

Project plan

Title

Högtemperaturkorrosion i returträ-eldade pannor – bränsleadditiv och ytbeläggningar

High temperature corrosion in used-wood fired boilers – fuel additives and coatings

Applying organisation

Swerea KIMAB AB

Project leader

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Co-applicants

Amec Foster Wheeler, Andritz, E.ON, Fortum, MH Engineering, Sandvik Heating Technology, Sandvik Materials Technology, Vattenfall AB

Project

This application refers to a new project that will be closely related and complementing to KME 708 (EM 39270-1)

Summary

Målsättningen är att minska drifts- och underhållskostnader i kraftvärmepannor som huvudsakligen eldas med returträ (RT-flis). Arbetet är inriktat mot eldstadsväggar och eldstadskorrosion. Effekten av bränsleadditiv för att minska korrosion och/eller minska bränslekostnader (med bibehållen korrosionshastighet) kommer att utvärderas med korrosionssonder. Två försök med additiv kommer att genomföras, varav ett med rötat avloppsslam. Därtill utförs försök med referensbränslet (returträ). Nya material för skyddande ytbeläggningar kommer att utvärderas med exponeringar med längre försökstider. Korrosionsmätning och avancerad analys av korrosionsangreppen kommer att utföras efter exponeringarna. Förväntade resultat är ökad kunskap om inverkan av additiv och ytbeläggningar på eldstadskorrosion.

The aim is to reduce operation and maintenance costs in heat and power boilers that predominantly fire used (recycled) wood. The effort will be directed towards furnace walls and furnace wall corrosion. The effect of fuel additives to reduce corrosion and/or reduce fuel costs (without increasing the corrosion rate) will be evaluated with corrosion probes. Two tests with additives will be performed, including one with digested sewage sludge. The reference fuel (waste wood) will also be evaluated. New protective coating materials will be evaluated by longer term testing. Corrosion measurements and advanced

analysis of the corrosion attacks will be performed after the exposures. Expected results are increased knowledge on the influence of additives and coatings on furnace wall corrosion.

Motivation

Increasing use is being made of used wood as a fuel in heat and power boilers, because it is cheaper than virgin wood. Electricity prices are at record low levels (at the time of writing autumn 2015) and power plant owners need to reduce their costs for biomass-fired boilers if they are to remain competitive. However used wood causes more corrosion problems, especially in the furnace where there is a lack of oxygen (low NO_x combustion) so this increases the maintenance costs. Previous work in KME 508/512 and 708 (EM 39270-1) showed that co-firing with treated sewage sludge can reduce the corrosion, at least in short-term tests lasting a few hours (14 h). The sludge also has a negative gate fee which reduces the operation costs. This project is a continuation of KME 708 and will investigate the effect of longer term testing (approx. 300 hours) with sewage sludge. In addition another fuel additive in form of a sludge with high-sulphur content (probably a waste product from the pulp and paper industry) will be investigated to see if it is suitable for long-term use and comparing its properties with sewage sludge. If the plant receives payment for burning a waste product this reduces the fuel costs. If these additives reduce corrosion or at least do not increase the corrosion then they can make a useful contribution to the economics of producing heat and power from biomass. Further new protective coating materials will be evaluated by longer term testing to investigate how they can reduce corrosion.

The project contributes very strongly to the programme goal of improved fuel flexibility by enabling the combustion of problematic fuels (e.g. fuels causing increased corrosion) while maintaining electrical efficiency (steam temperature). This project contributes primarily to the following programme goals :

- To further develop tools and techniques to facilitate the application of new material solutions in plants. *(Vidareutvecklat verktyg och tekniker för hur nya materiallösningar kan appliceras i anläggningar.)*
- To evaluate exposures and application tests of various solid and composite materials and/or coated materials with the aim to develop improved material solutions which help to bring about greater fuel flexibility and increased electricity production. *(Utvärderat exponeringar och applikationstester av olika solida och kompositmaterial och/eller belagda material i syfte att utveckla förbättrade materiallösningar som bidrar till en ökad bränsleflexibilitet och ökad elproduktion.)*
- Suggestions for measures and solutions in order to reduce superheater and furnace corrosion, erosion-related problems and low temperature corrosion should have been developed. *(Förslag till åtgärder och lösningar för att minska överhettar- och eldstadskorrosion, erosionsrelaterade problem samt lågtemperaturkorrosion, ska ha tagits fram.)*
- Suggestions for new design solutions, operating parameters and tools for assessing what technical demands a specific fuel places on the plant should have been developed for CHP plants with the aim to help achieve enhanced fuel flexibility and availability. *(Förslag till nya konstruktionslösningar, driftparametrar och redskap för att bedöma vilka tekniska krav ett visst bränsle ställer på anläggningen ska ha tagits fram för kraftvärmeanläggningar, i syfte att bidra till ökad bränsleflexibilitet och tillgänglighet.)*

