Study on Key Parameters about Impact Collision Simulate with LS-DYNA

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Abstract: Aimed at obtaining the influence laws of parameters on the simulation results with the finite element method, this paper research on these parameters. The results show that the hourglass mode, time step and the coefficient of friction have great influence on the simulation result. Finally, the general effects of these parameters on the simulation results are obtained.

1. Introduction

As an effective method to simulate the impact collision, finite element method can reasonable simulating the whole process of impact collision. The domestic and foreign scholars have used this algorithm to simulate ship-bridge collision or car-bridge collision, and carried on the project application. Yu Min simulates a total of 108 kinds of column under the car impact which includes the different pillar type, car type, impact velocity, boundary conditions [1]. Ye Xin et al adopt symmetrical penalty function simulate the collision process between rolling stone and anti-collision objects [2]. Du Bin studies the damage form and reinforcement measures of reinforced concrete columns under impact of different vehicle models [3]. Jiang Hua uses the elastoplastic constitutive model to simulate the experiment of the reinforced concrete beam with heavy hammer impact and get good simulation results [4].

However, the calculation of impact dynamics with finite element method involves multiple parameters, whose values directly influence the rationality of the final results. Therefore, based on the LS-DYNA software, this article studies the hourglass mode, time step, contact setting, rebar-concrete coupling mode and friction coefficient, aims at the influence law of these parameters on the simulation results, and provides a basis for impact simulation parameter settings.

2. Research on basic parameter of impact collision

In this section, the experimental model is established according to the literature [5], the finite element model is shown in Figures 1-2. The materials of the concrete are simulated by MAT_CSCM, and MAT_CSCM material adopts the default settings. The circular part of the hammer in contact with concrete is simulated by the MAT_RIGID, while the other part is simulated by elastic materials. The rebar is simulated by the MAT_PLASTIC_KINEMATIC. The contact type is the ASTS. The initial static friction coefficient and friction coefficient are set to 0, soft is set to 0, time step adjustment parameter is set to 0.5, the hourglass model is set to 5 and parameter is set to 0.05. The height of the

hammer is 1.5m and the velocity at which the hammer hits the beam is 1.715m/s. In the process of parameter analysis, the basic parameters remain unchanged and the parameters to be studied are changed. The calculation cases are shown in Table 1.

Table 1. Case parameters

Hourglass model	Time step	Soft	The coupling of rebar and concrete	Friction coefficient
1	0.4	0	CBIS	0
2	0.5	1	CLIS	0.1
3	0.6	-	-	0.2
4	0.7	-	-	0.3
5	0.8	-	-	0.4

Figure 1. Finite element model of rebar.

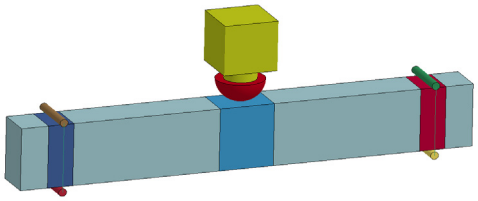

Figure 2. The finite element model.

2.1The influence of hourglass model

The hourglass model is one of the common problems in finite element analysis, which mainly occurs in the stress/displacement field analysis of linear reduction integral element. According to the calculation results, the time history of impact force, mid-displacement of beam span and hourglass energy/total energy are extracted. The results are shown in Figures 3-5.

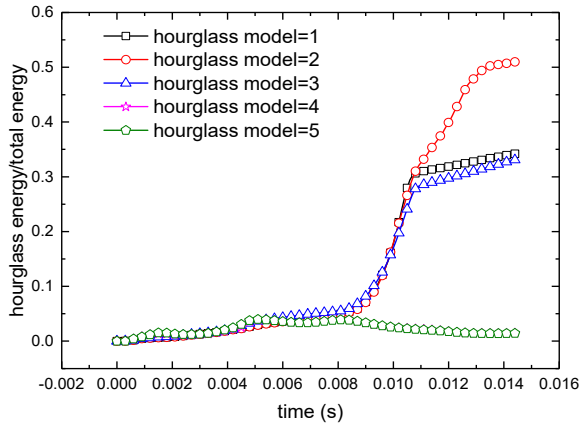

Figure 3. Hourglass energy/total energy vary with time.

