ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VIII [2015] Fascicule 4 [October – December]
ISSN: 2067 – 3809

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AS-CFD METHOD APPLICABILITY FOR ANALYZING Al 6061 ALLOY POROSITY

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Abstract: *Numerical modeling is widely used in many fields, therefore establishing correlations between properties. In our case, for example, the process and parameters of infiltration, mass parameters modeling, energy equilibriums according to Darcy's equations describe fluid flow in a porous cavity. Using AS-CFD we can improve the infiltration process (with the help of numerical simulation): on the one side analyzing particle interaction and on the other side analyzing the flowing process. In this paper we have analyzed the AS-CFD simulation method applicability for analyzing Al6061 alloy porosity through a pre-established surface. High applicability is encountered when using low diameter particles (required so that the Al6061 alloy passes the ductility test) because in this case the time frame is very high (approximately 30 hours for a standard test).*
Keywords: *infiltration; modeling; porosity; AS-CFD; Al6061*

1. INTRODUCTION

Aluminum is an important element with a complex applicability in various industries, nationally and internationally. Aluminum 6061 is widely used because of its properties: 2.71g/cm^3 density, Young: 68.9GPa, Poisson: 0.33μL. It is the most commonly used type of Al used, although it is differentiated in a few categories: 6061, 6061-T4, 6061-T6 (each one having physico-chemical properties which differ based on elaboration and destination). Maximum resistance is at 300MPa, 8% elongation, conductivity 77^{0}F at 152W/m·K, fatigue resistance up to 100MPa.

Aluminum 6061 is used in building certain aircraft parts (wings, fuselage), passenger planes, sometimes Al2024 is more resistant, but Al6061 has a better machinability and high corrosion resistance. It is also used for building yachts, boats, train parts, bicycle parts, fishing ware.

A similar alloy is ASF (synthetic aluminum) and it is used in similar fields, its physico-chemical characteristics being somewhat close to those of Al6061-T6 alloy. In ASF alloy's case, a similar test has been performed by Shizhao Li et all in: "CFD approach for prediction of unintended porosities in aluminum syntactic foam: a preliminary study".

Numerical modeling is widely used in many fields, therefore establishing correlations between properties. In our case, for example, the process and parameters of infiltration, mass parameters modeling, energy equilibriums according to Darcy's equations describe fluid flow in a porous cavity.

In this paper, we have used the numerical modeling based AS-CFD to analyze Al6061 flowing through a porous surface (created in the program) therefore proving the possibility of predicting high porosity areas at the end of the infiltration process.

Using AS-CFD we can improve the infiltration process (with the help of numerical simulation): on the one side analyzing particle interaction and on the other side analyzing the flowing process.

2. NUMERICAL AND GEOMETRICAL MODELING

Al6061 flow through a porous surface during the infiltration process is a nonlinear analysis in which two processes dominate: flowing and solidification. According to numerical simulation we have calculated:

a) the interaction between two particles,

b) thermic equations in which Al6061 is considered an incompressible Newtonian fluid.

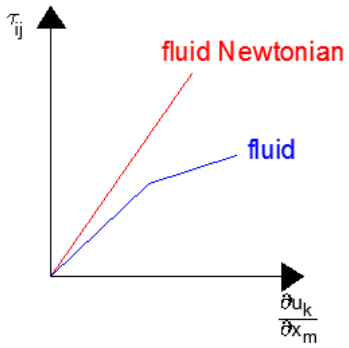

***Figure 1**. Variation graphic of a Newtonian fluid*

As general equations used to express Newtonian flowing process we highlight:

$$\nabla u = 0 \qquad eq1$$

$$\rho\left(\frac{\partial u}{\partial t} + u \cdot \nabla u\right) = -\nabla p + \mu \nabla^2 u \qquad eq2$$

where: u – fluid speed, ρ – density, t – time, p – pressure

Though this result is based on another principle:

$\tau_{ij} \approx$ *linear function for: effort size (tension)* $\equiv$ *speed gradient*

$$\frac{\partial}{\partial t}\left(\frac{\partial X}{\partial x}\right)=\frac{\partial}{\partial x}\left(\frac{\partial X}{\partial t}\right)=u \qquad \frac{\partial u_k}{\partial x_m}=\alpha_{ijkm} \qquad (eq3)$$

approx.81=Newton module

For isotropic fluids the equation is:

$$\tau_{ij}=\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)+\lambda\left(\frac{\partial u_l}{\partial x_l}\right)\rightarrow \nabla\cdot\vec{v} \qquad eq4$$

where: $\mu -$ *dynamic viscosity coefficient,* $\lambda -$ *elasticity coefficient*

For incompressible flow $\left(\frac{\partial u_l}{\partial x_l}\right)=0$, *and for isotropic and incompressible Newtonian fluid* τ_{ij} *variation is given by:*

$$\tau_{ij}=\mu\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right) \qquad eq5$$

Using AS-CFD we have established the model analyzed on a right prismatic surface.

