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Modeling and simulation analysis of pole side impact crash test sled

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Abstract: *For the analysis of car crash worthiness of the sled test, according to crash simulation theory， the finite element model of sled test impact with the energy absorption tube is set up based on the LS-DYNA solver. Simulated analysis is made on the process of sled test impact. verifying the strength of the simulation model, in order to meet the requirements of the test. By analyzing the strength of the sled test, we know the structure needs to optimized.*
Key words: *sled test; numerical simulation, optimize*

I. Introduction

Side pole impact refers to an accident form of collision between the side of the roadside of the vehicle and the roadside cylindrical objects(such as trees, utility poles, etc.).In China, though the proportion of side pole impact is not great, the consequences are often serious. So it is necessary to enhance the research of such accidents and make new safety standards research related to side pole impact. The U.S. Department of Transportation (DOT) has proposed a major regulatory revision of Federal Motor Vehicle Safety Standard (FMVSS) 214 concerning passenger impact protection . The present standard does not address side crashes into fixed narrow objects, which as indicated earlier account for approximately 20 percent of deaths and serious injuries that occur in side impacts. The current standard also does not address head injuries, which account for 43 percent of the total deaths and serious injuries. According to NHTSA the revision would require that all new passenger vehicles, trucks, and buses sold in the United States provide substantial head protection in side crashes [paper]. In NHTSA opinion, the new pole test will more accurately reflect the real world side impact collisions in which head injuries are more prevalent. Other dangerous side-impact crashes often happen when a large vehicle strikes a smaller one at an intersection. So it's necessary to design a sled test of pole side impact.

The article according to the requirement of pole side impact design a sled test. Simulated analysis was made on the sled test, and verifying the strength of the sled test in order to meet the requirements of the test. The sled design principle and analysis method can provide reference for the design of the similar sled.

Proposed Side Impact pole test under the FMVSS 214 regulation

Designing automobiles with improved protection to vehicle occupants in side impact collisions has become an important area of concern in safety research. One of which is the side impact crashes into fixed narrow obstacles like trees, utility poles, supports etc.

In the 214 regulation, MDB does not demonstrate the worst-case scenario since there is too much sill loading and pillar loading. The newly proposed test by NHTSA is more favorable since the area subjected to impact is much more narrow when compared to the MDB tests. Therefore, greater crash energy is concentrated on the driver's side and transmitted onto the occupant.

In this test procedure the vehicle is propelled sideways at an approach angle of 75 degrees with a speed of 20 mph into a fixed rigid pole. As the pole is relatively narrow, there is major penetration into the side of the car thereby affecting the occupant severely on the driver's seat.

In this test, the pole is set to align with the occupant or the driver's head, so that the worst case scenario can be obtained where the occupant's body strikes the inner door and the driver's head strikes the pole.

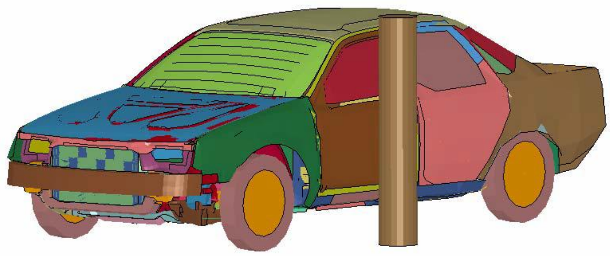

Figure 1 Proposed Side Impact Pole Test

II. Impact theory

The finite element analysis is the main approach for the analysis of structural strength. To clear the basic principal of different impact algorithms, strain energy is defined from Eq. meaning the potentially Absorbed energy corresponding to the work done accumulated in a material when is deformed. The integration is on the volume of each element based on the applied force, created elongation and stress distribution. Through light weight scopes, specific energy absorption parameter, SEA, is considered to consider the capability of a material to absorb the energy having less weight and achieving improved crash behavior or equal to the current structure from Eq.

