Institute for Thermodynamics and Thermal Engineering

University of Stuttgart

Performance of CQM's SRS System Subjected To Severe Crystallization Fouling of CaSO4

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About the Institute for Thermodynamics and Thermal Engineering (ITW):

The Institute for Thermodynamics and Thermal Engineering (ITW), University of Stuttgart was founded in 1962 and later by Prof. Dr.-Ing. Emil Theodor Schmidt (1962-1973) and Prof. Dr.-Ing. Erich Hahne (1973-2000) directed. Since April 2000, the Institute headed by Prof. Dr.-Ing. habil. Hans Müller-Steinhagen.

For many years, the Institute has focused its research activities on the two areas of advanced heat transfer processes and solar thermal systems for domestic applications. At present, the institute employs 35 staff out of which 25 are research scientists and engineers. Senior staff of ITW have been involved in fouling research since 1980 and have published more than 200 papers and several books on fouling fundamentals and mitigation. They have been organising and chairing the bi-yearly International Fouling Conferences since 2001 and been involved in numerous research and consultancy projects with industry. The second line of research of ITW is in the area of solar thermal water and space heating, where it operates Europe´s largest research and testing centre for solar thermal collector and heat storage systems. The Institute for Thermodynamics and Thermal Engineering has extensive laboratory infrastructure with modern instrumentation and equipment. Through a joined directorship it is closely linked to the Institute of Technical Thermodynamics of the German Aerospace Centre, which is located on the same campus in Stuttgart.

April, 2008

Dear Mr. Livni,

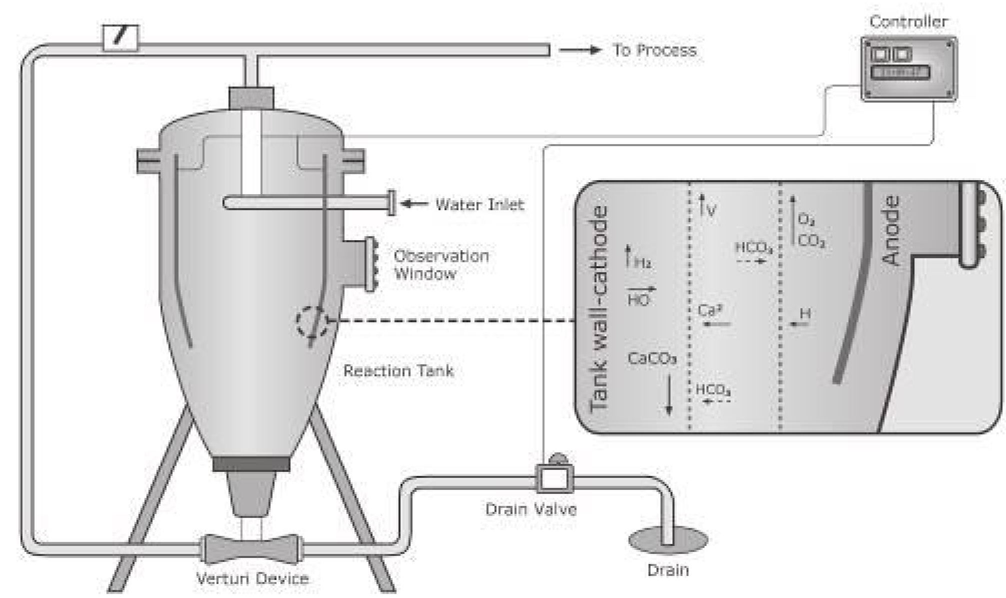
Please find attached the report on the performance of SRS system subjected to severe crystallization fouling of $CaSO_4$. The report is rather comprehensive and a result of 6 months intensive full experiment at ITW.

Report Conclusions:

The test results show that the SRS water treatment significantly reduces the water's $CaSO_4$ propensity for crystallization in roughened stainless steel surfaces, reducing fouling resistance as a function of time by up to 95% depending on the surface's roughness.

1. The SRS System

CQM SRS – Water Treatment System is a chemical-free solution for removing scale and for elimination of algae and bacteria to keep water circuits clean.