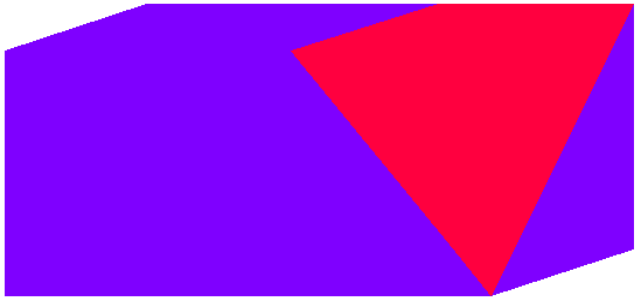

***Figure 2**. Prismatic surface AS-CFD modeled*

Tridimensional geometrical modeling is based on the following characteristics: general surface – regular rectangular prism, spherical particles, fraction volume approximately 33%. The surface can be divided in regular spherical surfaces or cubes in order to reach the 33%. Infiltration process parameters (adopted by Dopler) are important to differentiate the numerical simulation approximations.

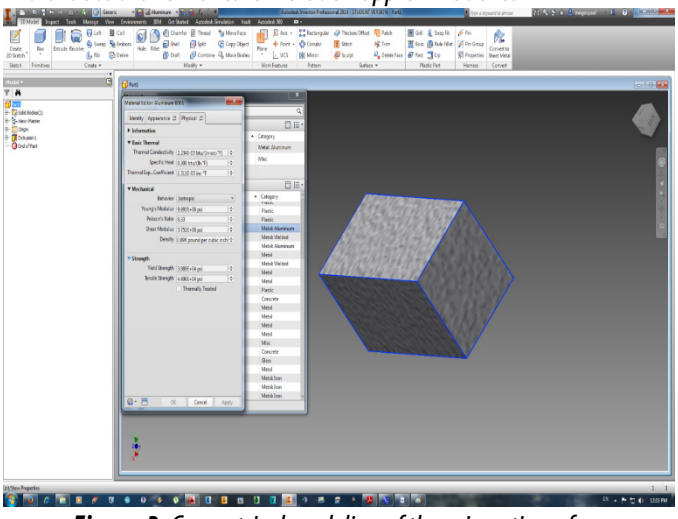

***Figure 3**. Geometrical modeling of the prismatic surface using Inventor Professional 2014*

AS-CFD modeling consists of creating a regular rectangular prism, with rectangular base L=20cm, l=10cm, h=10cm. The characteristics are presented in Figure 4, pressure 50Pa, external pressure 0.8MPa, all used for the simulation. Al6061 alloy density is 2.71 g/cm³.

3. RESULTS AND DISCUSSIONS

The simulation is presented in Figure 4 and shows variations on different particle diameters (spheres used to simulate): 700µm, 500µm and 300µm. The violet colored area represents Al6061 alloy, blue/green – area that is filled next and grey – area unaffected by flow.

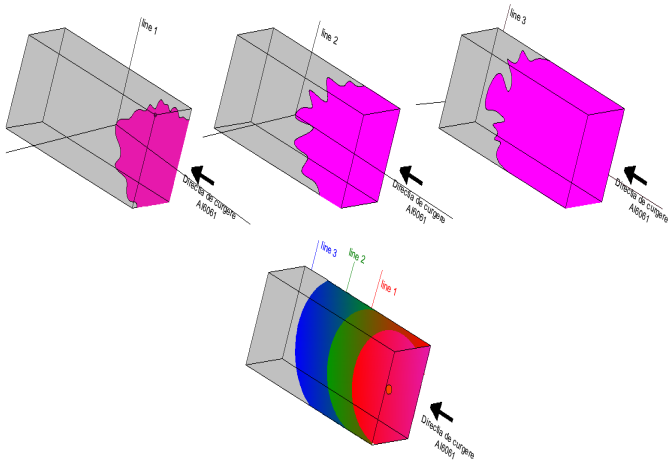

***Figure 4**. Al6061 alloy flow propagation in the used shape – simulation on the 3 advancement lines.*

The infiltration process is presented using AS-CFD and shows the program capacity of analyzing physical infiltration and propagation characteristics through a pre-established 3D surface (modeled using Inventor) of an Al6061 alloy. Flow symmetry and liquid fraction value are presented in Figure 4 (including air fraction volume) and finally, undetected porosities. These areas can be defined as unsecure areas and are analyzed and highlighted in the simulation.

