Centre for Research and Technology Hellas
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(CERTH/ISFTA)

"Methodology and implementation of online monitoring system on large scale pulverized fuel power plants"

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Methodology and implementation of online monitoring system on large scale pulverized fuel power plants

The problem

- Demand for increased power plant efficiency and availability as well as decreasing operating and maintenance costs have lead to the development of sophisticated instrumentation and control systems
- Energy sector across the world faces the challenge to improve energy production in terms of
  - efficiency
  - emissions
  - renewables utilization
- Many existing coal power stations across Europe and America have either implemented or demonstrated biomass and solid fuel co-firing
- The necessity to monitor the performance of pulverized fuel boilers online becomes essential, as it can lead to both financial and technical benefits especially in the case of biomass and coal co-firing in which slagging and fouling play important role

Methodology and implementation of online monitoring system on large scale pulverized fuel power plants

The solution

- The aim of this work is to present an online monitoring methodology and demonstrate its application on a large scale pf boiler
- For the implementation of the online monitoring system an integrated solution - software was developed in a graphical programming language
- The main objective of the developed solution is to enable the plant operator to:
  - monitor the performance of the boiler and heat exchangers online,
  - monitor the rate of ash deposits formation on the heat transfer surfaces, in order to minimize slagging and fouling problems
- The methodology and calculations adopted in the software, were performed according to DIN standards. Several semi-empirical correlations to estimate deposition properties were also incorporated in the solution.

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The solution - Features

- The software was developed in a graphical programming language, setting the priority on specific features as:
  - an intelligent and user-friendly interface
    - ✓ The operator is navigated through the different processes of the software
    - ✓ The operator is prevented from making typing mistakes
    - ✓ Many processes are performed automatically (conversions, crosschecks etc.)
  - modular form
    - ✓ Software can be configured easily for different PF power plants
    - ✓ Software can be easily configured in case of power plant modifications
    - ✓ Improvements can be made on specific modules without affecting the overall reliability of the software
  - fast and reliable coupling between software and plant instrumentation
    - ✓ The graphical programming language used was primarily created for real time processing of large amount of raw data, and easy coupling with data acquisition systems of the plant

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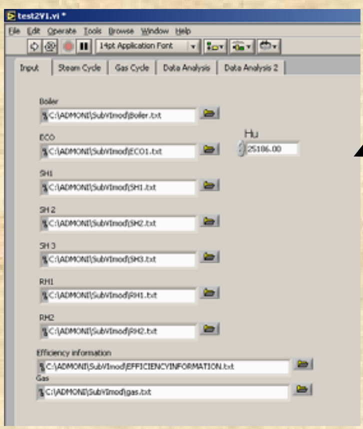
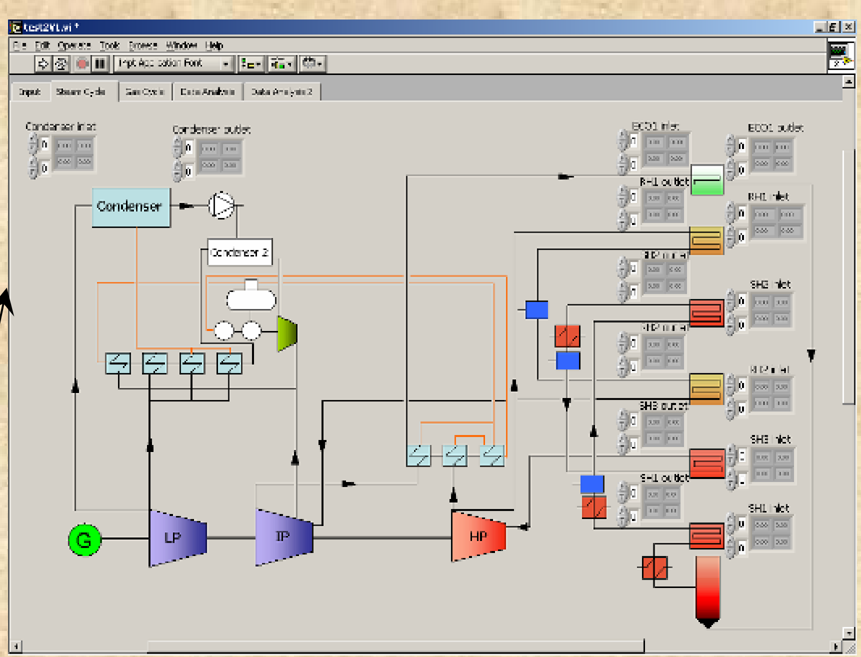
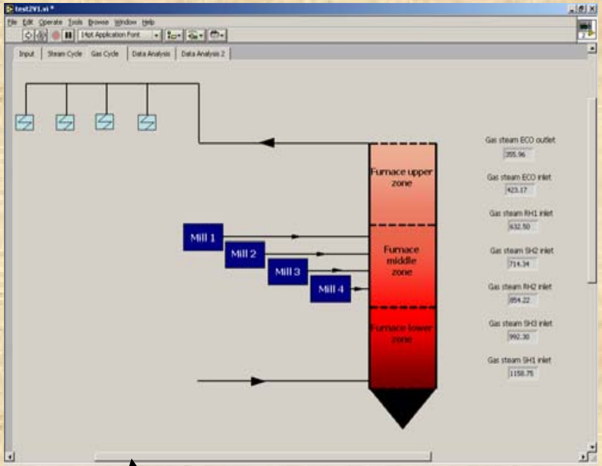
The solution - Features