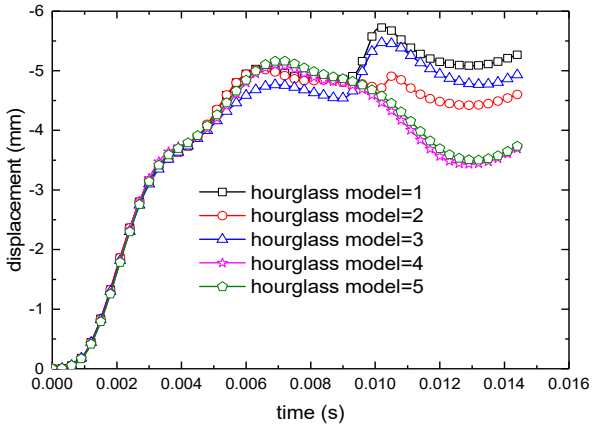

Figure 4. Displacement vary with time.

As can be seen from Figures 3-4, when the No. 4 and No. 5 hourglass energy mode is adopted, the calculation results of hourglass energy are stable and convergent, and the calculated results are basically consistent. In 0.009s, other mode of hourglass energy proliferating, subsequent calculation result is not credible, the displacement increases with the reducing of impact force, which does not conform to the objective facts. As can be seen from Figure 5, under the control of 5 kinds of hourglass mode, the maximum impact force is located around 0.0045s, whose value is between 160 kN and 180 kN, error is between 0% and 12.5% based on 160 kN, and impact duration time about 0.012s. Therefore, it is recommended to use the hourglass model 4 or 5 in LS-DYNA for calculation.

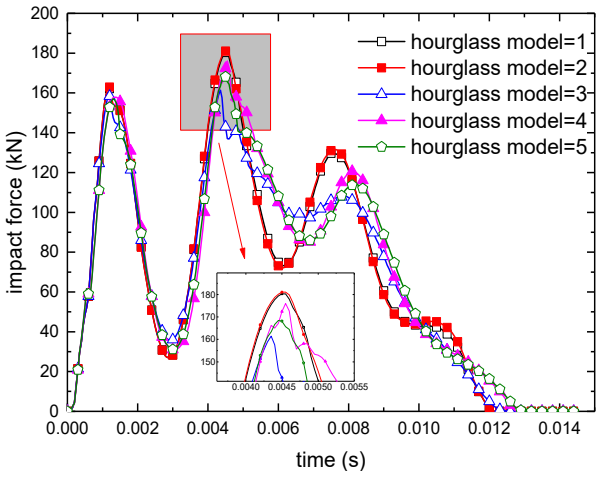

Figure 5. Impact force vary with time.

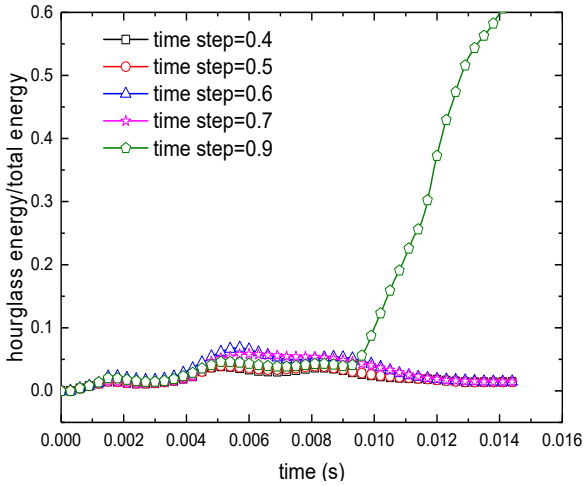

Figure 6. Hourglass energy/total vary with time.

2.2The influence of time step

The explicit analysis has a high demand for time step. Long time step will affect the accuracy of the calculation results, and short time step will lead to high computational time costs, although the calculation result is more reasonable. The impact duration, mid-beam displacement duration and hourglass energy/total energy duration history are shown in Figures 6-8.

