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The analysis of applicability of the FlowVision software for capillary effect simulation

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Abstract. The article discusses the modeling of hydrodynamic processes in the FlowVision software package, taking into account the influence on the capillary effect of changing various parameters of a liquid, such as capillary diameter, wetting angle, surface tension force and fluid viscosity. Authors solved test tasks about the effect of the above parameters on the difference between the values obtained by mathematical methods and modeling. A qualitative and quantitative analyses of the results were made, and conclusions were drawn about the possibility of using the FlowVision software to simulate the infiltration process of the frame of reinforcing fibers with a binder when forming products from metal-matrix composites.

1. Introduction

Over the past decades, composites have actively entered our life and replaced traditional materials in such areas as energy, transport, electronics and others.

Nevertheless, there is a high scatter of their stiffness and strength characteristics, the source of which is the instability of source materials, deviations in the implementation of technological processes, insufficient production culture, the choice of mode, and the calculation of the time of infiltration. Because of this, it is necessary to introduce additional safety coefficients when determining the projected load, which affects the cost of the manufacture [1].

To solve the problem of choosing the mode and calculating the infiltration time, modern modeling methods can be used in software products such as ANSYS Multiphysics, PAM-RTM, FlowVision, etc., which will reduce cost and time for the manufacture of test products.

Let us analyze the capabilities of the FlowVision software. It is intended to simulate the dynamics of the flow of viscous liquids and gases, taking into account the effects of wettability, surface tension forces, hydraulic resistance, etc. The advantages of this software package are relatively low requirements for computer resources and a relatively low cost in comparison to major global competitors, such as ANSYS, PAM-RTM, ProCAST.

To confirm the suitability of FlowVision for solving the tasks related to the infiltration of the frame of reinforcing fibers with a binder, a number of test tasks were solved. The results confirm the possibility of taking into account the capillary effect in the FlowVision software package. Qualitative pictures of the distribution of a fluid in the both problems correspond to the reality, but a comparison of the simulation results and theoretical calculations showed that the quantitative discrepancy in the data was about 30%. [2] To obtain a more accurate result, reduce the error, with the assistance of technical support service, some corrections were made and additional test tasks were solved to determine the effect of the capillary diameter, wetting angle, surface tension force, and fluid viscosity on the flow of a fluid in the capillary.

2. Results and discussion

With the assistance with technical support service, some changes in the program were made, and in the new version of the program we achieved the following results: we changed the parameters of capillary radius, surface tension, wetting angle and viscosity.

The parameters were not chosen randomly, almost all of them are contained in the Jurin's formula for calculating the height of a liquid:

$$h = \frac{2\sigma \cdot \cos\Theta}{r\left(\rho - \rho_0\right)g}$$

where
r is the tube radius;
ρ is the liquid density;
ρ_0 is the external medium (air) density;
Θ is the wetting angle;
σ is the surface tension force.

By changing these parameters in the simulation we obtained different heights of the fluid and compared them with the mathematical calculations. Various parameters were used to ensure that we could fairly say that the Jurin's formula is correct with all the differences in the FlowVision software package and the sofware can be used to simulate more complex fluid flow processes, such as modeling the infiltration of the frame of reinforcing fibers with a binder.

1. Under standard conditions, two different radii were used: 0.5 and 1 mm. In figures 1 and 2, one can see a line to which they have risen, these lines are the estimated capillary height, in the both cases the error was within 5%.