Input data & link with online data



Set up steam cycle



Set up flue gas cycle

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Monitoring system capabilities

- With the aid of the developed system, plant operator can monitor in real time
  - boiler efficiency
  - overall heat transfer coefficient for the heat exchangers
  - deposit layer thermal resistance
- Monitoring system was designed in order to be able to take into consideration and handle efficiently
  - partial load situations (e.g. load reduction over night)
  - sootblowing effects
  - low quality raw data from plant instrumentation
- Sootblowing process can -with the aid of the monitoring system- be optimized in a more efficient way, rather than based on the experience of the operator

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Methodology

- Boiler performance is based on the methodology proposed by DIN 1942
- DIN 1942, adopts two different approaches to assess boiler efficiency
  - input and output method:

    efficiency is determined as the ratio of heat absorbed by the working fluids to the heat input

$$\eta_{Boiler} = \frac{\sum Q_i}{Q_{input}}$$

Qi , is the heat gain by the individual heat exchanger component, which can be easily calculated using data such as the temperature, pressure, mass flow etc locations in the boiler

  - heat loss method (indirect):

    in case of solid fuels, where the accurate fuel mass flow measurement is difficult, boiler's efficiency is calculated with the indirect method taking into account the various losses

$$\eta_{Boiler} = 1 - \frac{Q_{losses}}{\sum Q_i + Q_{losses}}$$

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Methodology

- The heat losses in boiler according to DIN 1942 are distinguished in the following categories:
    1. Flue gas losses due to the dumping of high temperature flue gas into atmosphere
    2. Losses due to unburned combustibles in flue gas
    3. Losses due to enthalpy and unburned combustibles in slag and flue dust.
    4. Losses due to radiation and convection
    5. Other (including losses due to external cooling system etc.)

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Methodology

- Monitoring boiler's overall efficiency is not sufficient, as it does not indicate the performance of each heat exchanger. Hence, the rate at which the heat is being transfered between the flue gases and the heat exchanger surfaces is defined as the overall heat transfer coefficient:

$$U_{total} = \frac{Q_{total}}{A \ln \Delta T}$$

- The deposition thermal resistance on the heat exchange surface is calculated from the overall heat transfer coefficient as:

$$R_{deposition} = \frac{1}{U_{total}} - \left[\frac{D_{out}}{D_{slag} h_{gas}} + \frac{D_{out}}{D_{in} h_{water}} + \frac{D_{out}}{2K_{pipe}} \ln\left(\frac{D_{out}}{D_{in}} \right) \right]$$ and

The above equation is being solved following an iterative procedure (along with the other heat transfer equations that arise from water and gas side), since both deposition thickness and its thermal resistance are unknown.

