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Finite Element Analysis of Operator Top guard Impacted of Hydraulic Excavators

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Abstract. The nonlinear finite element model of the top guard is established. The contact arithmetic and loading method are discussed. The time-deformation curves of loading center are gained. The falling object experiment is carried out on the test equipment. The simulation results are accord well with the experimental ones. The dynamic simulation of the hydraulic excavators' top guard provides the basis for the structural design.

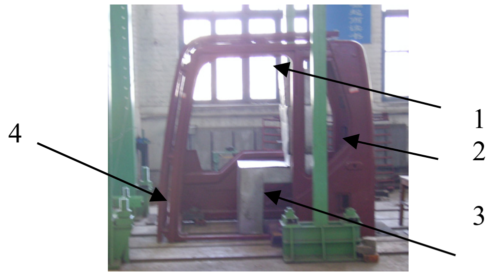
1. Introduction

Operator guards of hydraulic excavators are a set of barrier structure that fit on cab's exterior. Since top guard has complex structure, its structural member usually promptly transcends elastic stage and enters into plastic flow state, and it is quite likely to be penetrated when it is impacted. The parsing result is too difficult to obtain by applying the nonlinear dynamic theory. The author of literature three made use of the elastic-plastic dynamic response theory and only presented the mathematical model of board and shell structure without giving any resolutions. The stress deformation of protective structure was given through finite element technique, but the force loading is simulated by ideal square wave; thus neither the interaction between drop hammer and guard nor the disciplinarian of structural stress deformation is reflected during collision. In order to master the product's performance and optimize its structure at the design stage, the impacting process of the top guard entails simulation computer.

A typical top guard of excavators is taken as an example. The wholly impact course was simulated based on the transient nonlinear finite element technique. Point-plane touch mode was applied in the simulation. This top guard finite element model and the simulation result were validated by the corresponding physical prototype tests.

2.The dynamic equations and the solving algorithm of the impacting process of the top guard

2.1. The finite element model of top guard



1—top guard 2—operator cab
3—DLV 4—front guard

Figure 1. Operator guards of hydraulic excavators

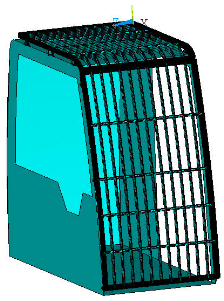


Figure 2. Finite element model of operator guards

The operator top guard of one certain excavator is mostly composed of beam and steel tube（as shown in picture1）. Nonlinear large deformation would occur when the top guard is impacted. Thereafter analytical calculation occupies a large sum of the computer resource. We must predigest the structural model to save computer resources. The model has been predigested as shown in picture 2.The cab is mostly welded by rolled-steel section and steel plate. The simulation of this structural finite element mode uses shell element and beam element combination which proves to be suitable for such structure._Plate and rolled-steel section are simulated by shell43 element and beam188 element respectively. Drop hammer is simulated by solid 45 element. Material characteristics are bilinear isotropic hardening model, and the material is Q235A.

2.2. Constraint and load

In order to faithfully simulate dynamic impact course, it is necessary to simulate the whole operator protective guards and drop hammer system. To simulate drop hammer free falling course, it is necessary to set up the drop hammer model over top guard and to specify the velocity of drop point.

Constraint conditions: fixed joint points between protective guard and frame, constrained their all freedom.

Loading: the drop hammer free falling negative direction is defined to be the direction of displacement, velocity and acceleration. Initial velocity v=8.5 m/s and gravity acceleration g=9.8m/s are applied to axial direction of drop hammer.

3. Numerical simulation and analyses

3.1 Maximum displacement of loading center

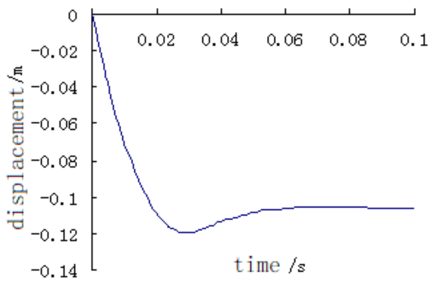


Figure 3. The displacement of loading center

Figure 3 is time-displacement curve of impacted center of the top guard as shown in picture 3.The maximum displacement of loading center is 119mm at 0.025s, the residual deformation is 109mm.

3.2 Effect of beam number on loading center displacement

In order to know the effect of beam number, we add a beam to top guard and the rest structure and loading conditions remain constant, the time-displacement of loading center is obtained, as shown in figure 4.

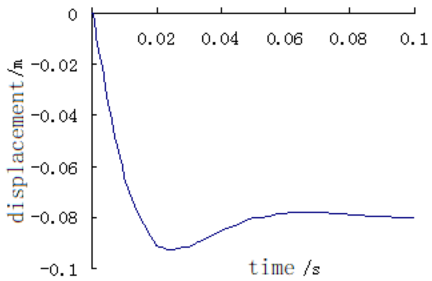


Figure 4. The displacement of loading center

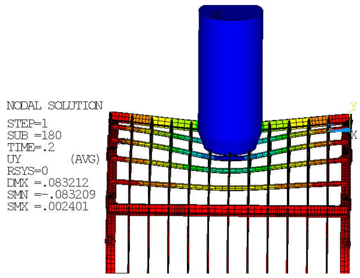


Figure 5. Simulated residual deformation of the top guard

The maximum displacement of loading center is 92.5 mm at 0.025s, residual deformation is 83mm.It is obvious that the increase of the beam number has large effect on structure performance.

4. Experimental verification


Figure 6. Experimental residual deformation of top guard

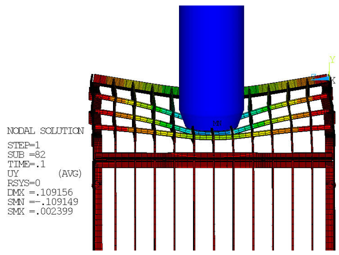


Figure 7. Simulated residual deformation of top guard

In reference to ISO10262, falling object test was proceeded (the top guard structure as shown in picture 1) on the experiment table of Jilin University engineering equipment center. The drop hammer did not penetrated top guard, the deformation of top guard and operator cab did not intrude DLV.
Residual deformation of top guard test and finite element mode are shown in picture 6 and figure 7 respectively.

In the test the residual deformation of loading center is 105mm, the distance between top guard and DLV is 270mm, and there is no penetration of DLV. The residual deformation of computation is 109mm. The simulation results are accord well with the experimental ones.

5.Conclusions

Transient nonlinear finite element analysis technique can be applied to analyze falling object impact process and simulate the whole impact time course. The simulation results of the present study are accord well with the experimental ones. Using this method, the resist impact capability can be estimated under design stage, it provides the basis of rational design.

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structures—specifications for deflection-limiting volume.