11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

# INTERIOR POINT METHOD BASED CONTACT ALGORITHM FOR STRUCTURAL ANALYSIS OF ELECTRONIC DEVICE MODELS

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**Key Words:** *Contact Problem, Interior Point Method, Finite Element Method, Electronic Device Models.*

In this paper, we present an interior point method based algorithm for frictionless contact problems of linear elastic bodies with multi-point constraints and the numerical result of its application to structural analysis of parts-assembled electronic device models.

In a design process of portable electronic devices such as laptop PCs and mobile phones, it is important to satisfy both of lightweight and toughness. Structural analysis based on finite element method is widely used in order to upgrade quality of the design and reduce the cost of experimental production. Recently, it is common to use parts-assembled model for the structural analysis to check if each part has sufficient toughness in the usage environment. This analysis is formulated as static stress analysis with contacts and multi-point constraints between parts, so we can write it as the following constrained optimization problem

$$\begin{aligned} &\text{minimize} \quad \frac{1}{2}\boldsymbol{u}^T\boldsymbol{K}\boldsymbol{u} - \boldsymbol{f}^T\boldsymbol{u}, \\ &\text{subject to} \quad \boldsymbol{T}\boldsymbol{u} + \boldsymbol{h} \geq \boldsymbol{0}, \boldsymbol{M}\boldsymbol{u} = \boldsymbol{0} \end{aligned} \qquad (1)$$

where $\boldsymbol{u}$ is displacement vector, $\boldsymbol{K}$ is stiffness matrix, $\boldsymbol{f}$ is external force vector, $\boldsymbol{h}$ is initial gap vector, and $\boldsymbol{T}, \boldsymbol{M}$ are the matrix representation of contacts and multi-point constraints. Contacts and multi-point constraints are modeled by node-to-segment contact in this study.

Major algorithms to solve this kind of problem are introduced in Wriggers[1]. The most simple one is active set method with the penalty method or the Lagrange multiplier method. Iterative update of active set is done until the complementary conditions between the gap and contact force converge. For portable electronic device models which consist of many thin parts such as liquid crystal displays and circuit boards with high density, active set method needs many iterations to find final active set because the number of contact constraints is large compared to total dof.

Interior point methods[2] are said to be efficient algorithms to solve convex nonlinear problems with the large number of constraints. Christensen et al.[3] applied primal-dual interior point method to linear elastic contact problem with friction. They also compared interior point method with semismooth Newton method, which is direct expansion of Newton method to non-differencial functions, and concluded that semismooth Newton method is faster and robust. However, their models are quite small and they also said that interior point method might need less iterations than semismooth Newton method for problems with a huge number of potential contact nodes. Tanoh[4] also applied primal and primal-dual interior point method, and show that interior point methods are efficient for large scale problem. Miyamura et al.[5] proposed the combination of active set method and primal interior point method and show that their algorithm are faster than simple application of interior point methods in some examples.

In this paper, we first remove multi-point constraints by penalty method and then apply primal-dual interior point method to the problem. We have implemented the algorithm to open-source FEM solver FrontISTR[6] which is made for large-scale finite element structural analysis and tested its performance using actual parts-assembled electoric device model. The Laptop PC model we used for numerical experiment is shown in figure 1. This analysis aims to evaluate stress at the liquid crystal display when the rear cover is pressed by external force. It consists of 25 parts and its dof is 523,426. Contacts or multi-point constraints are defined between parts and the numbers of them are 50,658 and 2,492 respectively. In our experiment, while active set methods needs 60 iterations to converge, our algorithm needs 48 iterations.

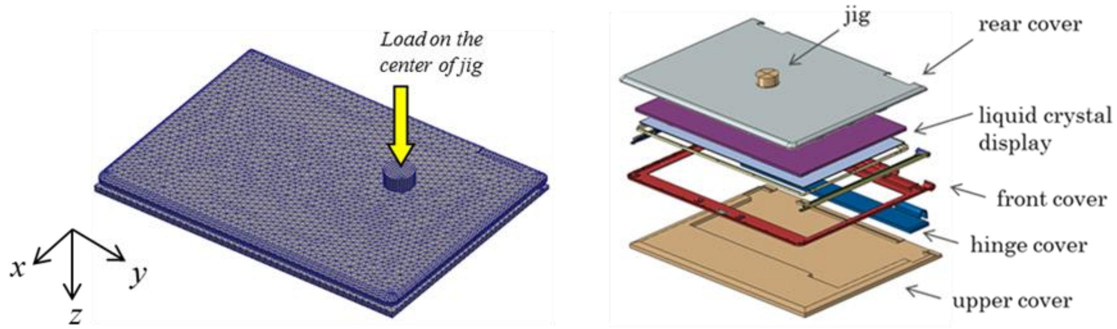


**fig.1 Laptop PC model (left: mesh model, right: assembled parts)**

## REFERENCES

[1] P. Wriggers, Computational Contact Mechanics (2nd ed.), Springer-Verlag, Berlin, Germany, (2006).
[2] Y. Ye, Interior-Point Algorithms: Theory and Analysis, John Wiley & Sons, NewYork, NY, (1997).
[3] P. W. Christensen, A. Klarbring, J. S. Pang and N. Stromberg, “Formulation and comparison of algorithms for frictional contact problems”, Int. J. Numer. Methods in Eng., Vol. **42**, pp. 145–173, (1998).
[4] G. Tanoh, Y. Renardy and D. Noll, “Computational experience with an interior point algorithm for large scale contact problems”, Optimization Online, http://www.optimization-online.org/DB_HTML/2004/12/1012.html, (2004).
[5] T. Miyamura, Y. Kanno and M. Ohsaki, “Combined interior-point method and semismooth Newton method for frictionless contact problems”, Int. J. Numer. Methods in Eng., Vol. **81**, pp. 701–727, (2010).
[6] H. Okuda, “Nonlinear Structural Analysis Open Software FrontISTR“, http://www.ciss.iis.u-tokyo.ac.jp/riss/english/project/structure/FISTR_JE_1303.pdf, (2012).