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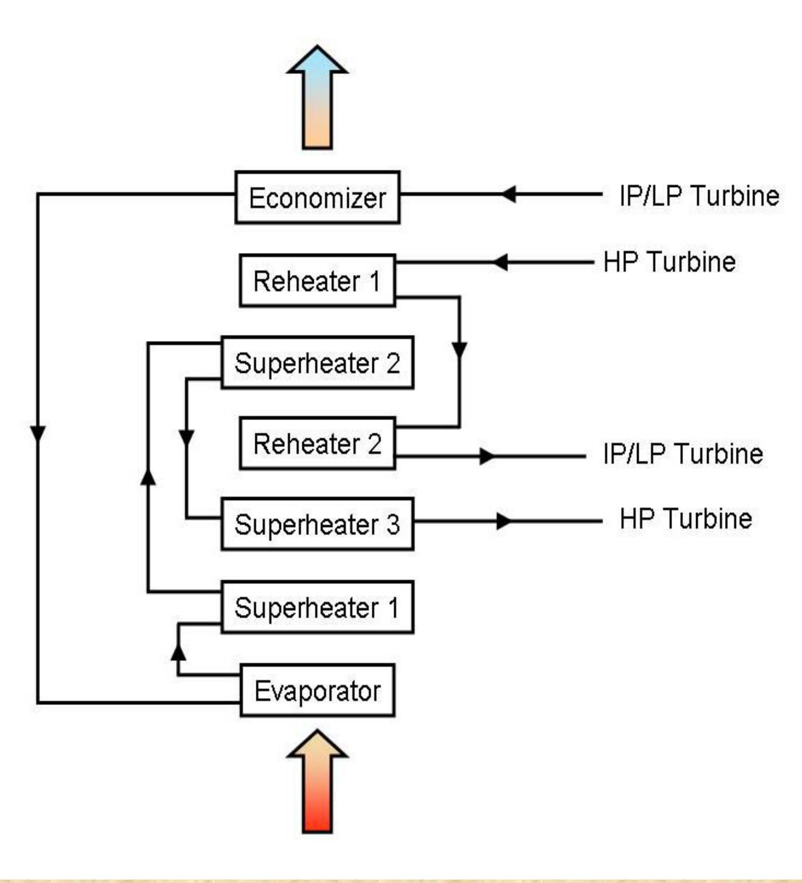
Raw data pre-processing

- Raw data was pre-processed in order to improve its poor initial quality (due to plant instrumentation and other reasons)
- Improper measurements
  - are recognised with the help of criteria set by the operator
  - can be corrected, completely ignored or replaced by appropriate values (typical, representative or predicted values)
- The objective of the pre-processing task is to
  - ensure continuous operation of the monitoring system without unexpected failures due to low quality input
  - improve accuracy of output variables

Methodology and implementation of online monitoring system on large scale pulverized fuel power plants

Application on $350MW_{el}$ power plant – Description

- The selected large scale power plant was designed to ensure maximum possible electrical efficiency whilst meeting the stringent environmental standards
- Power plant has the capability of burning coal and natural gas
- Boiler consists of 3 superheaters, 2 reheaters, 1 economizer and an evaporator
- The main fuel which is utilized in the power plant is Polish hard coal



Schematic diagram of the plant layout

Application on 350MW$_{el}$ power plant – Input data

- Difficulties arise from the need for accurate and real time appraisal of fuel characteristics. In the case under investigation, fuel quality is constant. Nevertheless, code allows variation of the fuel type (including biomass and coal co-firing scenario).
- The main online input data into the monitoring system is the flue gas and water/steam flow properties. More specifically:
  - mass flow *m*
  - temperature *T*
  - pressure *P*
- Other flow properties, heat exchangers geometrical characteristics and arrangement (number of tubes, distance between tubes and arrangement, length and diameters of tubes, etc.) are being provided into the system as off-line inputs.