How it Works

CQM SRS uses the electrolytic process, implementing a large cathode area that creates a high PH environment that encourages scale formation inside the device. A hydro cyclone structure ensures that all the water within the chamber is treated.

The water flows through the electrolytic chamber and functions as a medium that closes the electric cycle enabling the DC current to flow between the anode and cathode of the system. Two disinfecting processes occur on the surface of the anode (+):

- Anode oxidation reaction
- Acidic catalytic reaction

Chemical Reactions at Work in the SRS

The anode oxidation reaction is a series of reactions that produce gases and free radicals with high oxidation potential that disinfects the water.

Electrolysis works as follows:

- Water in the cycle is pumped into the electrolysis chamber.
- The water pH level is raised slightly increasing the alkaline environment and preventing corrosive processes.
- Free chlorine is produced which helps to destroy bacteria.
- Higher pH causes corrosion to aggregate into suspended solids that can be removed with a sand filter.

As a result of the basic pH conditions on the cathode surface the following reactions occur:

$Mg(HCO_3)_2 + 4OH^- \rightarrow Mg(OH)_2\downarrow + 2H_2O + 2CO_3^{-2}$

$Ca(HCO_3)_2 + 2OH^- \rightarrow CaCO_3\downarrow + 2H_2O + CO_3^{-2}$

$Mg(HCO_3)_2 \rightarrow MgCO_3\downarrow + 2H_2O + CO_2\uparrow$

$(SiO_2)_{aq} \rightarrow SiO_2)\downarrow$

The main ingredients of scale in water systems ($MgCO_3$, $CaCO_3$, $Mg(OH)_2$, SiO_2) are almost completely removed from the water in this process.

The following reactions occur on the face of the anodes:

$OH^- - e \rightarrow OH^\circ$	Radical OH°
$OH^\circ \rightarrow H_2O + O^\circ$	Radical Oxygen
$2OH^\circ \rightarrow H_2O_2$	Peroxide
$Cl^- - e \rightarrow Cl^\circ$	Radical chlorine
$2Cl^\circ \rightarrow Cl_2$	Molecular chlorine

In addition, this process produces Active Chloride that works to purify the water naturally, without harmful chemical additives.

2. Test Results

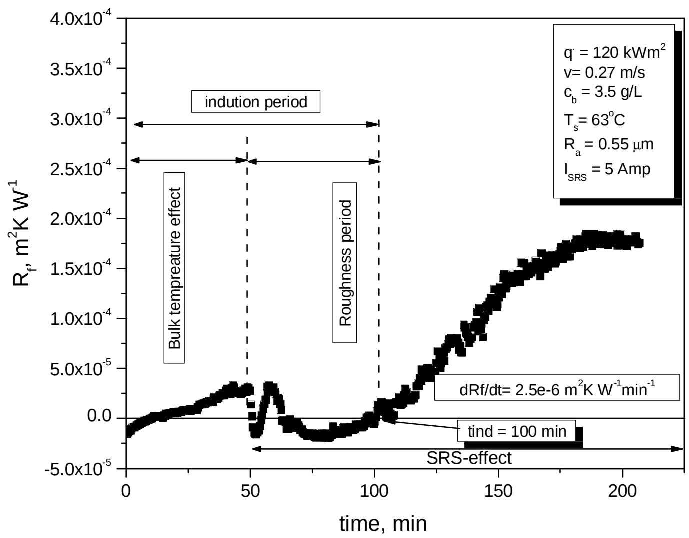


Fig. 1 Variation of fouling resistance with time as a function of SRS system of 0.55 μm roughened surface

