ANSYS-Based Accident Reconstruction on an Overhead Traveling Crane

JIN Guang-zhen
OUYANG Yun-hua
Wuhan University of Science and Technology, Wuhan, Hubei, 430081, China

Abstract

This paper introduces accident reconstruction technology and uses it to reconstruct an accident happened on a 4 beam 125/30t×16.5m overhead traveling crane. In the accident, two auxiliary beams were crashed by the hook beam and were seriously distorted. However, the damage about the main beams is unclear. In order to analyze the cause of the accident, the models of the main beams, the auxiliary beams, the hook beam, the vehicle and the steel water ladle are built using ANSYS platform. It makes the accident reconstruction more real and clear. Nonlinear Calculation and APDL are used in this paper. When the calculating deformation value of the auxiliary beams is close to the actual deformation value, The rough loading value which the auxiliary beams bore during the accident is acquired. At the same time the distribution of the stress on main beams, auxiliary beams and other frames are also acquired. These data may aid in repairing the crane.

Accident Reconstruction Technology (ART)

Accident reconstruction technology [1] is an important application of computer simulation. It uses the computing and displaying function of computers to aid technicians in examining working field, parameter computing and cause analysis of accidents in rapid and efficient way. It can be used to investigate the causes leading to the accidents and furthermore provide appropriate methods and strategies by which accidents can be avoided and damages can be reduced. Accident reconstruction could be carried out after the accidents. It can reconstruct the whole process of the accident by creating the kinematical and dynamic models that can be used to analyze the causes based on the final conditions of the damaged mechanical equipments. It can also assume varied situations in which accidents may happen, and then simulate the corresponding results and analyze the critical causes, or estimate the degree of the accident damages before the accidents. The later is known as Virtual Accident.

The general process of Accident Reconstruction (AR) has three steps. The first is Pre-processing, the second is object Analyzing, the last is Post-processing. In the Pre-processing, the spot draft about the accident needs to be drawn, corresponding parameters are input into computers and the accident models are created. In the object Analyzing, the mechanical behavior of the models is computed and analyzed. In Post-processing, the whole process of the accidents can be simulated with animated 3D graphics, and the final analyzing results can be concluded. Today several commercial softwares have been used in AR in different fields. Some of them are used in special field such as SMAC and CRASH that are developed in U.S.A. Using them, the period of development is very long and the cost is high. General FEM (Finite Element Method) software is also a good choice and can be well used in AR for mechanical facilities. This paper introduces the AR's application in an overhead traveling crane based on ANSYS.

Brief introduction of the accident

An accident happened on the 125/30t×16.5m Metallurgical Overhead Traveling Crane in a Chinese Steel-Making Plant. The auxiliary beams of the bridge were crashed seriously. The mechanical part of the crane is made up of a bridge frame, a primary vehicle, a secondary vehicle, a Dragon Gate hook and a steel water ladle. During the process of carrying steel water, the main hook of the crane should have descended with the ladle, but because of the failure of some electricity equipments, the hook with the ladle rose up quickly to the contrary side. And the driver didn't notice and stop it in time, so the crossbeam in Dragon Gate hook hit heavily into the lower cover boards of the auxiliary beams. The middle parts of the auxiliary beams bent up seriously, and the lower cover boards sank inward to the hollow and the ventral boards were crooked (see the figure 1). The ventral boards of the end beams were also damaged to some extent. The deformation of the main beams is unknown. This paper introduced the crane's accident reconstruction using the general FEM software ANSYS.

Figure 1. A photo of the auxiliary beam with the deformation

Molding

The FEM model used for Crane AR is more complicated than that used for pure FEM calculating. Some mechanical parts of the crane that do not bear forces and some that bear forces but can be omitted in the mechanics calculation, all need to be modeled in AR. The whole machine should include two kinds of models: calculating model and animating model. For small equipments, these two kinds of models can be built together, and those that are not involved in calculation may not to be divided into FEM mesh. In this paper the models are built respectively. Figure 2 shows the whole model (the secondary vehicle is not built).

The bridge of the crane was made up of two main beams, two auxiliary beams and two end beams, which forms a closing frame. The main beam is a quasi-truss beam whose assistant ventral boards are empty in its middle parts, while the auxiliary beams are box beams whose trams are departing to the beam center. Main beams are outside, auxiliary beams are inside and end beams are cave-formed. The bridge's calculating model and FEM mesh are shown in figure 3.