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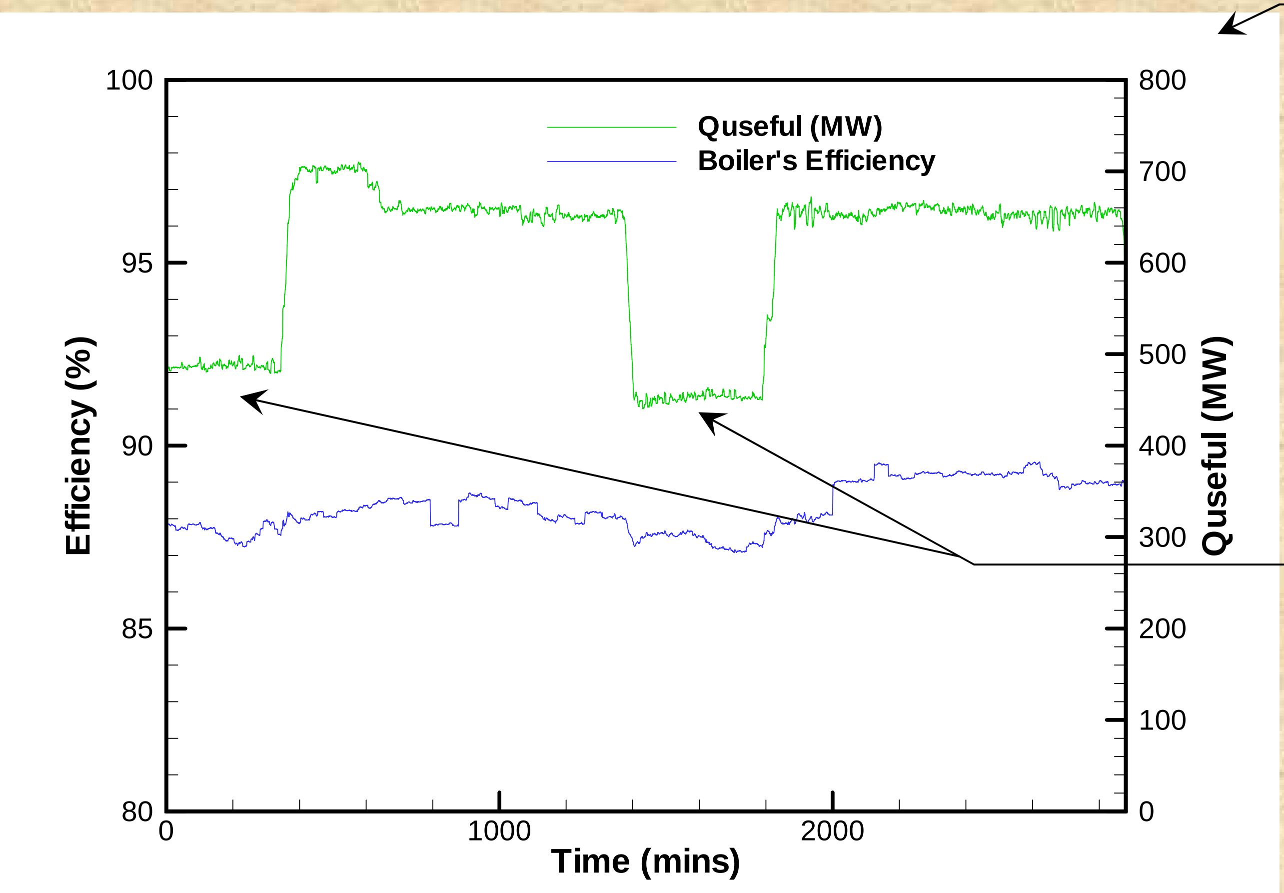
Application on 350MW$_{el}$ power plant – Results



total useful heat flux and boiler efficiency against time

The results were obtained from measurements on two consecutive days

The decrease in total useful heat is attributed to the change in load demand during the night period

