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Numerical Simulation of Aeration Sand Filling-High Pressure Squeeze Molding Method

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Aeration sand filling-high pressure squeeze molding method consists of two processes: aeration sand filling process with low pressure and the subsequent high pressure squeeze molding process. For numerical simulation, the aeration sand filling process has been simulated with a self-developed procedure based on Finite Difference Method(FDM), while a commercial software Abaqus based on Finite Element Method(FEM) has been used for the simulation of the high pressure squeeze molding process. Sand flowing state during aeration sand filling process can be seen from the simulation results. The simulation results can be used as the guideline for the production practice in order to produce a high quality casting. In this paper, some cases of 3-D numerical simulation and the correlative benchmark testings are reported in details.

Keywords: *green sand; aeration sand filling-high pressure squeeze molding; numerical simulation.*

1. Introduction

Aeration sand filling is a new sand filling method of green sand molding. For some unique advantages, such as better mold quality, less energy consumption and less pattern wear, aeration sand filling has been successfully applied in compound molding method - aeration sand filling-high pressure squeeze molding and also has been studied carefully [1,2].

The 3-D numerical simulation of aeration sand filling-high pressure squeeze molding process consists of two parts: aeration sand filling and high pressure squeeze molding. The aeration sand filling process is a typical gas-solid two phase flow problem. Different mechanical models, for example, discontinuous model [3, 4], continuous model and distinct cluster model [5], have been used to deal with this problem. The high pressure squeeze molding process is a static sand compaction problem and its simulation can be completed with some FEM software.

2. Numerical Simulation Model

The 3-D numerical simulation model of flaskless horizontal parting aeration sand filling-high pressure squeeze molding process could be divided into two parts: aeration sand filling and high pressure squeezing. The aeration sand filling part is a typical gas-solid two phase flow problem. The high pressure squeezing part is a static sand compaction problem, its simulation can be completed with FEM software.

2.1 The Aeration Sand Filling Part

Aeration sand filling is a typical two-phase flow phenomenon because sand flow and compressed air flow are mutually affected. As the sand phase can be treated as “fluid”, the continuous mathematical model is more suitable for its higher accuracy and lower performance requirement for computer. Eulerian approach is used to describe mass, momentum, energy and the interactions.

Due to the limit of pages, the governing equations for aeration sand filling part are not listed in this paper. They were reported in details by Li Hua [1, 6].

2.2 The High Pressure Squeezing Part

As the nonlinear characteristics of molding sand and its large deformation during the high pressure squeezing part, a commercial FEM software Abaqus has be chosen for the simulation of the high pressure squeezing part. The revised Drucker-Prager/Cap model is used for the mechanical model, which has been successfully used in simulation of the squeezing process of soil [7].

The model parameters of the revised Drucker-Prager/Cap model are listed in Table 1. The experimental results reported by Li Hongliang [8] are referenced to get the isotropic compression stress-strain curve.

Table 1 Parameters of the revised Drucker-Prager /Cap model [9]

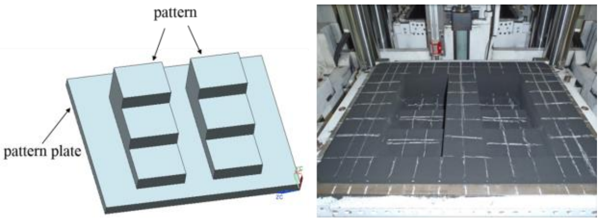
d	β	R	α	K	Yong’s modulus	Poisson ratio
1.6KPa	20.8 °	0.1	0.01	1	30MPa	0.35

3. Comparison of Simulation Results and Experimental Results

For the experiment, the step model is used (Figure 1(a)). The air pressure is set to be 0.1MPa during the aeration sand filling process and the squeeze pressure is set to be 1.0 MPa for the high pressure squeeze molding process.