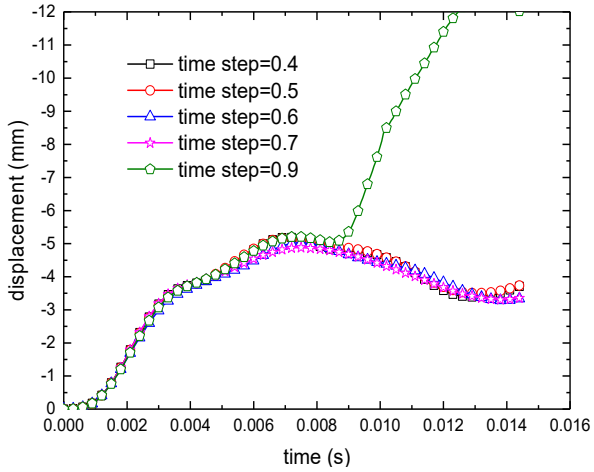

Figure 7. Displacement vary with time.

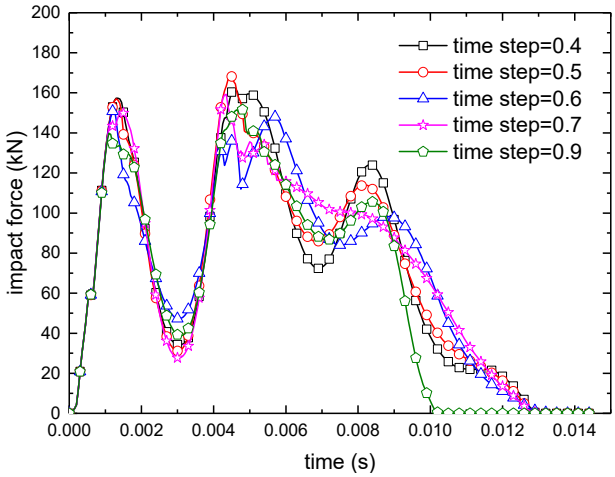

Figure 8. Impact force vary with time.

As can be seen from Figures 6-8, in addition to the time step of 0.9, other time step parameters are convergent, the hourglass energy is controlled within 0.1, and the maximal displacement is between 0.00503 m and 0.00488 m, with a maximum error is 3%. The peak impact force is between 151kN and 168kN, with a maximum error of 11.2%. According to the LS-DYNA software instructions, the default time step is 0.9, but the result does not converge at this time step, so the time step needs to be adjusted. On the basis of calculation results in this section, the time step can be set to 0.5, so as to balance the calculation time and precision.

2.3The influence of contact Settings

The soft parameters are directly related to the calculation of contact stiffness in contact collision analysis. The parameters of two commonly used settings is 0 and 1 in LS-DYNA, and the impact force and mid-beam displacement are extracted. The results are shown in Figures 9-10.

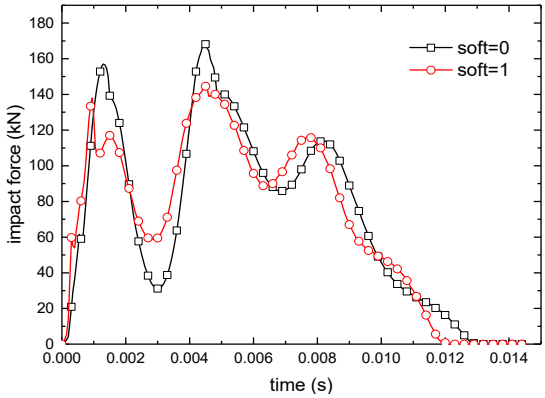

Figure 9. Impact force vary with time.

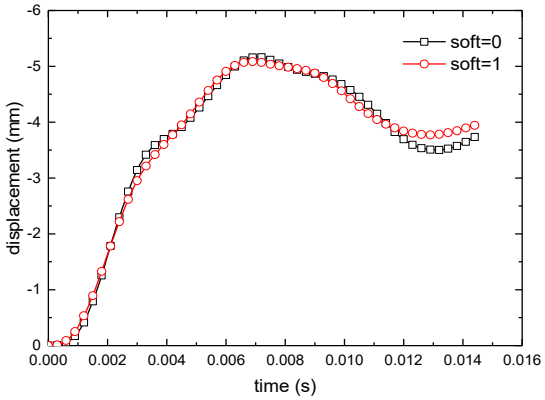

Figure 10. Displacement vary with time.