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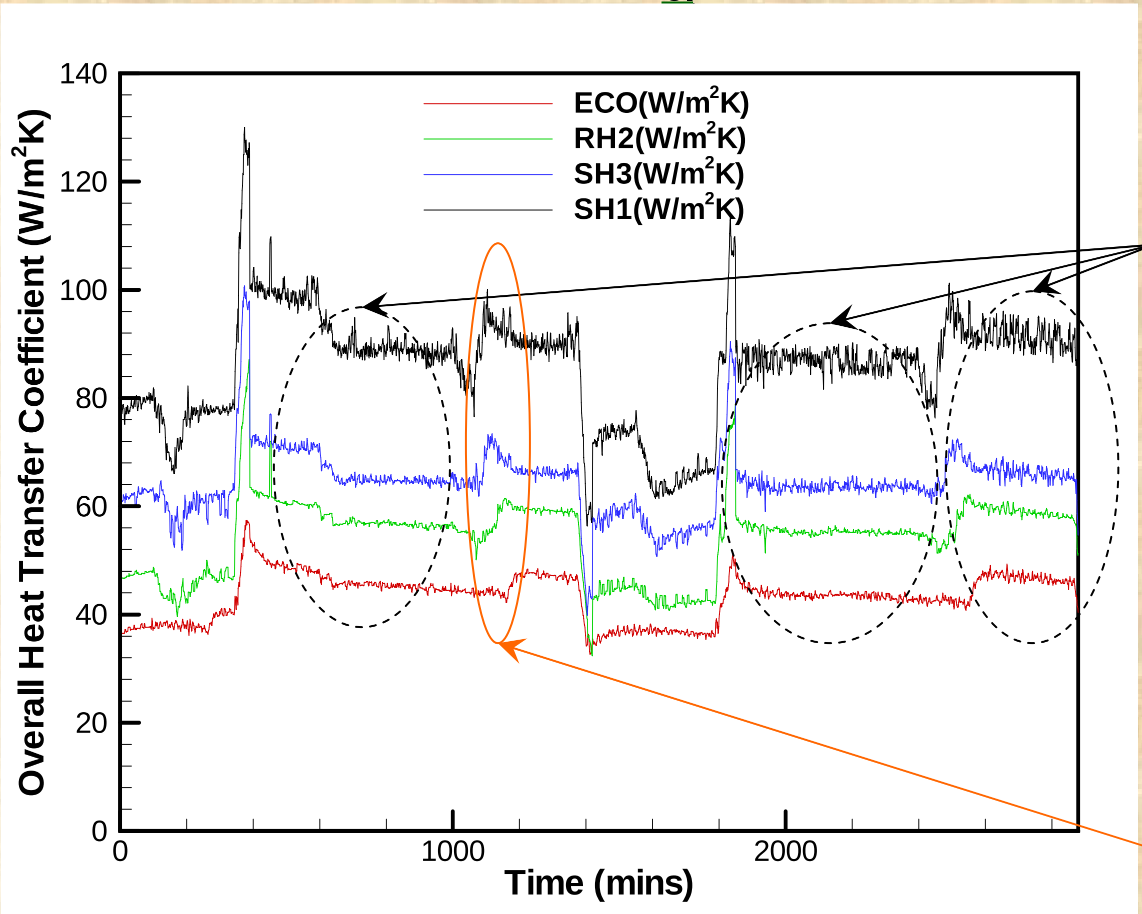
Application on 350MW$_{el}$ power plant – Results



overall heat transfer coefficient for heat exchangers

For constant load, overall heat transfer coefficient generally decreases with time. This is consistent with the nature of the deposition phenomenon: ash deposit layer builds up and total heat transfer resistance increases

Removal of the deposit due to sootblowing operation results to steep heat transfer coefficient increase

