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RESEARCH INTO OIL FILM COATING OF A STEEL PIPE INTERIOR BY OIL MIST BLOWING

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Corrosion protection is one of the most frequently addressed issues in metallurgic and engineering applications. Oil film coating of inaccessible areas such as interior of a steel pipe is technically complicated. Because of that, the choice of the interior pipe film coating via oil mist is a viable solution. However, it is necessary to establish what will be the composition of the oil layer and what distance the required oil thickness will span. These are the aspects dealt with in the present paper.

Key words: steel tubes, corrosion protection, coatings, oil film layer, modeling

INTRODUCTION

Wasteful management of operating overheads dedicated to maintenance necessitated by corrosion are estimated to account for up to 40 % of all maintenance costs. According to the same source, between 10 and 40 % of these overheads can be eliminated with an appropriate methodology and management of the maintenance process focusing on the aspect of corrosion protection [1].

If metallurgic companies are managed in a way that takes into account the need for competitiveness, are customer-oriented, reliable, and have quality management in place, they also score greater on the so called.

World Class Manufacturing [WCM] efficiency scale according to [2] Similar topic is also discussed in [3], with the authors putting more emphasis on simulation processes used as a way to include the greatest number of process-impacting factors in engineering or metallurgic production.

Among other topics, this paper [4] also explores the issue of production system effectiveness, necessary quality assurance and application of the CAx systems in this field. Troubleshooting tools applicable in both, the engineering and metallurgic plants, are discussed in the paper [5].

Corrosion-prone components and those subject to other great strain may benefit from similar film coating methods of strained functional parts as is stated in paper [6]. In this case, the authors stand by their allegation of increased lifetime of a component almost 1,8 times.

Special ECO-friendly film coating methods of metal but also ceramic materials for anticorrosion protection are introduced in paper [7] for example.

Welded parts require special anti-corrosion treatment, even more so when exposed to the weather [8].

One of the metallurgic plants in the Slovak Republic practices oil film coating of the steel pipe interior by submersion of pipes, or a pipe bundle, into a special oil bath. As soon as the steel pipe or a bundle of pipes has been sufficiently submerged, it is pulled out of the bath and let drip, thus getting rid of the oil which has covered both, the inside and the outside of the pipe or a pipe bundle.

This operating procedure is very noneconomical and unecological. First, a large amount of oil is consumed in this model of steel pipe oil coating and moreover, it is a time consuming and large space occupying activity. When this process is completed, a large amount of oil is consumed inefficiently, since the outer surface of a pipe or a pipe bundle is contaminated with an undesired layer of oil film. Therefore, due to handling and other requirements, the surface must be thoroughly cleaned. This is both, time consuming and technically difficult to perform. In the said plant, the cleaning of a pipe or a pipe bundle is done manually. A critical negative aspect is the high probability of an air bubble occurrence in the inner diameter of the steel pipe upon submersion of a long and thin pipe, or a pipe bundle, into the oil bath. In this way, the entirety of the required oil film composition is jeopardized. It is then clear that the untreated part of the steel pipe surface cannot be fit for the given purpose since the oil film has not been applied consistently throughout the entirety of the steel pipe surface.

In metallurgy, but also in other heavy duty industries, the method of thin oil film coating of interior of longer steel pipes is suitable for anti-corrosive but also other purposes. Some of the reasons are for example: anti-corrosive protection, reduction of surface friction, disinfection or various other reasons. [9-13]

For all the above-mentioned reasons, a device has been designed, producing oil mist and applying the same inside a pipe, achieving a consistent distribution

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of an oil film layer, performing any of the given tasks. No practical deployment of such device is known as of now. Due to this fact, the team of authors has applied for the patent protection of the device.

BASIC PRINCIPLE OF DESIGNED SOLUTION

One of the options how to an oil film coating requirement for interior of a steel pipe or a pipe bundle is mechanical oil film application through a long thin hose or a tube inserted into a steel pipe. This, however, creates many technical problems and with very thin and long tubes, inserting such set inside a pipe is very cumbersome.

For these reasons, after substantial brainstorming yielding many different solutions, a highly efficient design was chosen, with a sufficient speed of oil film coating, accuracy of the oil film layer thickness, the overall layer consistence and all of that at high cost effectiveness, as illustrated in Figure 1.

A long thin pipe with an interior of a given diameter in need of oil film treatment is placed into a stable pipe holder. Oil mist, prepared according to the diagram illustrated in Figure 1, is injected under the pressure of about 6 BAR via a jet at the pipe inlet. A filter is placed at the other end of the pipe, through which the oil mist exists the pipe. A portion of oil remains at the inner surface of the pipe. The filter captures oil to prevent air contamination. A container stores the oil captured by the filter. When filtered, this oil may be reused.

The real testing documented in Figure 2, a jet is aligned with the axis of the pipe subject to coating. Subsequently, a lubricant device is activated, producing oil mist with tried and tested composition and defined parameters, such as: suitable pressure of compressed air, required application time, defined temperature interval of the applied oil and ambient temperature etc.

