

Applying organisation

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Project

The application regards a new project.

Title

Composite Metal Polymer (CMP) for non-stick improvements in CHP plants

Metall-polymer-komposit (CMP) för förbättrade släppningsegenskaper i kraftvärmeverk

Summary

Heat and power production with "difficult" fuels often results in extensive fouling. This creates problems like efficiency decrease, deposit-induced corrosion, dew-point corrosion for boiler components at low temperatures and frequent need of soot-blowing. The aim is to make an initial study of the properties of a new Composite Metal Polymer (CMP) based on thermal spray coating of Ni-base alloy including a hard phase together with a polymer with good non-stick properties and resistant to elevated temperatures.

A composite coating with combined properties of corrosion and erosion resistance together with good non-stick properties should minimize or even eliminate these problems, when applied on the heating surfaces. A composite material that minimizes the fouling problems will give energy producers improved electricity and heat output, increased availability, allow more flexible use of various fuels, decreased environmental impact, lower maintenance costs and shorter down-time periods.

Kraft- och värmeproduktion med "svåra" bränslen medför ofta kraftiga avlagringar. Detta medför dels ineffektiv värmeöverföring, avlagringskorrosion, korrosion p.g.a. daggpunkt i pannornas kallare ytor, samt behov av återkommande sotblåsning. Målet är att göra en inledande studie av egenskaperna hos en ny metall-polymer-komposit (CMP) baserad på termiskt sprutat skikt av Ni-bas legering med hårdfas och en polymer med goda släppningsegenskaper ("non-stick") och beständighet vid förhöjda temperaturer.

Med ett kompositskikt med kombinerade egenskaper i form av korrosions- och erosionsskydd och goda "non-stick"-egenskaper på värmeytorna skulle dessa problem minska och i vissa fall helt elimineras. Ett kompositmaterial som klarar att minimera avlagringsproblematiken medger förbättringar för energiproducenterna genom ökad el- och värmeeffektivitet, högre tillgänglighet, ökad bränsleflexibilitet, minskad miljöpåverkan, lägre underhållskostnader och kortare underhållsstopp.

Motivation

Programme relevance

The project is relevant for the programme research area *Development of materials technology*, since it includes research on a solution to prevent low temperature corrosion and to minimize problems with high temperature corrosion and erosion, through the use of a novel composite-based surface coating in various boiler environments.

The project contributes to the programme goals as follows:

Goal 1: Investigating the possibility to increase the electrical efficiency through decreased amount of deposits, which minimise losses from decreased heat transfer and frequent soot-blowing, as well as through lowered inlet temperature to the economiser enabled by increased resistance to low temperature corrosion.

Goal 2: The research facilitates as the MAIN GOAL the development of a technique for applying Composite Metal Polymer (CMP) in a plant, which is a new material solution.

Goal 3: Performs and evaluates exposures and application tests of composite materials in the form of a coating. The aim is to increase both the fuel flexibility through minimising the problems related to fuels giving substantial amounts of deposit, and to increase the electrical efficiency through decreased need of soot-blowing and lower economiser inlet temperature.

Goal 5: Evaluates and investigates a new material solution that in different variants will contribute to minimising especially low temperature corrosion, but also superheater and furnace wall corrosion, as well as erosion problems.

Goal 6: The research facilitates the development of a new composite based design solution that will increase fuel flexibility and plant availability through minimised down-time caused by damages related to corrosion and soot-blowing related erosion, as well as caused by excessive deposits causing failure or blockage of for example electrostatic precipitator filters, fan blade, and ash release cones.

The project contributes to the programmes academic goals, since it will be part of a Ph.D. work performed at Swerea KIMAB and examined through Chalmers tekniska högskola. The

results are intended to be published in a peer reviewed scientific journal and to be included in a Ph.D. thesis.

The project contributes to the programmes industrial goals, since it is presumed that the research will facilitate to make the investigated technology become a commercial product frequently used in plants.

Energy relevance

Through surfaces that keep cleaner in both furnace and convection parts the following advantages are achieved for combined heat and power (CHP) plants:

- Increased electrical efficiency
- Increased fuel flexibility
- Decreased maintenance costs related to corrosion and erosion damages
- Increased availability in general through minimised planned and unplanned down-time
- Increased operation time during top load periods through minimised unplanned down-time

Industry relevance:

The aim is that a CMP coating depending on operating conditions shall last at least 3-5 years before it needs reapplying. It is expected that a large proportion of national and international CHP plants shall benefit greatly from these. With such a CMP the potential market for coatings in CHP plants will multiply. Presently there is no similar competing product and national coating companies, whom often are SME operating at the international market, will achieve a great advantage by the lead.