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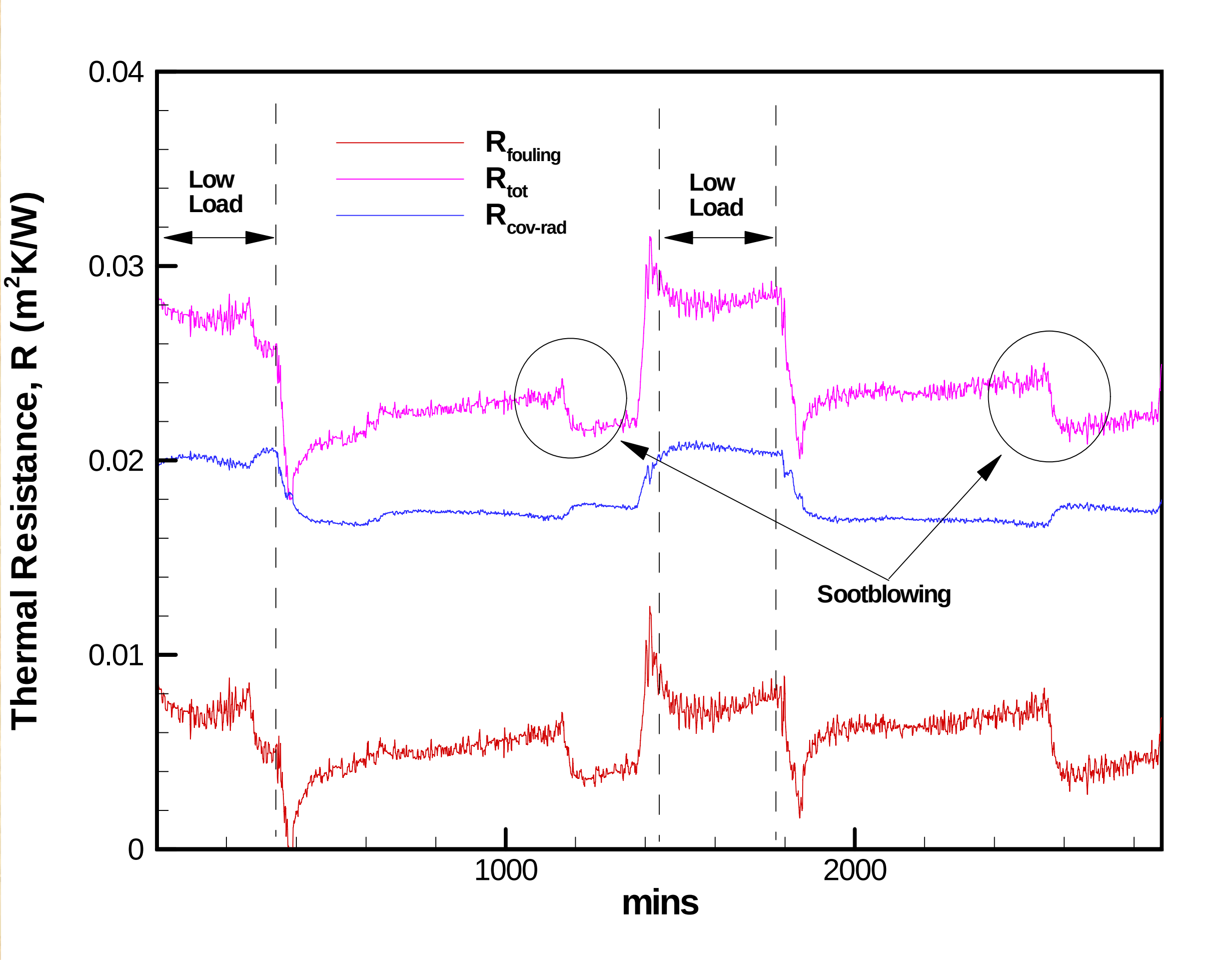
Application on 350MW$_{el}$ power plant – Results



- The increase of fouling resistance and consequently the growth of the deposit layer thickness are clearly depicted
- The fouling resistance reduces steeply as soon as the soot-blowing operation is initiated. This indicates the removal of the deposit from the heat exchanger surfaces.
- The level of fouling thermal resistance after sootblowing is almost constant. This can be owed to the after-sootblowing remaining depositions.

total useful heat flux and boiler efficiency against time

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Application on $350MW_{el}$ power plant – Conclusions

- The developed integrated monitoring system was proved capable of efficiently processing the online raw data, even in occasions of poor quality, e.g. caused by instrumentation failure.
- Slagging and fouling phenomena effects on the boiler and heat exchangers efficiency, can be captured efficiently by the developed monitoring system.
- Plant operators can use the developed integrated monitoring system to schedule the sootblowing operation in a more effective way than the conventional methods which are usually based on a period basis or experience.

Thank you for your attention !!

For further questions..

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