$$U_e = \frac{1}{2}\int_v \sigma \times \varepsilon \times dv = \frac{1}{2} K_{eq} . \delta^2{}_{\max}$$

$$SAE = U_e / Mass$$

Where σ , ε and v equal to stress tensor; strain tensor and element volume respectively. K_{eq} , an inherent characteristic of a material, is the stiffness of the body relating deflections(δ) and the result ant forces. In an event of a collision, it is quite important to discriminate two types of impacts. In the perfectly elastic collision, the masses could have different velocities after impact and an insignificant amount of energy is transferred among them. However, objects could receive the same velocity after striking together.

Automobile accidents include plastic deformations depending on the severity of the crash forces as this study implies for impacting of a rigid sled test impact to the energy absorption tube structure in low-speed conditions. On the other hand, vehicle manufacturers have always struggled to strengthen the automotive components to prevent failure happening and plastic deflections. Having dynamic kind of the problem causes form stress distribution along the contact area of the energy absorption tube and the sled test to be expected which is in interest of analyzing in this study.

The foundation of energy conservation in an inelastic impact conditions implies that the masses must have the same converted kinetic energy from the initiation of the movement up to the maximum deflection point and before the separation point.

$$\frac{1}{2} m_p v_p = \frac{v^2}{2}(m_p + m_d) + \frac{1}{2} K_{eq} . \delta^2{}_{\max}$$

Where m_p is the mass of the sled test, m_d is the mass of the energy absorption tube; v_p is the velocity of the sled test before the crash and is the final same velocity of the two masses after the impact. In this study, the initial velocity of the sled test is supposed to be zero. The impulse-moment um change theorem infers that the amount of moment um remains constant before and after collision express das follows:

$$m_p v_p = (m_p + m_d) v$$

The equation of kinetic energy and momentum conservation after the separation point could be specified as bellows:

$$\frac{1}{2} m_p v_p{}^2 = \frac{1}{2} m_p v'_p{}^2 + \frac{1}{2} m_d v'_d{}^2$$

$$m_p v_p = m_p v'_p + m_d v'_d$$

Where v'_p and v'_d are the final velocities of the sled test and the energy absorption tube from the initiation status up to the separation point. Another deterministic criterion in striking masses is the coefficient of restitution abbreviated by COR which is the ratio of the speed differences after and before striking.

$$COR = \frac{v'_p - v'_d}{v_p - v_d}$$

Since in a crash event, the masses of the contactors cannot be changed while the object's velocities are varying quickly, the factor COR is a useful parameter to check the converted energy and the generated deformation. The COR value of 1.0 represents elastic collisions while the value of zero is for perfectly plastic impacts explaining that the high amount of energy is converted to heat and deflections. It is necessary to mention that for the plastic impact of this study, the actual COR value is localized some where between this interval. The plastic strain energy relating directly to the permanent damage of the door plate is obtained by deducting the kinetic energy of the door and the sled test before and after collision.

III. Finite element analysis

The strength of the sled test has a great influence of the sled test, in order to keep the safety and reliably of the sled test. So it's necessary to analysis the strength and stiffness of the sled test by the finite element analysis. Compare to the conventional analytic method Analysis results is more accurate and reliable.

The finite element analysis was used on the sled test. The first is to establish a finite element model of car and energy absorption tube, Through analysis of the material properties of vehicle structure, unit selection and geometric partitioning of geometry modeling, set up the model of the sled test, Through the structure relationship of each model have built a complete system model, define the system model of contact condition, such as solving arithmetic, and putout the final. To verify the sled test structure, the simulation the sled test crash the energy absorption tube at the speed of 30 km/h. Figure 2 is the finite element model.