In this way, a required oil film layer is created inside the pipe's surface. With the oil successfully applied, the pipe is removed for further processing, or it is placed in a stack, either manually or automatically.

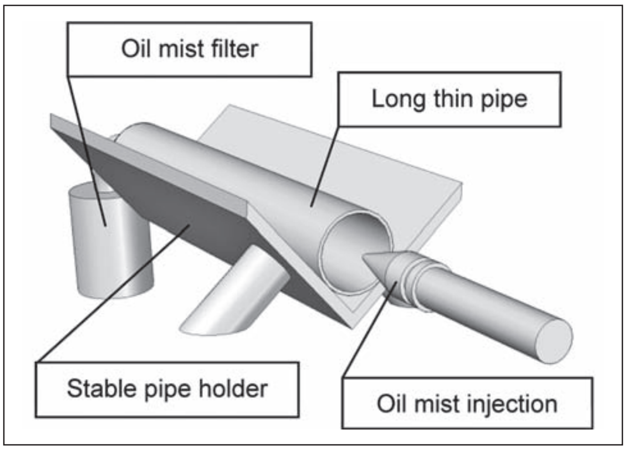

Figure 1 Diagram of the thin oil film coating device

Figure 2 Testing the pneumatic circuit of the coating device

In the end, the described technical solution may be applied to coating with other liquids, i.e., be able to spread a layer – a film, to inaccessible areas of narrow and long pipes of different profiles and caliber.

NUMERICAL ANALYSIS OF THE OIL MIST FLOW

Prior to the simulation itself, a contemplation on which CAx software tools are appropriate for verification and modeling [5] took place. Simulation was done in Ansys CFX. The numerical analysis was based on a 6 m long model tube of 35 mm in diameter.

The "meshing" was carried out via basic tetrahedrons as the elements of the mesh, where the average basic element was 3 mm, Figure 3.

The air flow speed was set at 0,5 ms^{-1} and so the Reynolds criterion was Re = 1 150. It follows from the above the oil mist will flow in a laminar fashion. To achieve as true a simulation as possible, a condensed layer was created on the outer surface, that should cover the high gradient of the oil mist of greater density at the tube's surface.

Flow simulation was carried out for the oil particle with the mean size of 1μm. Simulation temperature was set at 25 °C. The oil mist applied inside the tube acquires the volume fraction of oil in the air of

$7{,}56\ 10^5$. This value was established in experimental measurements. Density of the oil itself is 830 kgm^{-3}, its

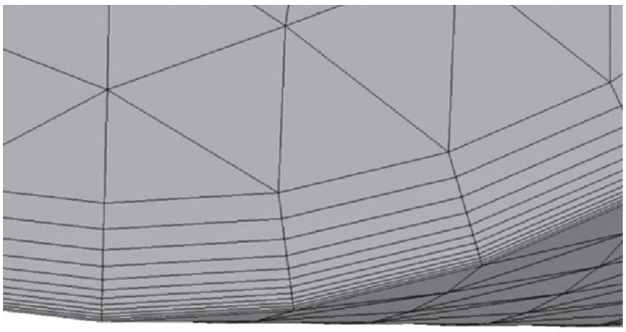

Figure 3 Detail of the mesh in Ansys CFX with the number of elements at 7,7 mil.

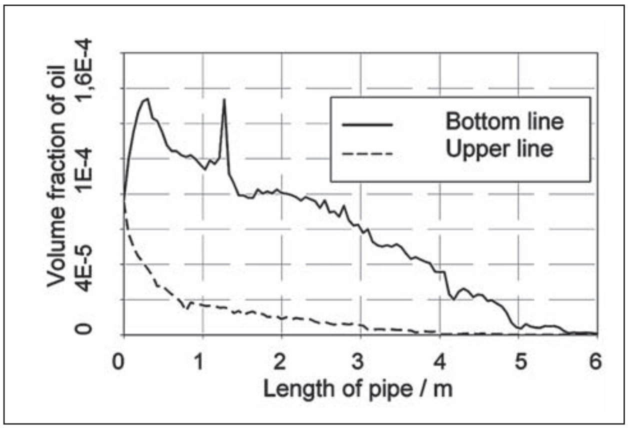

Figure 4 Final simulation course of oil mist blowing in the upper and lower region of a 6 m long pipe with 35 mm in diameter over a 10 s period, where the oil particle size is 1 μm

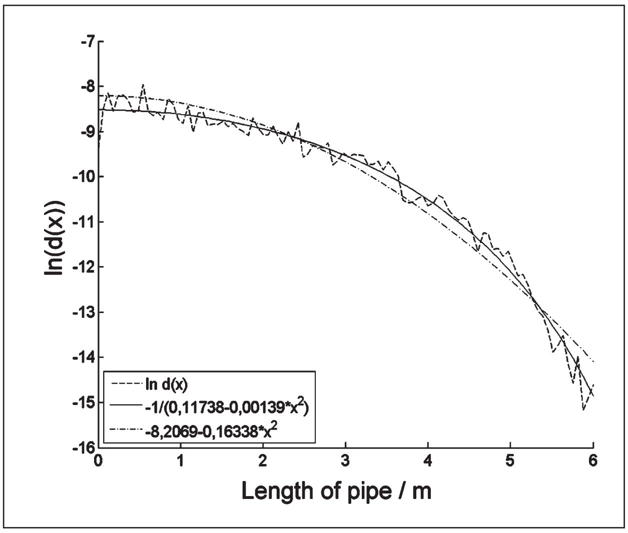

Figure 5 Logarithm approximation of the ″lower″ curve

dynamic viscosity is 3,82 10^{-3} Pa·s. Simulation pace was set at 0,05 s and the process came to the end after 10 s. Results of numerical experiment are illustrated in Figure 4.