The academic goal of this project includes one licentiate (Annika Talus 2017), as well as giving additional contribution to her PhD thesis (estimated 2018). The results will be published in one to two scientific papers.

Energy relevance

Serious corrosion problems are often a hindrance to using used (recycled) wood or other waste-products as a fuel because of high chlorine and heavy metal contents. As a consequence waste-derived fuels are often combusted in heat and power boilers with low steam data (low efficiency). Low electricity prices are also affecting the competitiveness of biomass as a fuel for electricity production. The results of this project will enable waste wood and other waste-derived fuels to be utilized at higher steam pressures and temperatures thus increasing the amount of electricity produced from renewables or to reduce operating costs thereby making biomass more attractive and financially competitive.

Industrial relevance

Boiler manufacturers will be able to produce boilers utilizing used wood with a higher efficiency, if it is known how to control their corrosion problems. Power companies will be able to use greater amounts of used wood or other waste products in the fuel mix, thus reducing their operating costs. Corrosion rates can be reduced, thus reducing maintenance costs. Longer term testing will be performed on Swedish developed Fe- and Ni-based coatings, which will facilitate their introduction or increased use for corrosion protection of furnace walls. This will be beneficial to not only the power industry but to material producers and coating companies as well.

News value

Only limited research has been performed on the use of additives to reduce furnace corrosion in used-wood fired heat and power boilers. The previous KME projects in this area, KME 508, 512, 708, produced new results regarding the use of treated sewage sludge as an additive with some short-term testing (8-14 h). This project will build on the results of these previous KME projects and longer term testing (~300h) with sewage sludge to reduce corrosion will be performed. In addition another new fuel additive in form of a sludge with high-sulphur content will be investigated.

Previous researchers have tested sewage sludge in the laboratory or in a boiler, but so-far no-one has studied longer term furnace wall corrosion (more than a few days) and mainly superheater corrosion has been studied. Short wall tests with sludge have only been performed in the KME programme.

For example tests with additions of sewage sludge have been performed

- near superheaters for 24 hours in a commercial bubbling fluidised boiler burning waste, [1]
- simulating superheaters in a BFB bench scale rig for 3 hours burning bark, [2],
- near superheaters for 24 hours in a waste fired grate boiler [3]
- simulating furnace walls and superheaters for 8 hours in a laboratory scale fluidised bed reactor firing used wood [4]
- at the furnace walls in a commercial BFB boiler for 14 hours burning used wood [5]
- simulating superheaters for 24 hours in a 12MW CFB laboratory boiler burning a mixture of biomass and waste [6].

In all these tests the addition of sewage sludge reduced the amount of chlorine in the deposits and reduced the corrosion (where corrosion was measured). For the tests simulating superheaters, the amount of sulphur in the deposits increased which is thought to have contributed to the reduction of

corrosion through the sulphation of alkali chlorides. However, in the furnace wall tests no increase in the amount of sulphur was seen in the deposit, although the sludge contained sulphur. This is expected as probably there is not enough oxygen available to convert sulphur into sulphates (or to maintain the stability of sulphates). Further the difference in oxygen partial pressure makes it difficult to predict the effect of fuel additives on water walls from superheater results. To our knowledge, this will be the first time that the longer term effects of sewage sludge on furnace wall corrosion of a used-wood firing boiler have been studied.

Implementation of results

The expected results are increased knowledge on the effects of additives and new coating materials on the furnace wall corrosion. The results can be implemented by boiler manufacturers to increase fuel flexibility or efficiency of new boilers or by power producers to increase fuel flexibility or reduce costs in existing boilers. A relatively large number of companies representing different industry segments with various interests in the power industry are represented in the project. This will ensure fast implementation of beneficial results.