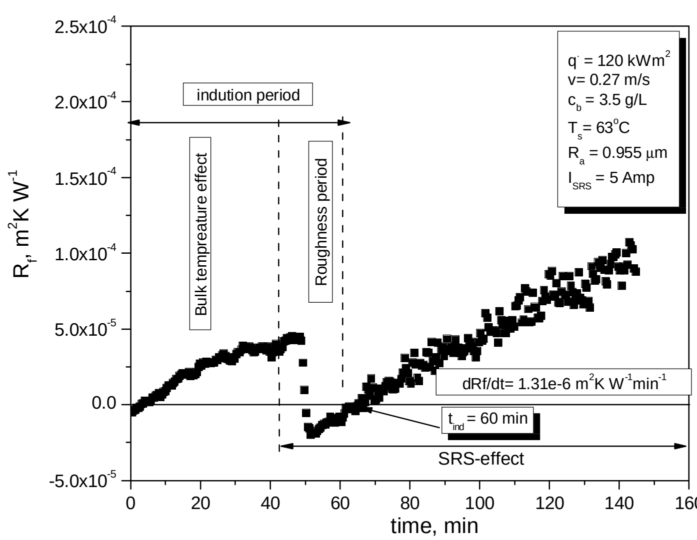


Fig. 2 Variation of fouling resistance with time as a function of SRS system of 0.955 μm roughened surface

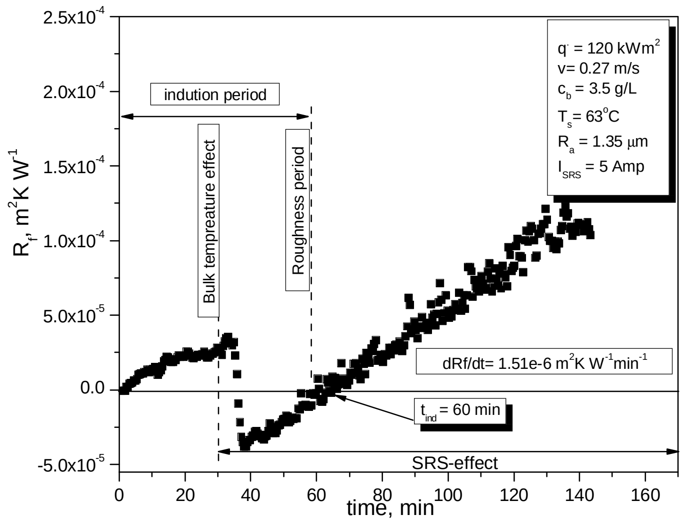


Fig. 3 Variation of fouling resistance with time as a function of SRS system of 1.35 μm roughened surface