By inspection the upper fiber in the pipe cross section, the simulation result shows the micro particles of oil in the oil mist are carried roughly over a 4m distance subject to gravity. Beyond this borderline, there is a minimum coverage of the upper fiber inside the steel pipe. As far as the lower fiber is concerned, attracting the micro particles gravitationally, beyond the 5 m distance the surface coverage is negligible.

OIL MIST FLOW NUMERICAL ANALYSIS APPROXIMATION

It is interesting in the most adverse case scenario, we will be paying attention to the lower curve of the final simulation course of oil mist blowing as per Figure 4. This curve describes the upper fiber inside a 6 m long pipe with 35 mm in diameter.

Having applied logarithms to the simulation data operating with the average particle size of 1 μm at the pace of 0,05 s, we can confirm the value drop is faster than exponential, while the latter would result in approximately a straight line, Figure 5.

Because the shape of the curve to which the logarithmic operation was applied, we decided to approximate it using the method of the least squares. First, we selected a type of quadratic dependence to obtain the relation:

$$\ln(d(x)) \approx -8{,}2069 - 0{,}16338 \cdot x^2$$

represented by the dash-curve line in Figure 5.

Next, we decided to test some kind of “fractional” function, starting with the approximation of the inverted logarithmic value by application of the quadratic function. First, we obtained the relation:

$$\ln(d(x)) \approx \frac{1}{-0{,}11738 - 0{,}00003 \cdot x + 0{,}00139 \cdot x^2}$$

A small coefficient at x suggested we could try to simplify the approximation. Thus, we „omitted“ the linear component in the quadratic equation. The final relation:

$$\ln(d(x)) \approx \frac{1}{-0{,}11738 + 0{,}00139 \cdot x^2}$$

is demonstrated by the solid line, Figure 5.

The qualitative difference between the logarithmic approximation and the inverted logarithmic approximation has become even more pronounced. At the same time, we can state that the final bi-parametric approximation:

$$d(x) \approx e^{-1/(0{,}1173771-0{,}00139\cdot x}$$

is an appropriate approximation of data yielded by the simulation. With increasing x, the denominator is decreasing (it reaches the zero value at $x = 9{,}18925$), i.e. the absolute value of the negative values inside the exponential function is an increasing one.

By omitting the linear component in the logarithmic approximation, a simplified approximation can be arrived at, expressed by:

$$d(x) \approx e^{-(8{,}2068608+0{,}1633833x^2)}$$

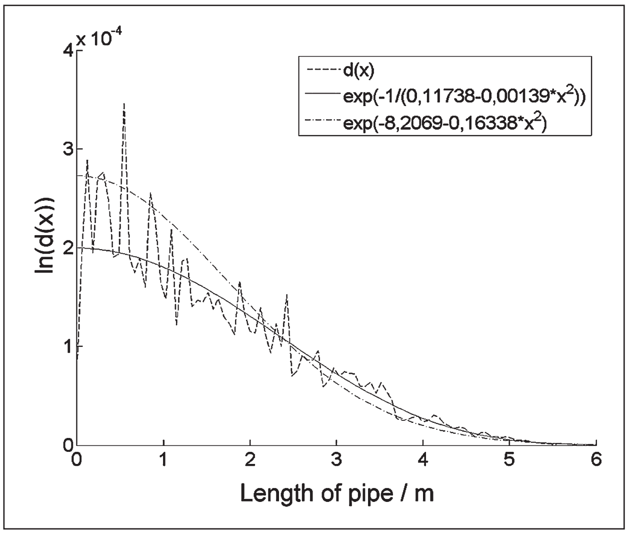

Figure 6 The “lower“ curve approximation

This approximation is demonstrated as the dash-curve line in Figure 6. It's also used to call bell function. Visually better is the approximation obtained based on an inverted value of the logarithm d.

CONCLUSIONS

The result of the numerical analysis obtained by approximation of the results yielded by numerical simulation and its subsequent approximation is a formula with practical applications. It is necessary to bear in mind that with change in parameters for film-coated pipes, i.e. with different pipe diameter, different oil mist flow velocity or density, size of oil particles, temperature and ambient humidity, etc., the relation and knowledge obtained prior need not exactly hold.

The next stage of the research needs to address algorithmic operations applied to the oil coating process, by construction of a mathematical model projecting correct application of the method onto real conditions. [13]

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Note: The responsible for English language is Mgr. Lucia Gibľáková from the Iluminata company.