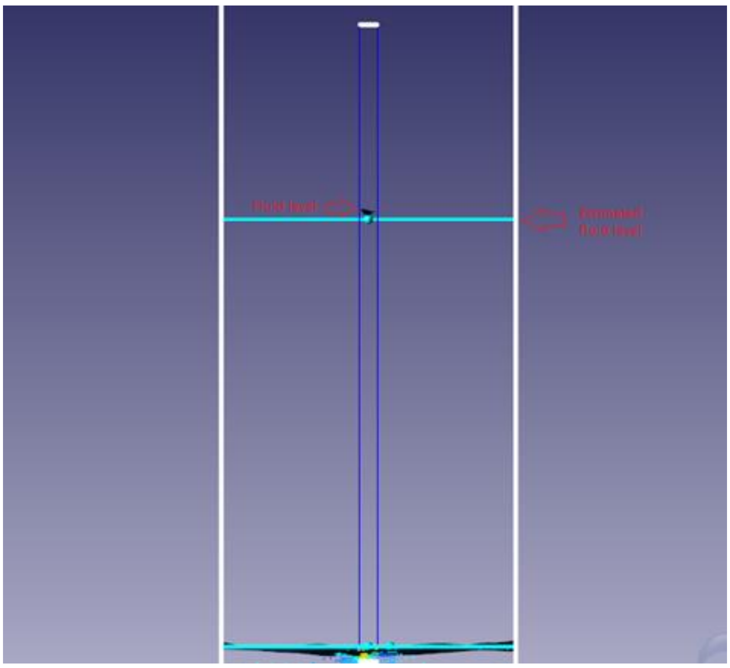

Figure 1. Tube radius is 0.5 mm.

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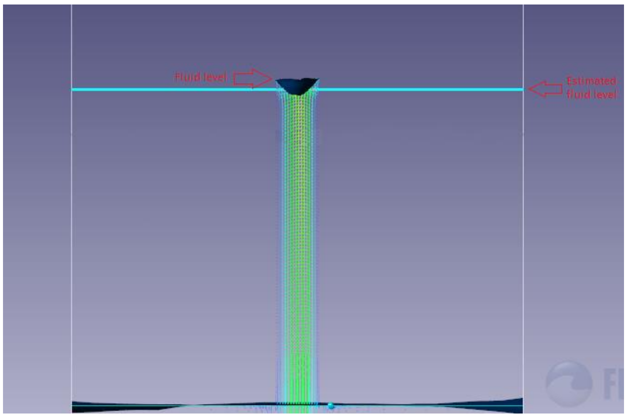

Figure 2. Tube radius is 1 mm.

2. Then, the radius was left equal to 1 mm and the surface tension of water equal to 0.0589 N m^{-1} at 100 ° C was used. At the same time, the height should have been lower than that under standard conditions (figure 3). A red line shows the calculated height, the capillary, after small oscillatory movements, stopped at the required height. The error was less than 5%.

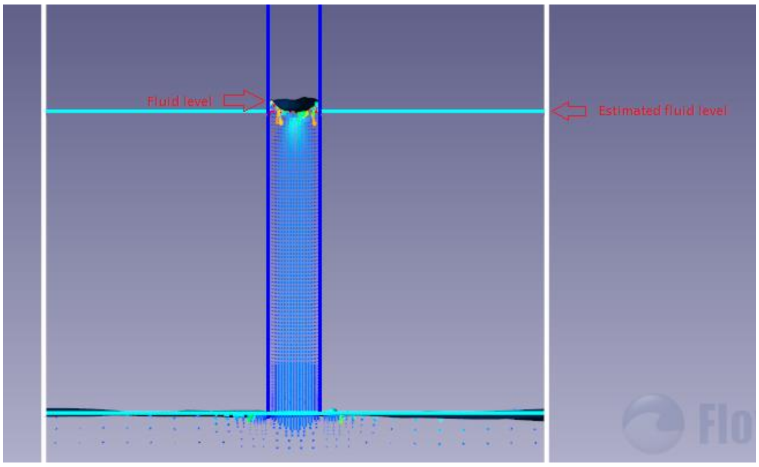

Figure 3. Surface tension is 58.9 N m^{-1}.

3. The height of a liquid column also depends on the material of a tube itself and its interaction with the liquid. To indicate the nature of this interaction in FlowVision, one can set a wetting angle for the surface. Under standard conditions, the value of 5 degrees was used, in the subsequent tasks we used the values of 70 and 145 degrees. At a wetting angle of 70 degrees, we observed a full agreement with the mathematical calculation (figure 4).