News value with the project:

Today there is no corresponding product to CMP for usage at elevated temperature. The challenge is to increase the temperature capability with polymers of good non-stick properties and to achieve high erosion resistance for the CMP. State-of-the-art polymers have not been tested for this application and within CHP plants to the limit of their temperature capacity. Limited testing has been performed to evaluate non-stick properties at low temperature sections.

Implementation of results:

It is expected that CMP will have a great potential to be used in almost all CHP plants operating on fuels causing deposit related problems. There is an increasing use of such fuels caused by its lower costs. Once fully developed a CMP solution can be implemented in existing plants with immediately improved results regarding deposit problems, increased efficiency and lower costs of soot-blowing. New CHP plants can be optimised to take full advantage of the benefits during the design phase.

Implementation of the project:

MH Engineering is an internationally established company (SME) that perform coating application to protect thermal power plants. Swerea KIMAB is nationally leading within low

temperature corrosion and polymer degradation within power plants, and well established within research on wear, high temperature corrosion and thermal spray coating technology.

Background

Heat and power production with difficult fuels such as municipal and industrial waste, waste wood and renewable fuels etc. often results in massive deposits on the boilers heat transfer surfaces. This situation results in ineffective heat transfer, deposit-induced corrosion and need of frequent soot-blowing, which causes material damage by corrosion and erosion, loss of electrical efficiency and substantial costs [1-5].

The deposit amount depends on the chemical complexity of the fuel and its high alkali content, primarily potassium [6]. Numerous combinations of low temperature melts may occur from elements such as Cl, K, Na, Pb and Zn.

The power producers experience the following problems:

- Low electrical efficiency because the steam temperature must be low because of deposit-induced corrosion.
- Increased demand of soot-blowing or other cleaning methods.
- Limited fuel flexibility causing increased fuel costs.
- Increased maintenance cost because of deposit-induced corrosion and erosion.
- Decreased plant availability because of increased planned and unplanned down-time for maintenance.

The negative consequences of boiler fouling for the maintenance work can be illustrated by Photo 1 showing an example from Öresundskraft Västhamnsverken. Before furnace maintenance work can be started the slag hanging at specially the fuel inlets need to be removed, as it will be quite some severe risk of it falling down. The cleaning work is quite spectacular and dangerous as can be seen from the illustration. The photo is quite typical for furnace fouling in boilers burning “difficult” biomass.

Within the paper industry CMP based on carbide containing metal spray coatings and polymers have been used for more than 20 years. The application has experience good non-stick properties and acceptable life. The primary use has been for the steam heated dryer cylinders. This application has now for long been a globally established and accepted product. Compared to boilers the chemical environment is quite different and depending on position the temperature is lower.

The applying company has made a first successful field exposure, where a similar concept of CMP has been tested in a boiler environment, see Appendix 1. The test was made on the blades of a flue gas recirculation fan at Västhamnsverket in Helsingborg, which operates at a temperature of about 200 °C. Previously it needed to be cleaned weekly to avoid unbalanced rotation and bearing failure. It operated without need of cleaning for one season and during the revision the coating was shown to be intact.

The tested CMP was produced by a metal spray and polymer coating technique. A special advantage of metal spraying compared to overlay welding is that it can be reapplied numerous times without risk of thermal cracking.

Areas of problems today where CMP could be considered are the furnace walls and when present evaporators panels, the first and depending on steam temperature the second superheater, as well as the economiser. Deposits on these parts decrease the boiler efficiency and increase the risk of deposit-induced corrosion and erosion from excessive need of soot-blowing. Partial blocking of the flue gas paths increases the flue gas velocity locally and causes erosion. Hygroscopic deposits give down-time corrosion, which contributes to the overall material loss but also attacks the oxide layer that shall protect against high temperature corrosion.

The incoming water temperature to the economiser is limited by low temperature corrosion, i.e. dew-point corrosion from sulphuric and hydrochloric acids. Increased corrosion resistance would allow lowering the temperature limit, which would give higher electrical efficiency. Sometimes this applies to air preheaters and fuel dryers as well.

