The dynamic visualization of the 3D thermal impression generated through the air friction with the petroleum coke plant structure

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Abstract: - The purpose of this study was to investigate the 3D thermal field (the thermal mark) generated as a consequence of the air frictions with the complex surfaces of the petroleum coke plant. A number of analyses were carried out to demonstrate the robustness of the model for simulation purpose. A finite element program was used for analysis and simulation. Computed results were compared with the measured ones. The model can be adapted for appropriate CAD applications.

Key-Words: - petrochemistry, petroleum coke plant, new technologies, air friction, CAD, FEM

1 Introduction
The production of the petroleum coke plant through the tardy method is applied on large scale in Romania and this method is found on the petrochemistry industrial platforms at Darmanesti, Brazi, Ploiesti and Onesti.

The 3D model of plant it is complex and the main dimensional sizes are relative big 28000 x 6000 x 6000 mm³.

The study on a plant with a production equal with \( m_C = 385 \) tones / 48 hours, that is found in exploitation on the petrochemistry platform of the oil distillery Onesti from 1996, is made. The installation presents an ensemble with four identical sections that work alternatively in cycles by 48 hours [1].

The paper investigates the 3D thermal impression as result of the air friction with the external surface of a single section of ensemble.

Because the petroleum coke plant has designed an exterior wall with heat insulating is possible and real to consider the hypothesis heating of air as consequence of the friction with the surface.

In principle the study of the temperature field is a problem of the aerodynamical flow around a body with complex geometry [2], [3], [4], [5], [6], [7].

The theoretical method used is the Finite Element Method and the obtained results are comparing with the experimental measurements obtained in [1].

2 The 3D model of the petroleum coke plant
The 3D model is conceived based on the execution drawings and the ensemble drawing shown in [1]. The software used in this simulation is the SolidWorks 2007 [8].

The isometric view of the installation is shown in fig. 1.

In fig. 2 and fig. 3 are shown the isometric view of assembling dome – spherical bottom and a detail of the reinforcing rings and the nerves of reinforcing.

The 3D model of support together with the taper bottom is shown in fig. 4.
3 The experimental measurements

The determination of the 3D temperature field in points placed into the domain of the aerodynamical flow, adjacent with the surface of the plant is made through mounting thermal sensors connected to the Multilyzer analyser.

These sensors are placed in plane 1 at the levels of the reinforcing rings in points $P_1, .., P_9$ and in plane 2 in points $P_{10}, .., P_{18}$ (fig. 5).

In [1] are presented a series of the experimental measurements of the flow parameters around the structure of plant from where we give a single case concerning the aerodynamical flow of the initial front of air uninterference which impacting with the plant in Table 1 and the thermal field resulting in points $P_1, .., P_{18}$ (in Table 2).

### Table 1

<table>
<thead>
<tr>
<th>$v$ [m/s]</th>
<th>$p$ [Pa]</th>
<th>$T$ [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.16</td>
<td>100963</td>
<td>15.5</td>
</tr>
</tbody>
</table>
4 The analyses with F.E.M. of the 3D temperature field

The study of the temperature field as consequence of friction of air with the structure using the F.E.M. is made with CosmosFlow 2007 software [9].

4.1 The initial data for simulation

The initial data of simulation are:
- the aerodynamical external flow 3D;
- the incident angle of the air with structure is $\alpha = 90^\circ$;
- the rugosity of the surface is $R_z = 1.5$ mm.

The data concerning the initial front of the air uninterference, that attacks the structure, is shown in Table 2.

4.2 The results of simulation

In this section we give the results of the theoretical study obtained using the F.E.M. of the 3D distribution of temperature field in measurement points $P_1$, .., $P_{18}$ placed on the installation and the error in calculus $\varepsilon$ obtained in rapport with the experimental values in Table 2.