Restriction and load

Restriction

Firstly, coordinate system should be established: the X axes is along the main beam length direction; the Y axes is along the end beam length direction; the Z axes is along the plumb direction. The bridge frame is supported on four hinged shafts of the equilibrium trolleys. So the restrictions are imposed to the inside cylinders of the hinged holes. Four degrees were restricted: three transfer degrees along X, Y, Z, and a rotational degree round Z.

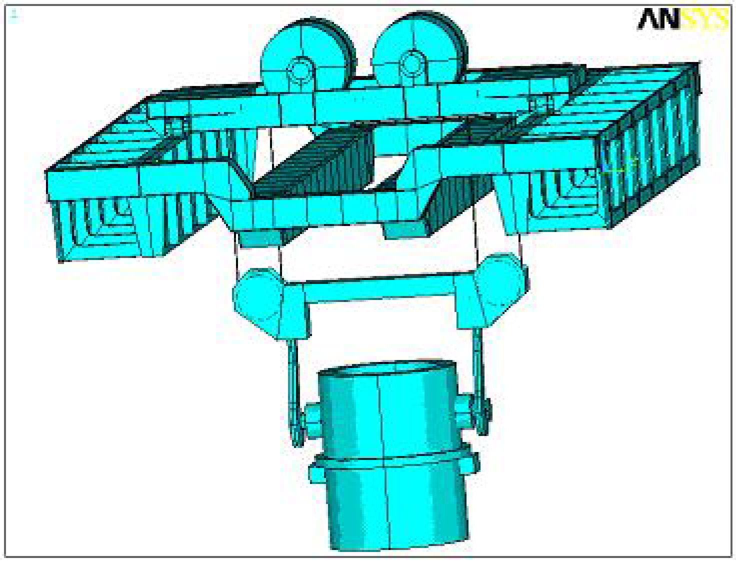

Figure 2. The whole model of the crane with the steel water ladle

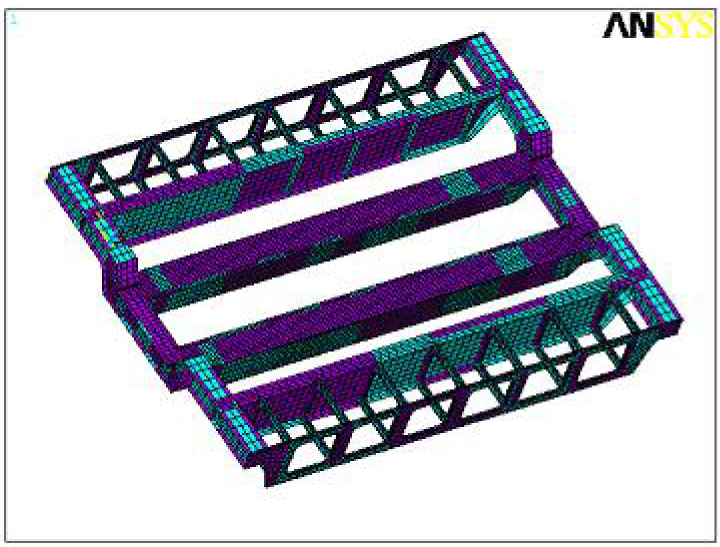

Figure 3. FEM calculating models of the bridge

Loading

Accident loads of auxiliary beams

The middle parts of the auxiliary beams were hit with the hook crossbeam. But the precise value of the force is unknown. It can be calculated by means of the boundary condition of the displacement – the maximal displacement of the auxiliary beams. In detail, firstly the smaller loads are applied to the structure, secondly it is calculated and the deformation of the just place on the auxiliary beams with the just force is obtained. If this displacement did not reach the required value, larger loads should be applied and it is calculated again. When the calculating value of the displacement is almost equal to the practical displacement of the auxiliary beams, that certain loads are the accident loads p.

This is a nonlinear problem. Its ε-σ curve [2] is shown in figure 4.There are two load steps for nonlinear. The first one is accident load which larger then P. The second is 0 so as to eliminate elastic strain (figure 5).