Other surfaces where deposit may cause corrosion or other types of problems include: fan blades where unbalance can cause bearing failure and fire may be caused by friction heat, if the deposits contain unburned fuel; components in electrostatic precipitator (ESP) filters, where the filtering effect may be lowered causing increased particle emissions; ash release cones of textile and ESP filters, where extensive deposit build-up gives increased pressure drop over the boiler decreasing its efficiency and increased risk of secondary combustion causing damages.

Although the use of CMP is new to boiler technology, thermally sprayed metal coatings containing hard phases to give high erosion resistance have been used and investigated for several decades [7-10].

This application refers to a new project. It partially connects to the ongoing project KME-711, which refers to field exposures with metal spray coatings of Ni-base material on the superheater of E.ON Händelöverken P15 in Norrköping. That project regards high temperature corrosion testing primarily and does not include any polymers. This project regards research on a Composite Metal Polymer (CMP) aimed at giving non-stick properties and corrosion and erosion protection.

The challenges to this new technology are several. The polymer part of the composite must withstand the temperature and chemical environment. Recently fluoropolymers have been developed with a temperature capability of 450 °C [11]. The metallic part must withstand corrosion and provide erosion protection for the polymer and corrosion protection for the underlying metal substrate. There shall be no or limited chemical interaction between the polymer and metallic parts. For example hypothetically at high temperature the polymer could cause carburisation of the metal accelerating its own break-down. Further fluoropolymers

releases HF during breakdown, which in its turn could cause a corrosion attack on the metal deteriorating the protective properties on its oxide layer. This in its turn would accelerate the carburisation process. Investigating these possible mechanisms will provide a better understanding of them providing a basis for further material development aiming at widening the possible area of use for CMP.

References:

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Photo 1. Cleaning of furnace wall fouling at Västhamnsverket

Goal

The project is relevant for program goals number 1, 2, 3, 5 and 6. The main goal is number 2 where the project aims at developing a technique for applying a Composite Metal Polymer (CMP) in a plant, which is a new material solution. This new material solution (goal 5) will help reduce especially low temperature corrosion, but also superheater and furnace wall corrosion, as well as erosion problems.

The project aims at contributing to the development of a CMP based on thermal spray coatings of Ni-base alloys including a hard phase together with a polymer with good non-stick properties and resistant to elevated temperatures by an initial investigation of its properties. The CMP shall reduce fouling and protect the underlying substrate against high or low temperature corrosion depending on application.

Specific Scientific Goals are:

1. To initially investigate how to obtain a certain “equilibrium” polymer-to-metal area ratio during abrasive wear or erosion and to explain why it is achieved, as well as to establish a criteria for a minimum ratio that results in a significant improvement of the non-stick properties.
2. To initially investigate the high temperature capability of the CMP and determine the type of failure occurring at the temperature limit.
3. To initially investigate the influence on fouling during field service with respect to amount and adhesion.
4. To initially investigate the corrosion behaviour and to some extent explain the ongoing corrosion mechanisms, when exposed to high temperature corrosion during field service.
5. To initially investigate the corrosion behaviour and to some extent explain the ongoing corrosion mechanisms, when exposed to low temperature corrosion during field service.

All Specific Scientific Goal are aimed at being generally applicable, when a CMP of the investigated or similar type is used in various types of boiler environments.

The overall scientific goal of the project is to obtain a broad scientific understanding of the properties and break-down mechanisms of a CMP in a boiler environment. One goal of this project, which is an initial study since the field of research is new, is to provide input for future studies where some of the identified mechanisms will be studied in-depth. The concept of such studies has been discussed with representatives of the HTC competence centre at Chalmers.

Project plan

The project consists of five Activities:

1. Initial literature study to find a polymer with a good combination of high temperature resistance and non-stick properties. (Recently fluoropolymers have been developed that withstand up to 450 °C.)
2. Laboratory investigation of the degradation of the CMP during abrasive wear and erosion.
3. Laboratory investigation of the temperature capability of the polymer when being part of a CMP during exposure in humid atmosphere.
4. Field exposure and post-exposure investigation of CMP exposed at boiler areas susceptible to high temperature corrosion.
5. Field exposure and post-exposure investigation of CMP exposed at boiler areas susceptible to low temperature corrosion.

For the material exposures samples consisting of the Ni-base material alone and as part of a CMP will be included, which will allow investigation of the influence of the polymer on the corrosion behaviour of the metallic component of the CMP. For comparison reference samples of materials relevant for each investigated application will be included as well.

