A NOVEL APPROACH FOR A SOLID OBJECT IMPACT ON HUMAN HEAD

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INTRODUCTION

This paper proposes a feasible methodology to estimate contact force between a solid striker and human head and to predict the human head response to the contact impact via an integration of a simple striker-head contact force model with finite element methods. The computational results from present methods were compared with Nahum's experimental data [1]. The results closely matched the experimental data, showing that present approach facilitates the study on the problem of a solid object impacting on human head.

METHODS

Consider a solid object impacting on a static human head. The three-dimensional finite element model consists of both the head and striker as shown in Fig.1(a). The head model includes the skull, the brain, cerebrospinal fluid (CSF) and the neck. The striker is a solid cylinder attached with soft robber padding. It has a total weight of 5.6kg and impacted on the frontal bone of the head at 9.94m/s along the mid-sagittal plane, which is the similar with the condition used in Nahum's test.

To estimate contact force between the solid object and human head during impact, a simple striker-head contact force model is proposed, as shown in Fig. 1(b). The striker-head contact force model contains five parameters; they are the head mass m_1, the striker mass m_2, the equivalent stiffness K_1 of the human head and neck, the effective contact stiffness K_2^* and the initial striker velocity V.

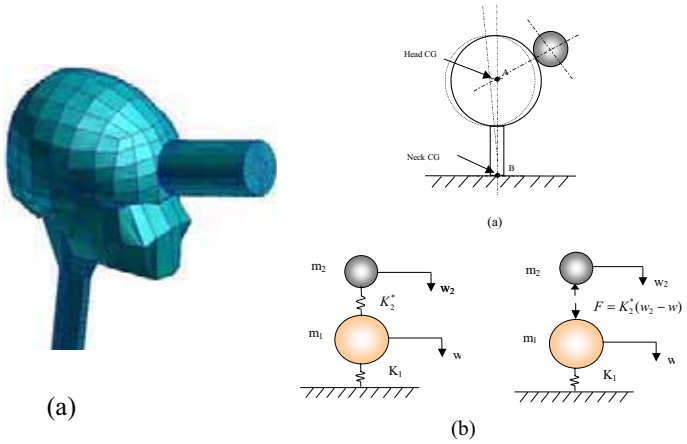

Figure 1: (a) 3D FE head and striker model; (b) Striker-Head Contact force model.

Based on the striker-head contact force model, the contact force function is formulated in terms of the five parameters as follows:

$$F(t)=\begin{cases} K_2^*[a_1(c_1-1)\sin(\omega_1 t)+a_2(c_2-1)\sin(\omega_2 t)] & 0<t<T \\ 0 & t>T \end{cases} \quad (1)$$

In the force function, T is the contact duration and

$$\omega_{1,2}^2=\frac{1}{2}\left(\frac{K_1+K_2^*}{m_1}+\frac{K_2^*}{m_2}\right)\mp\sqrt{\frac{1}{4}\left(\frac{K_1+K_2^*}{m_1}-\frac{K_2^*}{m_2}\right)^2+\frac{K_2^{*2}}{m_1 m_2}}$$

$$c_1=\frac{K_2^*}{K_2^*-\omega_1^2 m_2} \qquad c_2=\frac{K_2^*}{K_2^*-\omega_2^2 m_2} \qquad a_1=\frac{V}{\omega_1(c_2-c_1)} \qquad a_2=\frac{V}{\omega_2(c_1-c_2)}$$

The contact force predicted by Eq (1) can be directly applied to the FE head model to substitute the FE striker model.

RESULTS AND DISCUSSION

Figure 2(a) shows the contact force histories estimated by contact force function (1), computed by contact-impact algorithm implemented in the commercial code DYNA3D, and recorded from Nahum's experiment, respectively. The comparison shows that the present contact force function (1) produces a reasonable result. Figure 2(b) shows a comparison between Nahum's test results, Ruan's numerical data [2] and present simulation outcomes. The present result has good agreement with the experimental results.

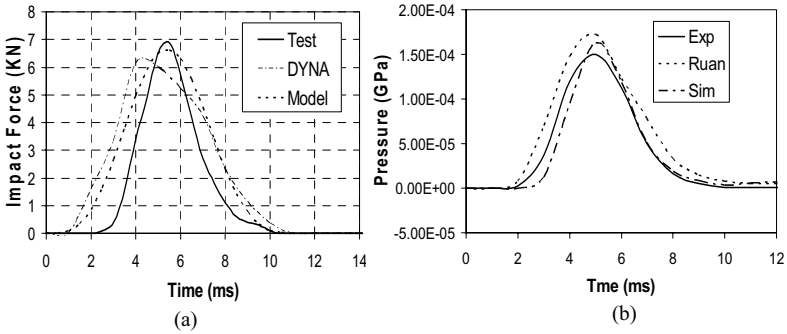

Figure 2: (a) Comparison of contact forces; (b) Comparison of Coup Pressures

CONCLUSIONS

The proposed approach facilitates the estimation of striker-head contact force and the prediction of human head response to solid contact impact. It can also be used to evaluate the influences of a solid striker's material properties, mass and velocity on head injury.

REFERENCES

1. Nahum, A. M., Smith, R., and War, C. C., 1977. Intracranial Pressure Dynamic During Head Injury. 21st Stapp Car Crash Conference Proceedings, SAE 770922.
2. Ruan, J. S., Khalil, T. B., King, A. I., 1994. Dynamic response of the human head to impact by three-dimensional finite element analysis. *Journal* of Biomechanical Engineering 116, 44-50.