Table 2

<table>
<thead>
<tr>
<th>Point</th>
<th>$T_{\text{exp}}$ [°C]</th>
<th>$T_{\text{theor}}$ [°C]</th>
<th>$\varepsilon$ [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$</td>
<td>16.08</td>
<td>16.502</td>
<td>2.63</td>
</tr>
<tr>
<td>$P_2$</td>
<td>16.04</td>
<td>16.490</td>
<td>2.81</td>
</tr>
<tr>
<td>$P_3$</td>
<td>16.03</td>
<td>16.504</td>
<td>2.96</td>
</tr>
<tr>
<td>$P_4$</td>
<td>16.12</td>
<td>16.584</td>
<td>2.88</td>
</tr>
<tr>
<td>$P_5$</td>
<td>16.12</td>
<td>16.605</td>
<td>3.01</td>
</tr>
<tr>
<td>$P_6$</td>
<td>16.06</td>
<td>16.561</td>
<td>3.12</td>
</tr>
<tr>
<td>$P_7$</td>
<td>16.09</td>
<td>16.564</td>
<td>2.95</td>
</tr>
<tr>
<td>$P_8$</td>
<td>16.08</td>
<td>16.584</td>
<td>3.14</td>
</tr>
<tr>
<td>$P_9$</td>
<td>16.09</td>
<td>16.624</td>
<td>3.32</td>
</tr>
<tr>
<td>$P_{10}$</td>
<td>15.65</td>
<td>16.100</td>
<td>2.88</td>
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<tr>
<td>$P_{11}$</td>
<td>15.51</td>
<td>15.964</td>
<td>2.93</td>
</tr>
<tr>
<td>$P_{12}$</td>
<td>15.54</td>
<td>16.018</td>
<td>3.08</td>
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<td>$P_{13}$</td>
<td>15.53</td>
<td>16.017</td>
<td>3.14</td>
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<tr>
<td>$P_{14}$</td>
<td>15.54</td>
<td>16.013</td>
<td>3.05</td>
</tr>
<tr>
<td>$P_{15}$</td>
<td>15.58</td>
<td>16.083</td>
<td>3.23</td>
</tr>
<tr>
<td>$P_{16}$</td>
<td>15.57</td>
<td>16.096</td>
<td>3.38</td>
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<tr>
<td>$P_{17}$</td>
<td>15.56</td>
<td>16.079</td>
<td>3.34</td>
</tr>
<tr>
<td>$P_{18}$</td>
<td>15.61</td>
<td>16.142</td>
<td>3.41</td>
</tr>
<tr>
<td>$P_{19}$</td>
<td>15.65</td>
<td>16.175</td>
<td>3.36</td>
</tr>
</tbody>
</table>

In fig. 6 is shown the fields of temperature distributions in plane $P_1$ and in fig. 7 the same distributions in plane $P_2$.

In fig. 8, fig. 9, fig. 10 and fig. 11 are shown the 2D distribution of the temperature fields in the horizontal planes which pass through the points $P_1$, $P_4$, $P_7$ and $P_9$.

The complexity of the spatial distribution of temperature field is point out in evidence through the presentation of the 3D flow trajectories of air on is mark the values of the temperature field in sense of flow, fig. 12 and in opposite sense in fig. 13.
Also the 3D distribution field of temperature on the installation surface in isometric view in sense of flow is shown in fig. 14 and in opposite sense in fig. 15.

Figure 8  The 2D distribution field of temperature in the horizontal plane which pass through the point P₁

Figure 9  The 2D distribution field of temperature in the horizontal plane which pass through the point P₄

Figure 10  The 2D distribution field of temperature in the horizontal plane which pass through the point P₇

Figure 11  The 2D distribution field of temperature in the horizontal plane which pass through the point P₉

Figure 12  The 3D distribution of flow trajectories with mark of the temperature field view in sense of flow.

Figure 13  The 3D distribution of flow trajectories with mark of the temperature field view in opposite sense of flow.

Also the 3D distribution field of temperature on the installation surface in isometric view in sense of flow is shown in fig. 14 and in opposite sense in fig. 15.

The 3D views of the isothermal surfaces for $T₁ = 15.75 \, ^{°}C$, $T₂ = 15.9 \, ^{°}C$ and $T₃ = 16.1 \, ^{°}C$ in superpositions over the 3D distribution of temperature field on the exterior surfaces of plant are given in fig. 16, fig. 17 and fig. 18.
Figure 14 The 3D distribution of air temperature on the surface of the petroleum coke plant in view of flow sense.

Figure 15 The 3D distribution of air temperature on the surface of the petroleum coke plant view in opposite of flow sense.

Figure 16 The 3D isothermal surface for $T_1 = 15.75 \, ^\circ C$.

Figure 17 The 3D isothermal surface for $T_2 = 15.90 \, ^\circ C$.

Figure 18 The 3D isothermal surface for $T_3 = 16.10 \, ^\circ C$. 
5 Conclusion
The experimental data confirm that the 3D distribution field of temperature as consequence of fiction of air with external surface of plant is nonuniform.

This fact is also confirmed by the results of the theoretical analysis made using the F.E.M. given in Table 2, the 2D plots from fig. 6, to fig. 11, and the 3D plots from fig. 12. to fig. 15.

The high temperature of the thermal mark is met in the hydro-dynamical back air and this depends from the velocity flow, the rugosity and the area of surface which is on contact of air.

The area of isothermal surfaces decreases with the increasing of the temperature, fig. 16 to fig. 18.

The maximum thermal growths in analyzed case and is $\Delta T = 0.50 \, ^{\circ}C$.

The error in calculus for theoretical method is acceptable and this is $\varepsilon < 3.5 \%$, justifiable by accepting the hypothesis of a constant and uniform rugosity of surface and a uniform front of initial air that is in collision with the surface with a constant angle $\alpha$.

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