General applicability

The results concern fuel chemistry and materials and are applicable to all plants firing used-wood and biomass used-wood mixtures. They will also give valuable information to plants burning other sorts of waste (household or industrial).

Background

The combustion of biomass and waste is making an increasing contribution to Sweden's energy production and reduces the dependence on non-renewable sources. In order to reduce operating costs (which is especially important when electricity prices are low) low quality fuels like used (recycled) wood are often utilized instead of forest residues (virgin biomass). Used wood consists of by-products from consumption, like demolition wood and recovered building wood and often contains traces of paint or plastics or other polymers. This gives rise to an increase in the amount of chlorine, zinc and lead in the fuel and increases the corrosion risk to the boiler components, when compared to virgin biomass. It would be useful to reduce the amount of corrosion caused when burning used wood or reduce the operating costs still further.

Problems have been experienced with furnace wall corrosion with used wood contents as low as 20% in combination with low-NO_x combustion and advanced steam conditions of about 140bar/540°C (KME 508 final report). In Vattenfall's 100MWth bubbling fluidized bed boiler using 100% used wood in Idbäcken, Nyköping, corrosion rates of up to 1.5 mm a year were measured on the low-alloy steel walls made of 16Mo3. This corrosion rate gives a lifetime of 3 years and a new furnace wall for a boiler of this size costs around 25 MSEK.

The walls have since then been overlay welded with the nickel-base material Alloy 625 to reduce the corrosion, but even this alloy corrodes (albeit at a lower rate) so the problem is not solved. In addition, Ni-base alloys are expensive. Long-term probe testing (1000 h) in KME 508, 708 (EM 39270-1) showed that an FeCrAl alloy from Sandvik had excellent corrosion resistance when tested as solid material, indicating its potential as a coating material. This alloy will be evaluated as a weld overlay coating in this project, in parallel with testing of some other coatings. A particular benefit of highly corrosion resistant

coatings is that they require less use of rare and expensive raw materials than the use of solid tubes of similar composition.

In KME 512 and 508 short-term tests (8 and 14 hours respectively) with treated sewage sludge showed that adding digested sewage sludge to the fuel mix reduces the corrosion in low alloyed steel as well as high alloyed steels and Ni-base alloys.

The specimens have been analysed in more detail in KME 708 where it was found that the co-firing of sewage sludge with recycled wood reduced the amounts of K, Na and Cl on the furnace wall deposits. This led to a reduction in the corrosion. Attack by a potassium-lead combination appeared to be the main corrosion mechanism in the Alloy 625 during used wood combustion. This resulted in the formation of a non-protective potassium-lead chromate. The addition of sewage sludge suppressed this attack and the protective chromia layer was maintained resulting in a lower corrosion rate. In the FeCrAl alloy APMT, K attacked the pre-existing alumina layer, but the addition of sludge reduced this attack. It is thought that the presence of aluminosilicates in the sludge interacts with the alkali leading to a reduction in corrosion.

These short-term tests gave qualitative information. In this new project longer term tests with sewage sludge will be performed in a boiler to obtain more quantitative information on the reduction in corrosion rates on furnace wall and the mechanism behind the effect of sewage sludge will be more closely analysed. In addition another fuel additive in form of a sludge with high-sulphur content (probably a waste product from the pulp and paper industry) will be investigated to see if it is suitable for long-term use and comparing its properties with sewage sludge.

The project group comprises academics and industrial partners who are experts in their own areas (corrosion in biomass-fired boilers, boiler construction, manufacturing of advanced materials, heat and power production) and have an excellent ability to carry out the project. They have successfully performed previous KME projects. The project has a direct link to the environment quality goal called "Limited climate impact" by reducing CO₂ emissions.

This application refers to a new project that will be closely related and complementing to KME 708 (EM 39270-1). The project groups are largely comprised by the same companies and persons. This will ensure swift and accurate knowledge transfer. The main personnel are active also in project KME 717 (EM 40892-1). Although not related to furnace walls, connection with that project is of relevance as it relates to material performance at the same temperature region but at a higher oxygen partial pressure. Some of the participating industries are also participating in project KME 720 (EM 41048-1), which in parts involves furnace wall corrosion. In that project a different approach is taken to the question by investigating corrosion properties by partial and not predominant used-wood firing. In addition, the applying project leader and co-leader are members of the reference group of that project. This will greatly facilitate exchange of new knowledge and suggestions for research approaches in between the projects.