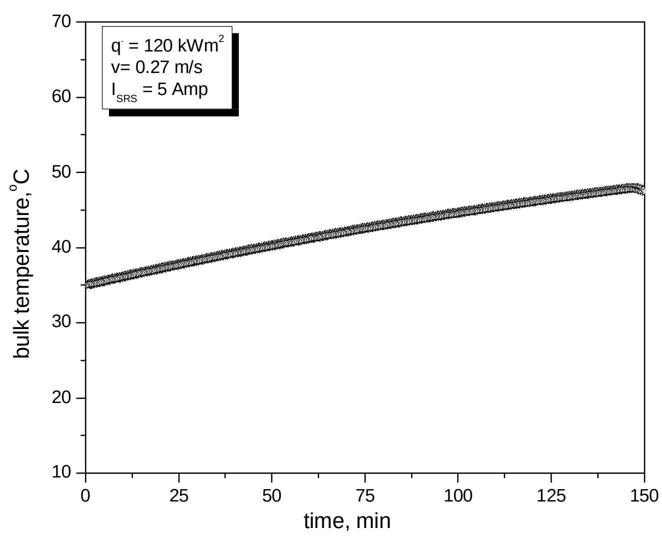


Fig. 4 Variation of bulk temperature with time

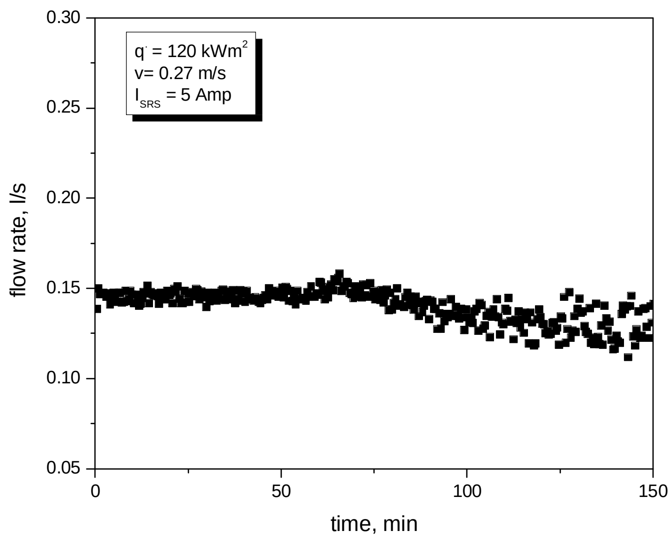


Fig. 5 Variation of bulk velocity with time

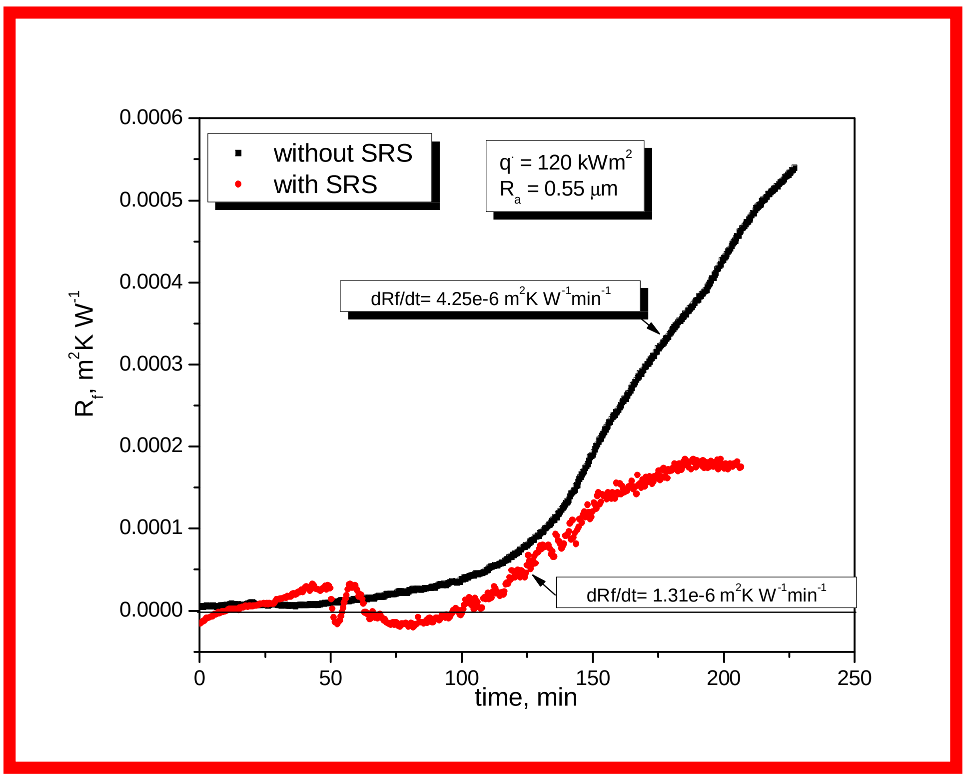


Fig. 6 Fouling resistance as a function of time of 0.54 μm roughened stainless steel surfaces with and without SRS

0.55

0.95

1.35

Fig.7 Fouling layer of stainless steel roughened surfaces at $q^{\cdot}$ = 120 kW/m^2, v = 0.27 m/s, and I_{SRS} = 5 Amp

