and W have been studied for such applications, but are still under development, with no industrial application so far. Conventional coatings such as epoxy, carbonaceous, zinc-rich etc do not exhibit promising anticorrosion performance, indicating a need for novel alternative approaches.

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