The relation for Figure 5 is important to establish matches between sphere diameters and time frames, resulting for: 700, 500 and 300 µm.

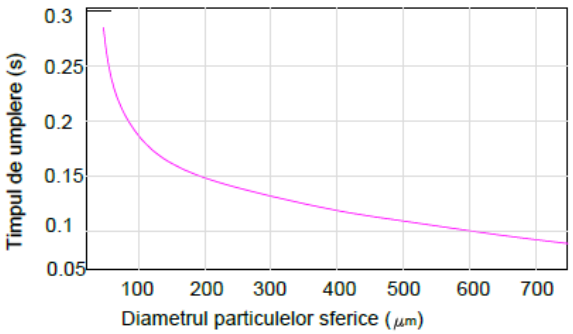

***Figure 5**. Relation between particle size and porous cavities filling time*

The filling time frame grows with decreasing spherical particle diameter used for simulating, therefore the graphic is a descending parable, such as Figure 5. Spherical particles dimension influences the simulation volume (CFD) which exponentially rises with increasing sphere diameter. Therefore at 700µm, 500µm, 300µm we have a time frame of 5 hours, 10 hours, 30 hours. Because of this it is important to follow the infiltration process for particles with 300µm diameter using AS-CFD because it requires a large time frame.

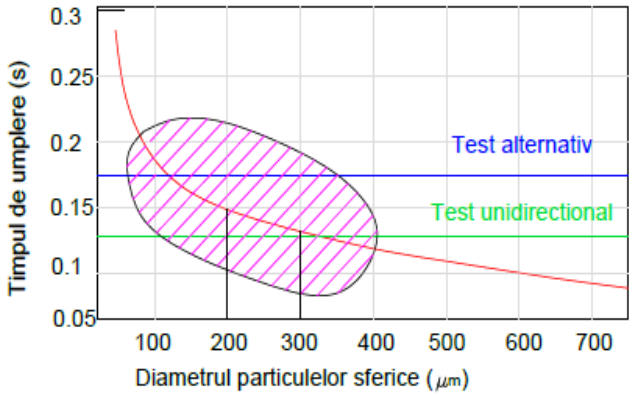

***Figure 6**. Ration between particle diameter, cavity filling time and ductility (according to alternative and unidirectional tests)*

At the same time, depending on these two parameters: filling time and spherical particles diameter used in the simulation we can characterize the ductility interval of Al6061 alloy, checking the alternative and unidirectional test variation (process highlighted in Figure 6). The graphic suggests that both tests, unidirectional and alternative, should use 200µm-300µm diameter spheres, with a time frame of 0.15s, hence the necessity of using an information simulation solution to analyze the whole process.

4. CONCLUSIONS

In this paper we have presented an analysis of the undefined porosity areas in Al6061 alloy using the infiltration process through a surface created using Autodesk Inventor Professional 3D, and for the network nodes we have designed spheres of different dimensions.

1. *AS-CFD simulation is similar to the method of approximating permeability on a pre-established surface. In these cases we can calculate undefined porosity areas based on the diameter of the spheres used in the simulation.*
2. *Decreasing Al6061 sphere diameters involves an exponential growth of the time frame when simulating. This process involves difficulties in analyzing these irregular surfaces (in our case for particles of 300µm because of the very large time frame), but using AS-CFD we can obtain rapid and conclusive results.*
3. *Using AS-CFD we can also introduce the temperature parameters in correlation with volume and time of the infiltration process. Therefore, we can obtain conclusive information between the experimental data and the numerical simulation.*
4. *Undetermined or undefined porosity on our model made in AS-CFD influences the ductility of the Al6061 alloy so that not all implicated surfaces can participate in the process, but only the low diameter ones (in our case 300µm) i.e. the ones that require the highest time frame.*

***Acknowledgement**:*

The work has been funded by the Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132395.

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ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING
ISSN:2067-3809