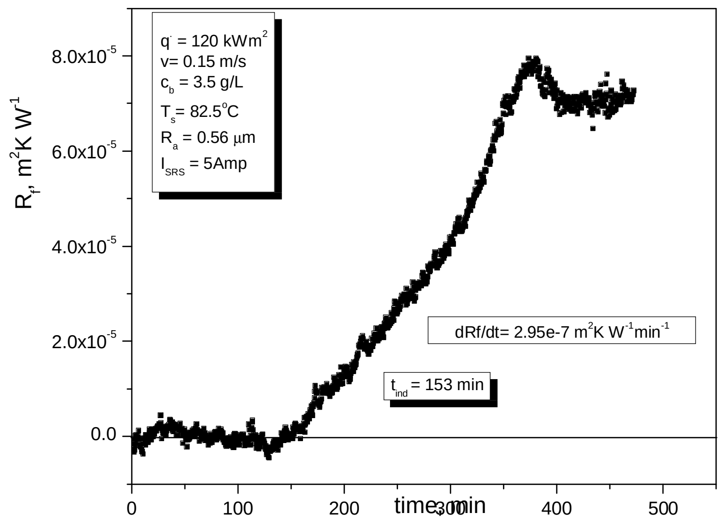


Fig. 8 Variation of fouling resistance with time as a function of SRS system of 0.54 μm roughened surface

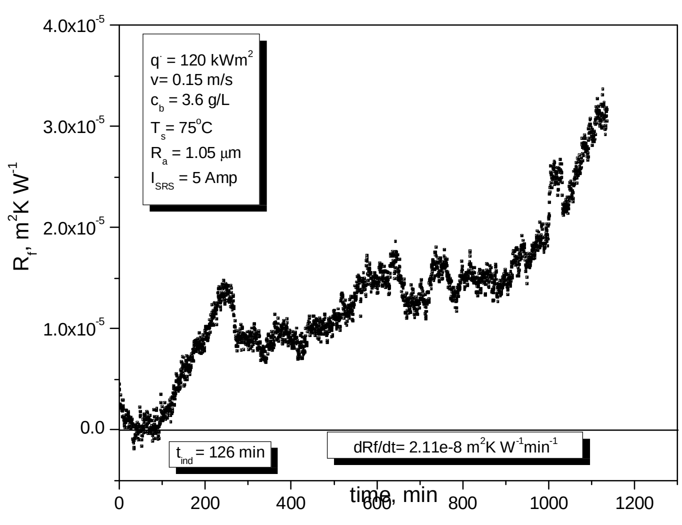


Fig. 9 Variation of fouling resistance with time as a function of SRS system of 1.1 μm roughened surface

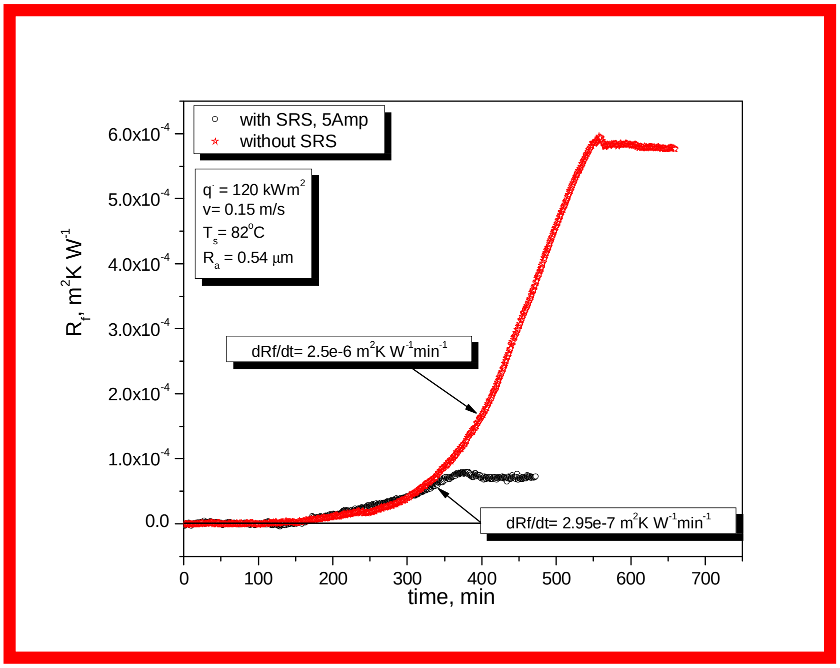


Fig. 10 Fouling resistance as a function of time of 0.54 μm roughened stainless steel surfaces with and without SRS