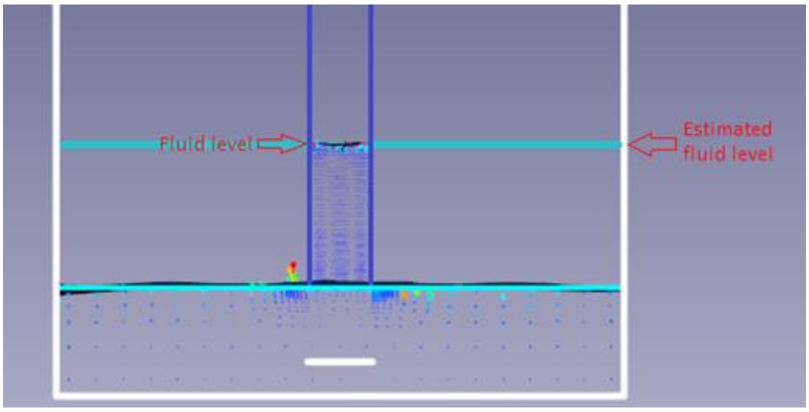

Figure 4. Wetting angle is 70º.

4. In the case of a “non-wetting” capillary surface, we observed a qualitatively correct picture (figure 5), but quantitatively there were discrepancies, the error with the mathematical model was 10%, and the capillary with a wetting angle of more than 90 degrees needs optimization.

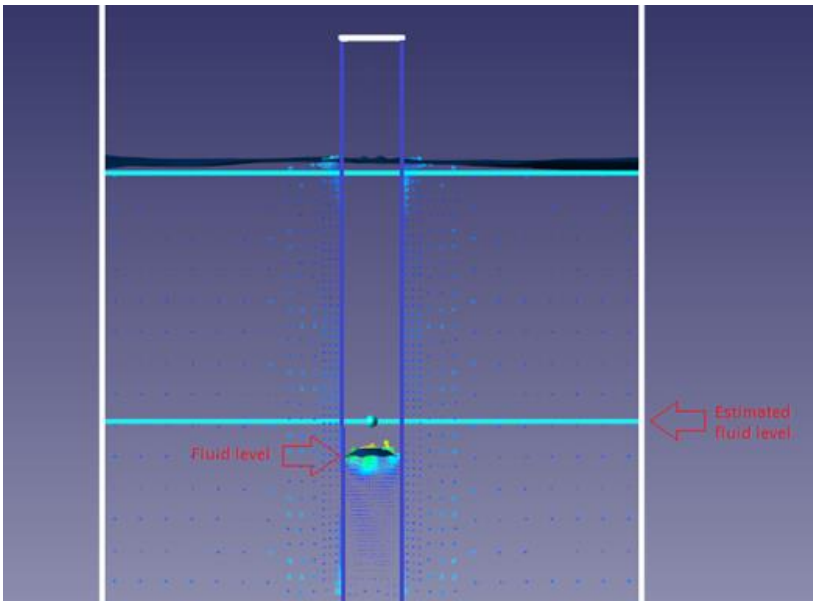

Figure 5. Wetting angle is 145º.

3. Conclusion

The FlowVision software package shows good results in matching the mathematical and computed visualized models, the discrepancy for most tasks was only about 5%. However, for a task with a non-wetting surface, the discrepancy is about 10%, and it is necessary to optimize for tasks with a wetting angle of more than 90 degrees. The qualitative and quantitative pictures of modeling correspond to the reality, which enables us to use it for the further simulation of the flow of liquids in more complex structures, taking into account wettability, surface tension, viscosity, capillary effect, etc. This makes possible to solve the task of impregnating reinforcing fibers with a binder when forming metal-matrix composites in the FlowVision design package.

4. References

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