As can be seen from the figure 9, when soft is set to 1, the maximum impact force is obviously small and the maximum impact force is 144kN. When soft is set to 0, the maximum impact force is 168kN and the duration of impact force is agreement basically. The mid-beam displacement is the same but the end of the impact process.

2.4The Influence of rebar-concrete coupling mode

The concrete and rebar work together in stress process of reinforced concrete. The connect method of two materials determines the accuracy of the simulation result. In this section, the fluid-solid coupling method is compared with rebar-concrete coupling method, and the impact force, mid-beam displacement, the curves of the axial stress of steel are extracted. The results are shown in Figures 11-13.

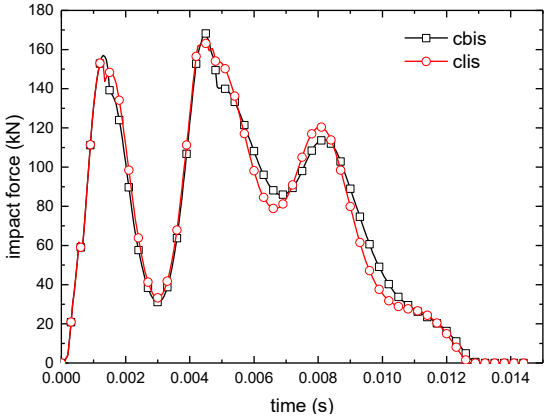

Figure 11. Impact force vary with time.

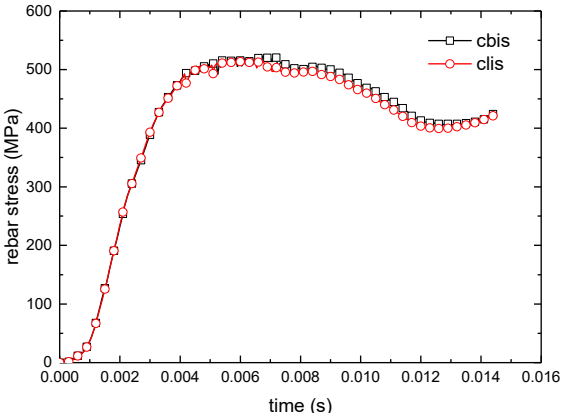

Figure 12. Rebar stress vary with time.

As you can see by the Figures 11-13, the maximum impact force of ship is good agreement, and the difference between rebar stress and mid-span displacement is about 2%, which shows that results of two methods of simulation is almost the same. However, from the point of parameter setting and using convenience, CBIS method has more advantage. It is suggested to use CBIS simulate the connection of rebar and concrete.

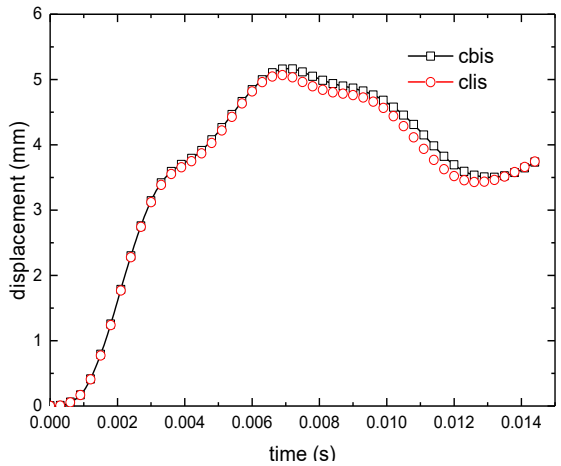

Figure 13. Displacement vary with time.