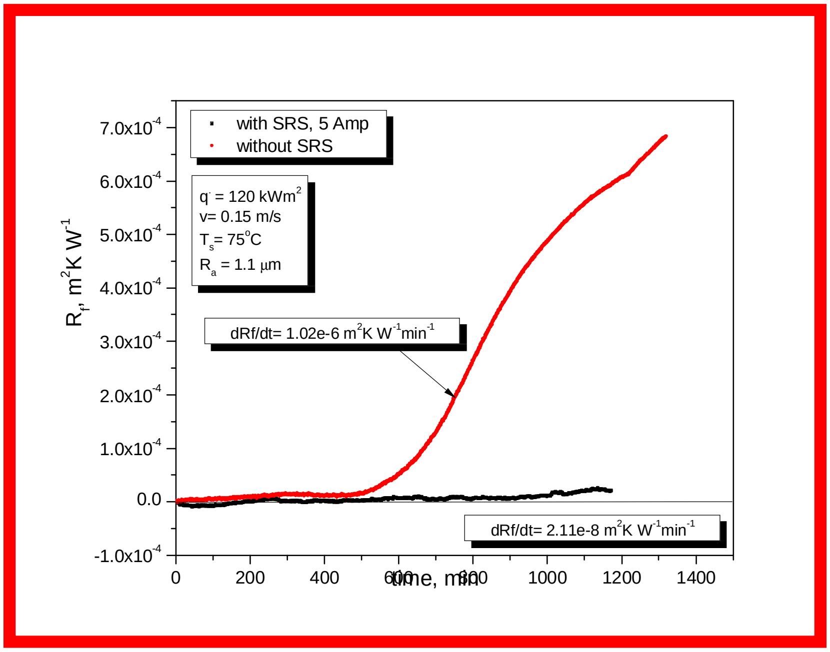
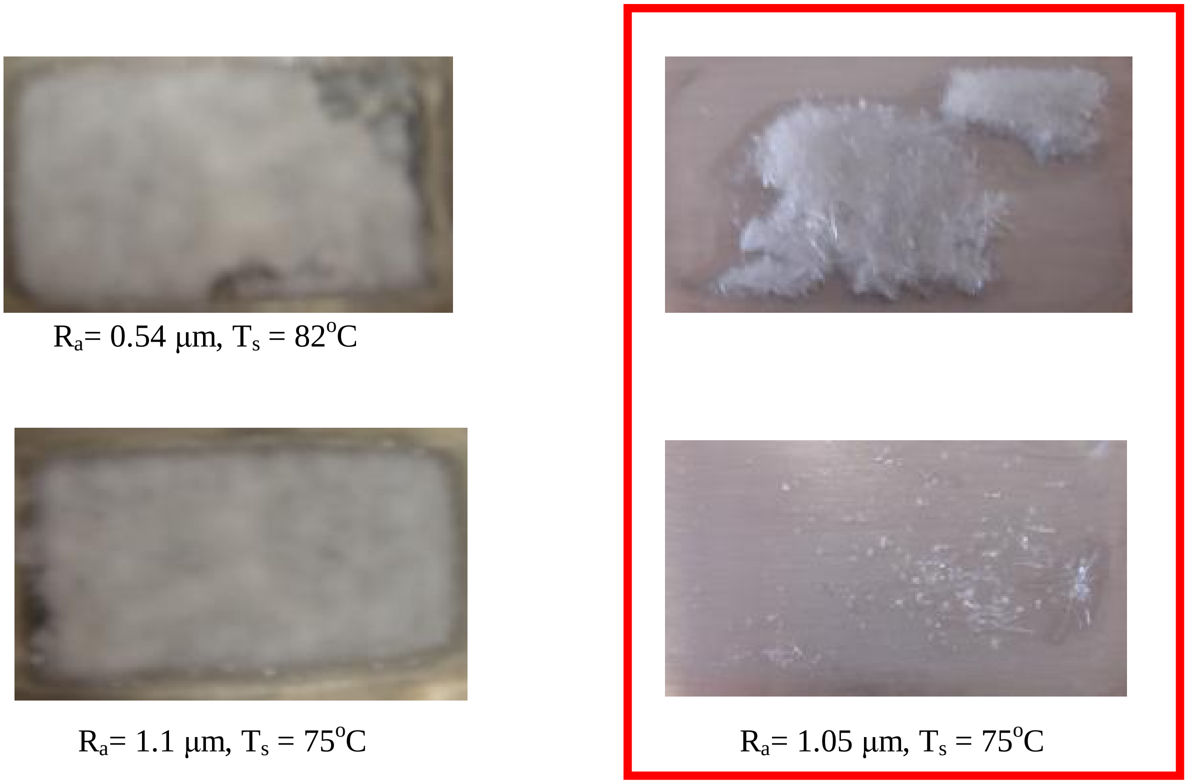