Goals

The overall aim of the project is to reduce operation and maintenance costs in heat and power boilers that burn predominantly used (recycled) wood by the use of additives to the fuel and the use of new

coating materials. The effort will be directed towards furnace walls. In general this will result in increased fuel flexibility and make biomass a more attractive and financially competitive energy source.

Specifically the project aims at acquiring new knowledge from longer term studies on the effect of using sewage sludge as fuel additive on furnace wall corrosion. It further aims at finding a sludge that can be used as an alternative to sewage sludge and investigate the effects of it and evaluate whether it is suitable for longer term use.

The project aims at acquiring in-depth knowledge on the corrosion behaviour of materials typically used for furnace walls both when fuel additives are used and when firing the reference fuel. It also aims at investigating the corrosion properties of some new coating materials and their related performance with respect to furnace wall protection.

The academic goal of this project includes one licentiate (Annika Talus 2017), as well as giving additional contribution to her PhD thesis (estimated 2018). The results will be published in one to two scientific papers.

Project plan

Project participants : Amec Foster Wheeler, Andritz, E.ON, Fortum, MH Engineering, Sandvik Heating Technology, Sandvik Materials Technology, Swerea KIMAB, Vattenfall AB.

Corrosion testing will be performed by Vattenfall in their 100MWth BFB (bubbling fluidized bed) boiler in Nyköping. This boiler runs on 100% used wood and high corrosion rates have been measured in the lower furnace region, which is where the corrosion testing will be performed. Vattenfall has developed a special probe for this purpose, which contains four specimens and can be inserted vertically into slits made in the fins between two tubes in the furnace wall. Tests will be performed with fuel additives, whereof one is sewage sludge, and with the base fuel as a reference.

Corrosion measurements will be made with two different sludges in special campaigns with wall steel (16Mo3) and conventional Ni-base material (Alloy 625) used for comparison.

Longer term probe testing with the reference fuel will be performed on Swedish developed Fe- and Ni-based coatings, including alumina-formers. The results will be evaluated and compared with conventional Alloy 625 as a reference material.

E.ON, Fortum, Andritz and Amec Foster Wheeler will contribute with advice and knowledge on the combustion of used wood and sludge. Some testing and corrosion results will also be obtained from boilers manufactured or operated by these companies.

Swerea KIMAB will analyse the deposits and corroded specimens from Vattenfall. The analyses will be made with Scanning Electron Microscopy with Energy Dispersive X-ray Spectrometry (SEM-EDS). FIB (focused ion beam) may be used to prepare fresh sections of the corrosion front beneath the oxide layer. The GD-OES method will be developed and used by Swerea KIMAB to obtain chemical depth profiles from the samples.

By using the above-mentioned analysis techniques information will be acquired to obtain a better understanding of the effect of sludge in reducing the corrosion caused by recycled wood and the corrosion mechanisms of different materials when burning used wood. Qualitative information on corrosion rates will be obtained.

Solid materials for testing are available to the project originating from earlier projects. Coatings for testing will be provided by the Sandvik group and MH Engineering. The amount and costs of raw materials required to produce the test samples are expected to be negligible, though not the time consumption related to the manufacturing of the coatings. In addition to this the Sandvik group will provide expert material advice and MH Engineering will contribute with expert knowledge on applying coatings on furnace walls and their performance.

Participants

Swerea KIMAB : Rikard Norling (project leader) and Annika Talus (PhD-student). The average degree of activity for the project leader (senior researcher) and PhD-student is intended to be 5-10% and 25-30%, respectively.

Vattenfall AB : Pamela Henderson (project co-leader), Annika Stålenheim, Carl Nordenskjöld, Christer Forsberg, Mattias Mattsson. All part-time.