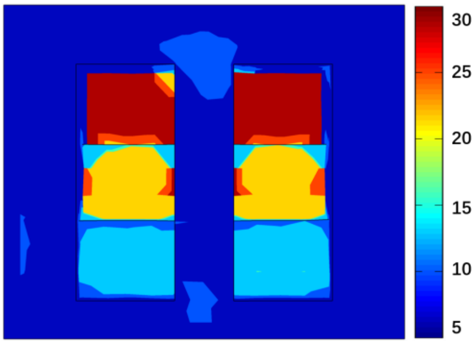
For the simulation, the parameters are set to be the same as in the experiment. To combine the aeration sand filling process with the high pressure squeeze molding process into a complete molding process, the sand bulk density distribution after aeration sand filling has been used as the bridge between aeration sand filling and squeezing [10].

In the experiment, the mold strength of the sand mold is measured on the parting surface and the cut face (Figure 1(b)).

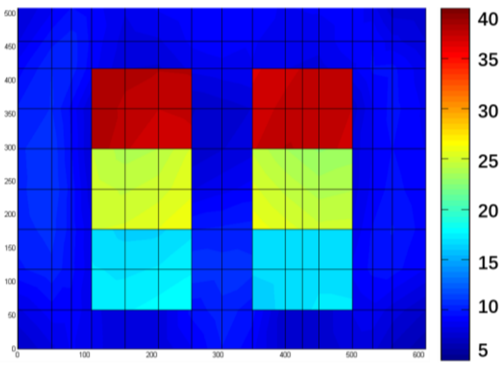


(a) (b)

Fig. 1 (a) The step model, (b) The corresponding drag mold.



(a)



(b)

Fig. 2 Comparison between the simulation results (a) and experimental results (b) (unit: N/cm^2)

It can be seen from Fig. 2 that the experimental results and the simulation results have the same tendency, the strongest part and the weakest part are the same. When the height of the steps goes higher, the mold strength increases. But the simulation results are about 30% lower than the experimental results.

4. Conclusions

(1) A 3-D numerical simulation procedure for the aeration sand filling-high pressure squeeze molding process has been developed based on the two-phase flow theory and soil mechanics.

(2) The simulation results can give some guidelines for production practice and provide useful information to improve quality of casting. As for the differences between the simulation results and the corresponding experimental results, practical situation and complexity of aeration sand filling-high pressure squeeze molding method should be taken into account carefully.

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References

[1] LI Hua, WU Junjiao, HUANG Tianyou, MAKINO Hiroyasu. 3-D Numerical simulation for aeration sand filling process. *The 69th World Foundry Congress* (2010).

[2] M. Hirata, K. Sugita, "New sand filling method in flaskless molding and its controls," AFS Transactions (2005):319-326.

[3] H. Makino, Y. Maeda and H. Nomura, International Journal of Cast Metals Research (1997).

[4] Alexander Barth, "Computer simulation optimizes coremaking operation," Casting Plant & Technology (2008):46-52.

[5] Xiangjun Liu, Xuchang Xu, "Modeling of dense gas-particle flow in a circulation fluidized bed by distinct cluster method," Power Technology (2009):235-244.

[6] LI Hua, "The Experimental Study and 3-D Numerical Simulation on Shoot-Squeeze Molding Method," Doctor of Engineering Dissertation, Tsinghua University, Beijing (2011).

[7] Mizuno E, "Cap Models in Soil Mechanics," *Preprints-Asce Convention & Exposition* (1982).

[8] LI Hongliang, "The experiment study and numerical simulation on low pressure shoot-high pressure squeeze moulding," Doctor of Engineering Dissertation, Tsinghua University, Beijing (2005).

[9] Simulia Corporation, "Abaqus Help Document," Simulia Corporation, France (2006).

[10] ZHANG Yifei, "Experimental Study and Numerical Simulation on Shoot Squeeze Moulding and Air Impact Moulding," Doctor of Engineering Dissertation, Tsinghua University, Beijing (2003).