Fig. 11 Fouling resistance as a function of time of 1.1 μm roughened stainless steel surfaces with and without SRS



R_a= 0.54 µm, T_s = 82^{o}C

R_a= 1.1 µm, T_s = 75^{o}C

R_a= 1.05 µm, T_s = 75^{o}C

a) without SRS

b) with SRS

Fig. 12 Fouling layer of stainless steel roughened surfaces a) without SRS and b) with SRS at $q^{\cdot}$ = 120 kW/m^2, v = 0.15 m/s, and I_{SRS} = 5 Amp

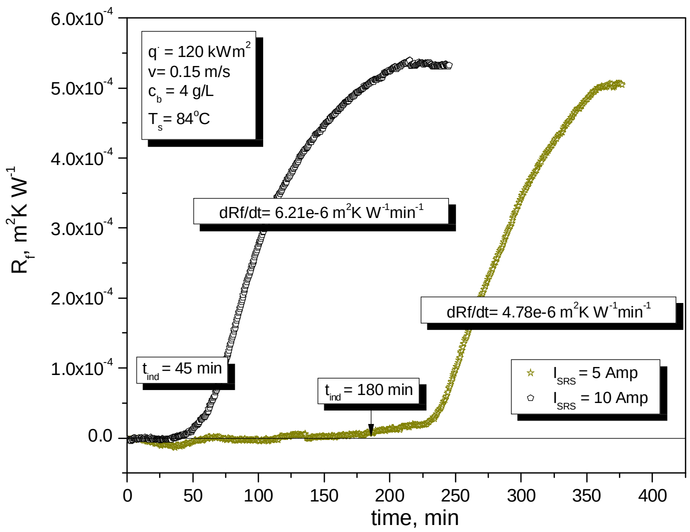


Fig. 13 Fouling resistance as a function of time of 0.54 μm roughened stainless steel surfaces at 5 and 10 Amp

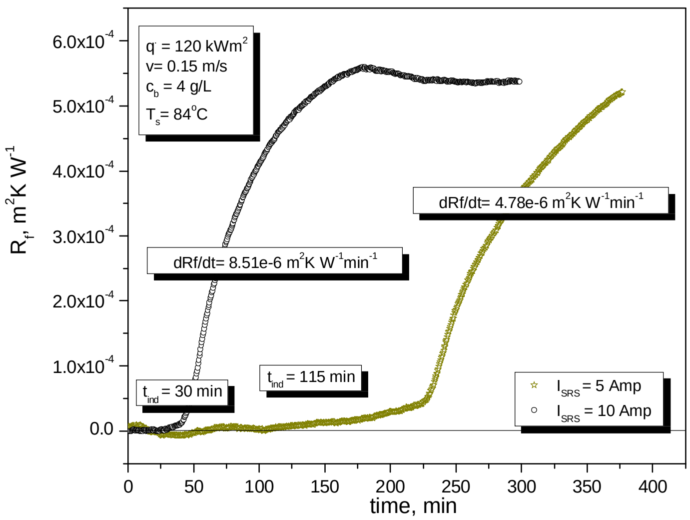


Fig. 14 Fouling resistance as a function of time of 1.55 μm roughened stainless steel surfaces at 5 and 10 Amp