Structural and Thermal Analysis of 3D Printing Process

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Summary. 3D printing, also called Additive Manufacturing, has become a popular and promising way to produce parts in various fields, as it can produce parts with very irregular shapes in a shorter period of time. However, during 3D printing processes, some issues could decrease the accuracy and quality of the printed parts, such as warpage due to thermal strains, collapse due to inadequate support, deformation due to self-weight, etc. In order to overcome those problems and reduce manufacturing failings, the printing processes need to be evaluated in advance and then improved by adjusting manufacturing and design parameters. Numerical simulation is one of the efficient ways for evaluating engineering problems. Generally, the finite element method has been adopted popularly. Nevertheless, the models needed in the finite element method, i.e. element meshes, for irregular objects always are irregularly distributed; therefore, the element meshes cannot match the vertical growing shapes of the printed parts in the additive process. Here, a newly developed method, based on so-called meshless method and combined with the finite element method, is proposed to overcome above problems. With the proposed method, the analysis models can be designed to match the growing shapes, i.e. layer by layer, and used to simulate the parts' layer-by-layer growing behavior in 3D printing processes. Besides, the Stereo-Lithography (STL) formatted geometry model is adopted for the simulation. The STL formatted geometry is a De facto standard format used in 3D printing industry. This makes the proposed method not only straightforward but also simple. Several 3D printing cases have been simulated to demonstrate the effectiveness and efficiency of this proposed method.

Introduction

3D printing has become a popular way to produce parts in various fields because of its promising features, e.g. it can produce complicated parts with irregular shapes. However, during adopting 3D printing to manufacture parts, some issues could decrease the accuracy and quality of the printed parts, such as warpage due to thermal strains, collapse due to inadequate support, deformation due to self-weight, etc. In order to overcome those problems and decrease the manufacturing failings, it is advised to evaluate the processes in advance to obtain information to improve possible defects. Computational analysis is one of the efficient ways for evaluating engineering problems. Among all computational methods, the finite element method has been commonly adopted due to its flexible and powerful features. Nevertheless, the models needed for the finite element method, i.e. element meshes, always are irregularly distributed when dealing with irregular objects; therefore, the element meshes cannot match the growing shapes of the parts in the middle of the 3D printing process, which is growing layer by layer. Consequently, this has become a drawback for the finite element method. On the contrary, the proposed method based on the so-called meshless method [1] doesn't need element meshes, so its analysis models can be designed to match the growing shapes in 3D printing processes and used to simulate the 3D printing processes.

In 3D printing industry, Geometry data in STL (Stereo-Lithography) format has been most adopted as a De facto standard format to transfer geometry data between different systems. The geometry in STL format is simple and flexible for representing irregular geometry. Due to this, the proposed method adopts STL geometry as the geometry model, which is needed during the simulation, e.g. the analysis model is generated based on it. This STL-based way can simplify the geometry data handling. With the proposed method, several structural and thermal simulations have been conducted to demonstrate the effectiveness and efficiency of the proposed method.

Method

In 3D printing the parts are printed in a layer-by-layer (additive) way. In each layer, the material is paved horizontally. If the simulation uses a whole model to do the analysis, the results are proved to be wrong as shown in Fig. 1. In order to simulate the additively-growing situation, the simulation should adopt a layer-by-layer way. In order to do that, the analysis models also must follow the same condition, i.e. each layer is horizontally distributed. However, it is hard to generate a layer-by-layer analysis model with the finite element method. The finite element meshes, normally generated by auto-mesher and always irregularly distributed for parts with irregular shapes, as shown in Fig. 2, cannot match the horizontally-distributed condition and cannot be used to do simulation. In order to overcome above problems, a newly developed method [2][3] based on so-called meshless method is proposed since meshless method doesn't need any element meshes and the analysis models can be designed to match the layer-by-layer additive shapes. Hence the proposed method can then be used to simulate the growing behaviors in 3D printing. In addition to taking advantage of basic meshless scheme, this proposed method also includes schemes for handling the STL geometry and generating the layer-by-layer analysis model, which is used to do simulation. The generation of the layer-by-layer analysis model is also automatic without any manual operation; this makes the proposed method efficient and straightforward.

Conclusions

Evaluating manufacturing processes in advance is advised to assure the product's quality. However, in 3D printing, the parts are printed in a layer-by-layer (additive) way. In order to simulate the additively-growing situation, the simulation should also adopt a layer-by-layer way. Nevertheless, the finite element method becomes difficult to use due to the difficulty to generate a layer-by-layer analysis mesh. Herein, a newly developed method based on the meshless method is proposed; besides, the analysis model can be generated to match the layer-by-layer condition and used to do simulation. Moreover, the proposed method directly adopts the De facto geometry standard, i.e. STL geometry, which is commonly used in 3D printing industry for transferring product geometry. With all these features, the proposed method can be used to simulate the 3D printing processes.

References

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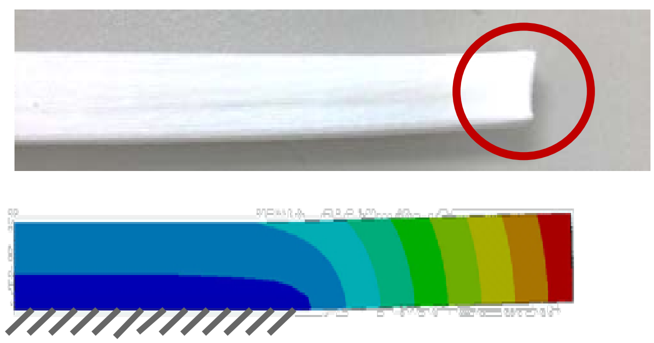

Fig. 1 Simulation with a whole model generates wrong results

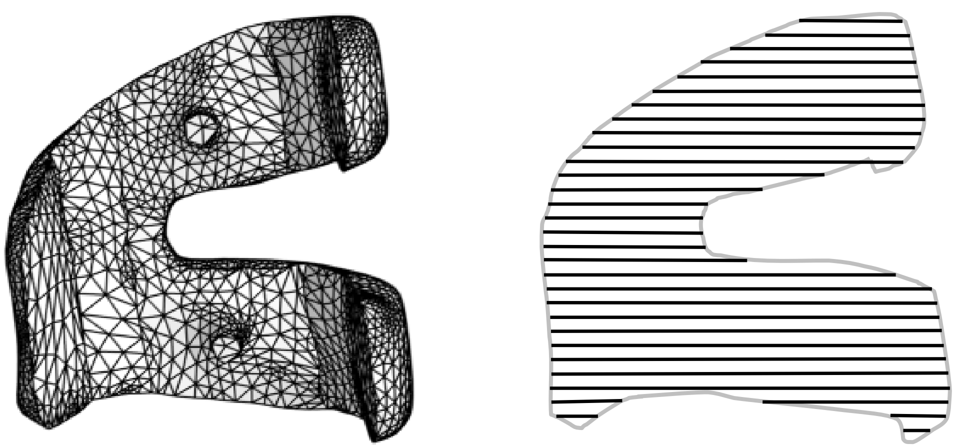

Fig. 2 Element mesh (left) by auto-mesher cannot match layer-by-layer situation
Layer-by-layer model (right) is needed for simulating 3D printing process