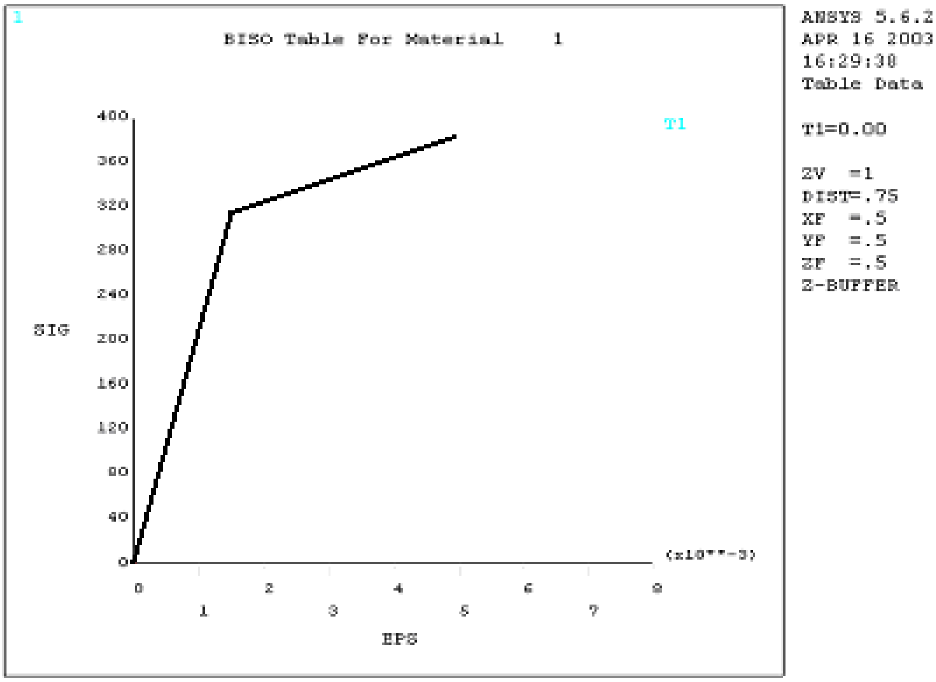

Figure 4. ε-σ curve

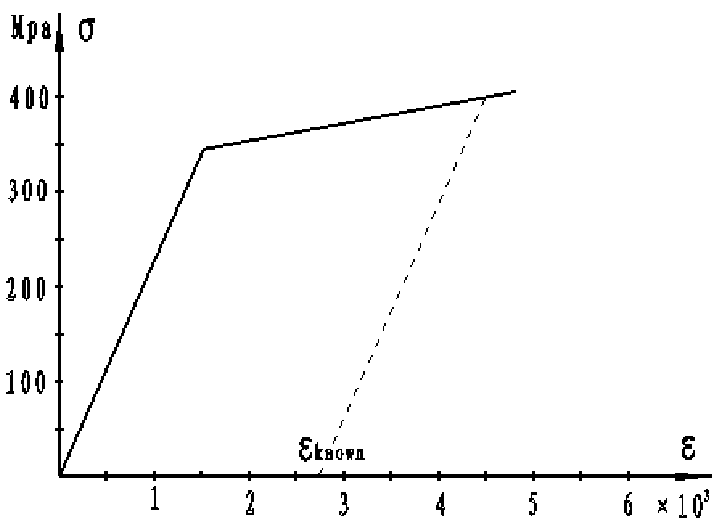

Figure 5. Eliminating elastic strain

Accident loads of the main beams

When the hook crossbeam brings some forces to the auxiliary beams, the main beams receive equal loads in the contrary direction. The loads are transferred through the primary vehicle. The function points are the contacting point between the main beams and the four wheels of primary vehicle.

In addition, the main beams still bear their gravity, so do the auxiliary beams. The weights of primary and secondary vehicles, electricity equipments and carrying load are also imposed upon 4 beams respectively.

These fixed loads are imposed once and no longer change while the accident loads are changeable and they were imposed through the APDL programs [3].

The process of the Crane Accident Reconstruction (CAR)

The process of the CAR is divided into three steps:

1. Analysis of the bridge frame through ANSYS;
2. Animation of the bridge deformations; and
3. Displaying animation of the whole machine using Flash 5.

Because plastic deformations occurred in the accident, it is a nonlinear problem and a nonlinear solution is needed in this paper.

The analyzing results through ANSYS show that when each auxiliary beam received accident load P=2200 kN, the deformation is similar to the actual deformation with an error no more than 5%. Accordingly the strains and displacements of the bridge are regarded as actual value. Figure 6 shows the deformation graph of the bridge. By comparison of Figure 6 with Figure 1, the appearance of the auxiliary beam from ANSYS is just like the actual one. Figure 7 shows the final state of the animation of the Crane Accident Reconstruction (appearance after accident).