Common analysis methods that will be used for the evaluations within Activities 2-5 are metallographic investigation by means of light optical microscopy (LOM) and scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy (EDS). In addition, X-ray diffraction (XRD) will be used for Activities 4 and 5. These analyses will aim at determining the morphology of the CMP and the chemistry of the corrosion attack and to a minor extent the composition of remaining deposits. Measurement of wetting angle is relevant for Activities 2-4 and will be performed when practically possible, as indication of the non-stick properties before and after exposure.

Activity 2 will be performed as room temperature exposure of metal coupons approximately 5x5 cm in a rotating wear test rig filled with an erodent. Various test times will be used to allow fulfilment of the Specific Scientific Goal 1.

Activity 3 will be performed as laboratory exposure in a closed furnace system through which humid synthetic air or flue gas is purged in order to fulfil Specific Scientific Goal 2. The temperature capability of the polymer may be defined as the temperature where a metallographic investigation shows that it has decomposed or detrimentally affected the metal part of the composite by for example carburisation or initiation of a fluorine-induced corrosion attack. Alternatively the temperature limit may be identified as when the polymer undergoes substantial defluorination by release of hydrogen fluoride (HF).

Activity 4 and 5 will be performed as field exposure of samples during field exposure. One set of samples will be removed after 1 year and one set after 2 years of exposure. The material will be tested as attached coupons, on-site applied coating or by exchanging parts of components/tubes to parts that has been coated off-site depending on what is more practical for each test position. To fulfil Specific Scientific Goal 3 visual inspection will be made when possible during exposure and when removing the samples. Further the deposit adhesion will be evaluated by manual scraping before sample removal. Specific Scientific Goal 4 and 5 are aimed to be fulfilled by post-exposure analysis through the above mentioned analysis techniques.

The applying company MH Engineering is responsible for the literature study of Activity 1, producing the test materials for Activities 2-5, and inserting/inspecting/removing the test materials during the field test of Activities 4-5, as well as the on-site evaluation of material/fouling behaviour. They will cooperate with Alu-Releco Oy to get access to the necessary technology with relation to the polymer part of the CMP material.

The co-applicant Swerea KIMAB will be responsible for performing Activities 2-3 and the post-exposure evaluation related to Activities 4-5.

The field exposures of Activities 4-5 will be performed at Västhamnsverket in Helsingborg belonging to Öresundskraft and at a straw-fired boiler (to be decided) belonging to Dong. Exposures will be made at areas susceptible to high and low temperature corrosion. At Västhamnsverket testing is intended at furnace parts with fouling issues, at a lower temperature superheater, in the economiser area and at the cones of the electrostatic precipitator (ESP) filter. At the straw fired boiler the exposure are expected to be made in the furnace and in the economiser area.

The results are to be included in a final report, scientifically published and constitute part of a Ph.D. thesis.

Time plan

Project start: 1 Feb 2015

Project end: 15 April 2018

Table 1. Project time plan

	2015				2016				2017				2018
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Literature study – polymers	x												
Laboratory testing and analysis		x	x										
Manufacturing and installation of field test samples			x	x									
Inspection and dismounting of field test samples						x	x			x	x		
Laboratory analysis of field test samples							x	x			x	x	
Scientific evaluation and publishing				x				x				x	x
Final reporting												x	x

Costs and financing

Table 2. Project total costs

	2015	2016	2017	2018	Sum
Salaries	770 000	450 000	400 000	209 000	1 829 000
Consultants	275 000	0	0	0	275 000
Equipment	25 000	0	0	0	25 000
Material	46 000	0	0	0	46 000
Laboratory costs	30 000	20 000	20 000	0	70 000
Travel	32 000	32 000	32 000	0	96 000
Other costs	5 000	5 000	5 000	5 000	20 000
Indirect costs (university OH)	0	0	0	0	0
Sum	1 183 000	507 000	457 000	214 000	2 361 000

Table 3. Project financing

	2015	2016	2017	2018	Sum
Energimyndigheten	350 000	240 000	240 000	114 000	944 000
MH Engineering AB	683 000	117 000	117 000	100 000	1 017 000
Dong Thermal Power, Nesa Alle 1, 2820 Gentofte, Denmark Hans Henrik Poulsen +45 99559743	50 000	50 000	50 000	0	150 000
Öresundskraft Kraft och Värme AB Atlantgatan 10, 25225 Helsingborg. Org. Nr. 556501-1003 Henrik Wangsell, 042-4903000	100 000	100 000	50 000	0	250 000
Sum	1 183 000	507 000	457 000	214 000	2 361 000