Amec Foster Wheeler : Edgardo Coda Zabetta, Jouni Mahanen and Kyösti Vänskä. All part-time

Andritz : Christoph Gruber. Part time

E.ON : Anna Jonasson, Bengt-Åke Andersson and Colin Davis. All part-time

Fortum Värme : Eva-Katrin Lindman, Jukka Meskanen. Part time

Sandvik group : Jan Högberg, Johanna Nockert Olovsjö. All part-time

MH Engineering : Kristian Huhtakangas, Matti Huhtakangas. All part-time

Time-plan

Project start 2016 02 01. Project end 2018 04 15

	2014		2015				2016				2017				18
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
KME 708 (related project)	X	X	X	X	X	X	X	X	X	X					
Start-up, planning							X	X	X	X					
Corrosion testing								X	X	X	X	X	(X)		
Analysis of specimens									X	X	X	X	X		
Final project and reference group meeting														X	X
Reporting and publishing												X	X	X	X

Cost distribution

Part		Kostnadsfördelning										Finansiering		
		Lön	Konsult	Utrustning	Material	Laboratorie	Dator	Resor	Övrigt	Indirekta	Summa	Egen	Energi- myndigheten	Annan finansier
KIMAB	2014										0			
	2015										0			
	2016	210 000		40 000				11 000			261 000		261 000	
	2017	510 000		50 000				11 000			571 000		571 000	
	2018	210 000						11 000			221 000		221 000	
	Summa	930 000	0	90 000	0	0	0	33 000	0	0	1 053 000	0	1 053 000	0
Vattenfall AB	2014										0			
	2015										0			
	2016	300 000		30 000				10 000			340 000	340 000		
	2017	540 000		30 000				10 000			580 000	580 000		
	2018	240 000						10 000			250 000	250 000		
	Summa	1 080 000	0	60 000	0	0	0	30 000	0	0	1 170 000	1 170 000	0	0
Amec Foster Wheeler	2014										0			
	2015										0			
	2016	15 000						5 000			20 000	20 000		
	2017	15 000						10 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	45 000	0	0	0	0	0	15 000	0	0	60 000	60 000	0	0
Andritz	2014										0			
	2015										0			
	2016	15 000						5 000			20 000	20 000		
	2017	15 000						10 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	45 000	0	0	0	0	0	15 000	0	0	60 000	60 000	0	0
E.ON	2014										0			
	2015										0			
	2016	15 000						5 000			20 000	20 000		
	2017	15 000						10 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	45 000	0	0	0	0	0	15 000	0	0	60 000	60 000	0	0
Fortum	2014										0			
	2015										0			
	2016	15 000						5 000			20 000	20 000		
	2017	15 000						10 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	45 000	0	0	0	0	0	15 000	0	0	60 000	60 000	0	0
MH Engineering	2014										0			
	2015										0			
	2016	15 000						5 000			20 000	20 000		
	2017	15 000						5 000			20 000	20 000		
	2018	10 000									10 000	10 000		
	Summa	40 000	0	0	0	0	0	10 000	0	0	50 000	50 000	0	0
Sandvik Heating Technology	2014										0			
	2015										0			
	2016	20 000									20 000	20 000		
	2017	20 000						5 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	55 000	0	0	0	0	0	5 000	0	0	60 000	60 000	0	0
Sandvik Materials Technology	2014										0			
	2015										0			
	2016	20 000									20 000	20 000		
	2017	20 000						5 000			25 000	25 000		
	2018	15 000									15 000	15 000		
	Summa	55 000	0	0	0	0	0	5 000	0	0	60 000	60 000	0	0
Total		2 340 000	0	150 000	0	0	0	143 000	0	0	2 633 000	1 580 000	1 053 000	0

	SUM	2016	2017	2018
Salary costs	2 340 000	625 000	1 165 000	550 000
Consultants	0	0	0	0
Equipment	150 000	70 000	80 000	0
Material	0	0	0	0
Laboratory	0	0	0	0
Computer	0	0	0	0
Travel	143 000	46 000	76 000	21 000
Other	0	0	0	0
Indirect (Univ.)	0	0	0	0
SUM	2 633 000	741 000	1 321 000	571 000

Financing

Company	In-kind contribution SEK
Vattenfall AB	1 170 000
Amec Foster Wheeler	60 000
Andritz	60 000
E.ON	60 000
Fortum	60 000
MH Engineering	50 000
Sandvik Heating Technology	60 000
Sandvik Materials Technology	60 000
Total in kind	1 580 000
Swedish Energy Agency	1 053 000
Total project cost	2 633 000

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