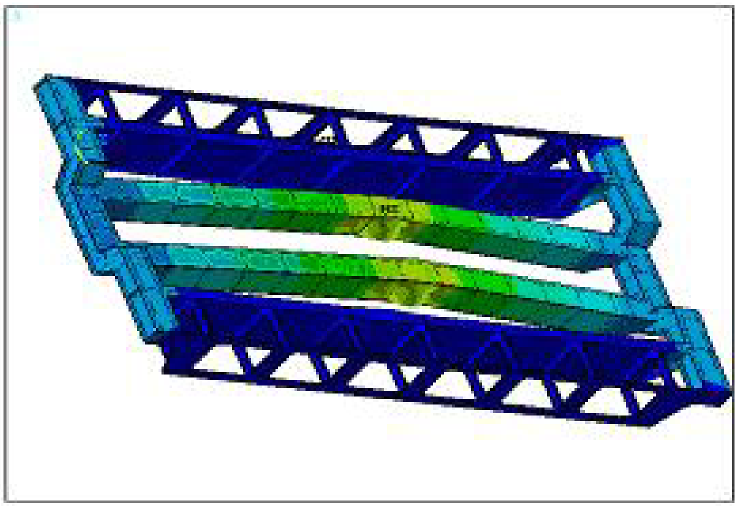

Figure 6. The deformation graphic of the bridge

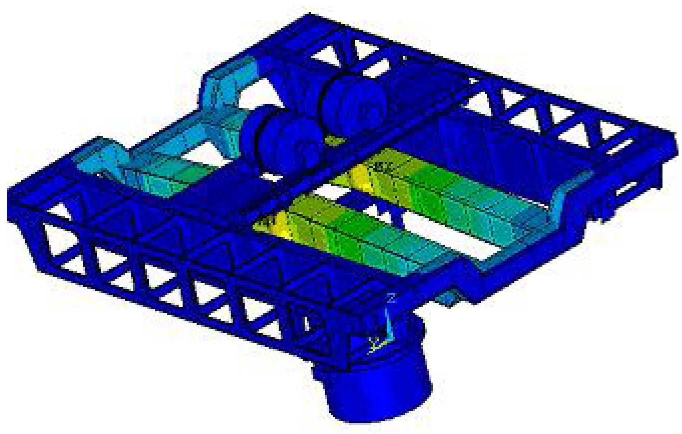

Figure 7. The final state for animation of the Crane Accident Reconstruction

The results of the Crane Accident Reconstruction and treatment plans

The material of the bridge is 16Mn, σ_b=500 MPa, σ_s=345 MPa.

Since $\sigma_s/ \sigma_b=0.69<0.7$, its safety factor should be : $n_{II}=1.33$. The allowable stress is: $[\sigma]_{II} = \sigma_s/1.33=259.4$ Mpa.

The maximum calculating stress in main beams is σ_{max} =319.297 Mpa, which exceeds the material's allowable stress $[\sigma]_{II}$, but is less than the material's yield stress σ_s. By examining and none-damaged exploring carefully, the plastic deformation and crack were not found in the main beams. The calculation results and the testing result fit well. It proves that the main beams are not damaged seriously.

It is suggested that it is unnecessary to make any disposal of the main beams. After replacing the auxiliary beams and repairing the end beams, the crane can continually be used. Thus a lot of expenses can be saved.

Conclusion

ANSYS can be used in the accident reconstruction of machinery equipment. It can aid in studying the occurrence mode and results of the accidents, which can be used to take prevention measures. The AR can also provide a vivid visual effect of accidents and warn workers of the danger and the harm from accidents.

1. The process of the CAR includes modeling, calculating and animating, etc. There are two kinds of models: computing model and animating model. Flash 5 can be used in the animation of CAR. Of course some animating pictures produced from ANSYS are necessary.
2. The repairing plan for the whole Crane can be made based on the results of the CAR. It saves funds and guarantees safety.
3. The methodology can be extended to other situations, for example another Crane, other metallurgical equipments, and so on.
4. For future AR simulations about a springback analysis, it would be better that automotive AR and metal forming is done in ANSYS. Here is a brief description of how that would be done:
    - Using ANSYS/LS-Dyna, place the hook crossbeam close to the auxiliary beams. Apply an initial velocity to the crossbeam (Ansys EDVEL command). Run the impact simulation. Note: Placing the crossbeam close eliminates unnecessary iterations through space.
    - Switch to implicit element types and impact the initial stresses from the impact with the ISTRESS command.
    - Solve again and compare to actual deformations.

Thanks to reviewers for their timely help.

References

[1] Li Yi-bin etc, The Research of road traffic accident reconstruction imitate analyzing system, Automotive Engineering, 2001(vol.23). NO4 (China)

[2] YANG Yun-hua, JIN Guang-zhen, 3DEFA Analysis of Metallurgy Crane, Journal of Hubei Polytechnic University, Vol.18 No.2 Apr.2003 (China)

[3] Liu Tao etc, Conversant with ANSYS, Beijing: Tsinghua University publishing company, 2002.9.