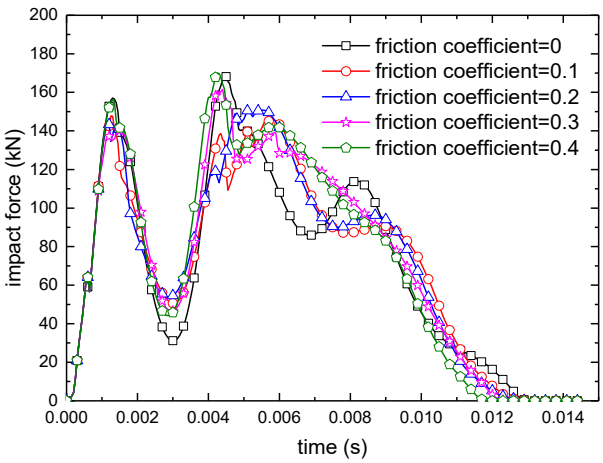

Figure 14. Impact force vary with time.

2.5The influence of friction coefficient

Friction coefficient affects the energy consumption of impact process. So far, there has not been any discussion on the friction coefficient. In this section, the friction coefficient is studied, and the dynamic and static friction coefficients are calculated with 0, 0.1, 0.2, 0.3 and 0.4 respectively. The results are shown in Figures 14-15.

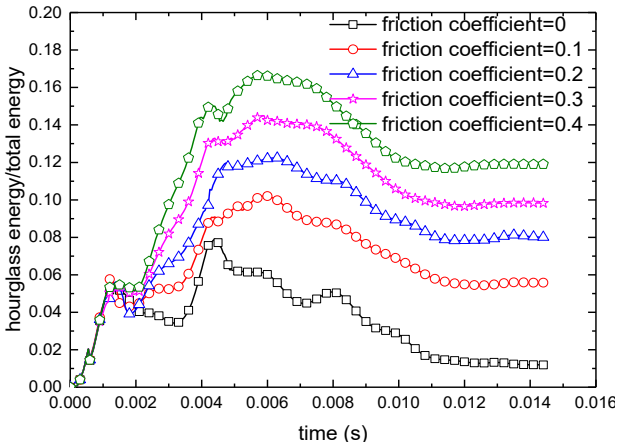

Figure 15. Slide /total energy vary with time.

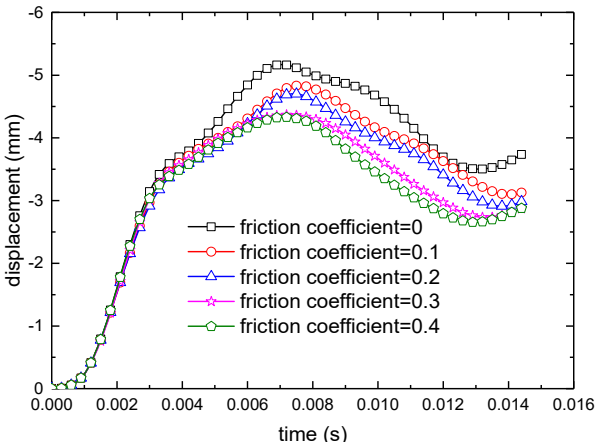

Figure 16. Displacement vary with time.

As you can see by the figures 15-16, both displacement and slip energy are greatly affected by friction coefficient. With the increase of friction coefficient, beam displacement gradually decreases, and slip energy increases, which is consistent with theory. The ratio of the gravitational potential energy of the drop hammer to the kinetic energy of the beam decreases, so the beam displacement decreases. The maximum impact force has no obvious rule with the change of friction coefficient, and the duration of impact force is basically the same. The value of friction coefficient should be determined by experiments, otherwise the influence on the final simulation result will be greater.

3. Conclusions

In this paper, with help of LS-DYNA software, the finite element model of the hammer hit the beam is built and the key parameters are analyzed, getting the following conclusion:

(1) For impact collision simulation, it is advisable to use the hourglass model 4 or 5 in LS-DYNA. The default time step of LS-DYNA is 0.9, which may lead to non-convergence of hourglass energy. To achieve the balance of calculation time and precision, the time step can be set to 0.5.

(2) The different value of soft in contact setting will lead to the different analysis results. It is

recommended to adopt the CBIS method of coupling between rebar and concrete.

(3) Both the displacement and slip energy are greatly affected by the friction coefficient. The value of friction coefficient should be determined by experiments, otherwise there will be a greater influence on the final simulation result.

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