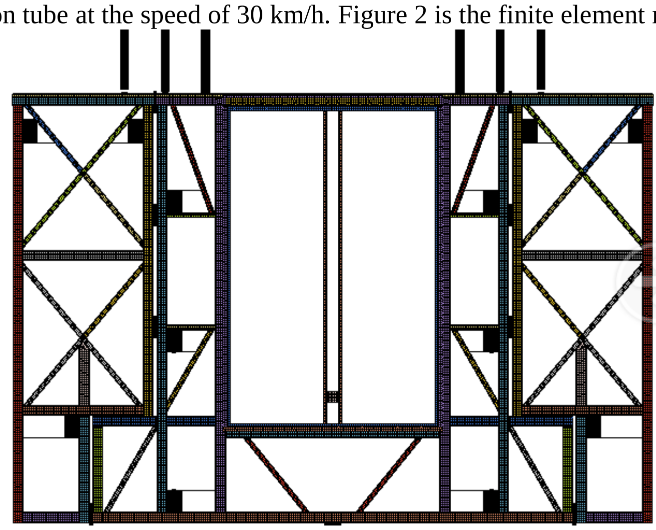

Figure 2 the finite element model

the sled test crash the energy absorption tube at the speed of 30 km/h. The stress strain diagram as shown in figure 3.

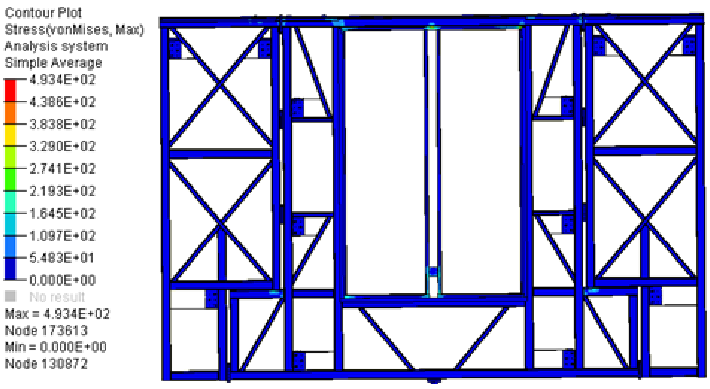

Figure 3 The stress strain diagram

From the figure 3 we can know that the place which used lay up the glass has stress yield, the highest stress value is 493.4 M pa, the yield stress value of the steel tube which we select is 350 M pa, so the place of this has yield stress, we need to strength this place, the place which used to lay up the glass was increased two oblique support. And use the same way to analysis. The stress strain diagram as shown in figure 4.

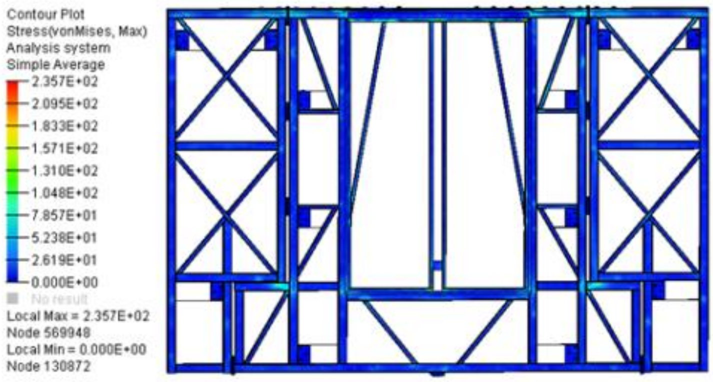

Figure 4 The stress strain diagram after add two oblique support

From the figure 4 we can know that the highest stress value is 234.7 M pa, which is below the steel yield stress. So add two oblique support can improve the strength of the sled test and meet the requirements of the test.

IV. Conclusion

The article use infinite element analysis software built crash finite element model of the sled test and use the model to calculate, the calculation results are post-processing analysis, in order to evaluate the strength of the sled test. From the evaluate we can know that the place which used lay up the glass has stress yield. Improve the structure and than analysis, so that the sled test can meet the requirements of the test.

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