Dynamic Simulation Analysis of Key Components of Special Transport Vehicle for Blowout Prevention Equipment Based on ADAMS

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Abstract. The mounted structure is a part of the whole vehicle, and determines the rationality of the vehicle design. First of all, through the ADAMS and CATIA data transmission interface, the use of CATIA to create a special model of the blowout prevention equipment, the model is imported into ADAMS; Secondly, ADAMS related settings in the definition of force, boundary conditions, and calculate the time step and other related parameters. Finally, the simulation results of the flipping mechanism are obtained by dynamic simulation analysis. The results show that the design of the truck loading structure meets the actual performance requirements.

1. Introduction

In general, the equipment used for the transport of the jetting equipment is very large in size and weight, usually around 25t[1], and the loading structure as the carrying base of the carrier, the full force exerted by the upper equipment and Moments are acting on it. At the same time, due to the rugged road of the transport vehicle, and the operating conditions and road conditions are more complex, carrying equipment volume and quality is large, and the loading structure is complex, through its dynamic correlation analysis, can fully understand the movement characteristics of the loading structure, In order to avoid defects in the design process, in which case the frame itself must have sufficient bending rigidity and strength to ensure that the relative position between the load-bearing upper assembly is kept constant during operation and minimized Small body of the deformation; and sufficient strength is to ensure the reliability of the frame and the premise of life[2]. Spraying workover equipment for the use of special transport vehicles used in the chassis and its sub-frame shown in Figure 1, the test deformation and fracture of the situation shown in Figure 2.

Figure 1 Two types of chassis and subframe
Figure 2 Subframe deformation and fracture diagram
The loading structure is a key component of the jet repair work over vehicle, so it needs to carry on the dynamic simulation analysis

2. Overview of Virtual Prototyping Technology
Virtual prototyping technology is to solve the shortcomings of traditional product design process, the use of computer technology developed from high-tech. Traditional product design and manufacturing process, the general process is the concept of design, product design, prototype experiments, product improvement [3-5]. In the prototype experiment process, need to spend a lot of manpower and material resources, increase the cost of product design, extend the design cycle, the traditional design means cannot meet the needs of market competition. Through the analysis of different mechanical systems can get the optimal performance of the work, but also can reduce the complex mechanical system production costs, the number of tests, research and development cycle, improve the mechanical system design quality and R & D efficiency [6].

3. Dynamic Simulation and Analysis Process of Special Transport Vehicle for Blowout Prevention Equipment
The process of dynamic simulation analysis of special transport vehicle with ADAMS software is mainly divided into four steps. The analysis flow is shown in Figure. 3

- The simplified model is imported into ADAMS using SD
- Check the truck model
- Apply movement and exercise constraints, apply the load
- Set the lifting mechanism and the relevant supporting device constraint parameters
- Set the measurement items and output contents, and set the time and precision for the solution
- Through the parameter settings to achieve the actual conditions and simulation of the transition
- Simulation analysis, output analysis results, drawing simulation curve
- Output the simulation results in graphs, curves, and so on

**Figure 3** Analysis of dynamic simulation of special vehicle

3.1 The Basic Theory of Dynamics Analysis
When solving the dynamic problem of the lifting mechanism of the special transport vehicle, it is possible to simplify the motion analysis of the mechanical system if the coordinate system can be set reasonably. In the process of mechanical system motion analysis, three coordinate systems are commonly used: ground coordinate system, local component reference coordinate system, frame coordinate system. The speed of solving the dynamic equation depends largely on the choice of generalized coordinates. Through the study of the motion of the rigid body in the inertial space, this paper adopts the Euler parameter as the generalized coordinate of rotation, and its variables are not too many, Euler angle when there is no singularity.
The generalized coordinates used in Admas are determined by the Cartesian coordinate system of the component center and the Euler angle of the component position, \( \mathbf{q} = [x, y, z, \psi, \theta, \phi]^T \), set \( \mathbf{R} = [x, y, z]^T \), \( \gamma = [\psi, \theta, \phi]^T \), \( \mathbf{q} = [R^T, \gamma^T]^T \). The coordinate transformation matrix between the component centroid reference coordinate system and the ground coordinate system is:[7]:

\[
A = \begin{bmatrix}
\cos \psi \cos \phi & -\cos \psi \sin \phi & \sin \psi & 0 \\
\sin \psi \cos \phi & \cos \psi \sin \phi & -\sin \psi & 0 \\
\sin \phi & \cos \phi & 0 & 0 \\
\end{bmatrix}
\]

The above three Euler shafts as a unit vector can be used to establish a new coordinate system - Euler axis coordinate system. The coordinate transformation relationship between the Euler axis coordinate system and the component centroid Cartesian coordinate system is given by the following matrix:

\[
B = \begin{bmatrix}
\sin \theta \sin \phi & 0 & \cos \theta \\
\sin \theta \cos \phi & 0 & -\sin \theta \\
\cos \theta & 1 & 0 \\
\end{bmatrix}
\]

The angular velocity of the component movement is expressed as:

\[
\omega = B \dot{\gamma}
\]

When using Admas for kinetic analysis, the component of the angular velocity in the Euler axis coordinate system is set to:

\[
\omega_c = \dot{\gamma}
\]

Combined with the constraint equation, the following expression is deduced by the energy form of Lagrange first type equation:

\[
\frac{d}{dt} \left( \frac{\partial \mathbf{T}}{\partial \dot{\mathbf{q}_i}} \right) - \frac{\partial \mathbf{T}}{\partial \mathbf{q}_i} = \dot{\mathbf{Q}}_i + \sum_{j=1}^{n} \lambda_j \frac{\partial \phi}{\partial \mathbf{q}_j}
\]

In the above formula: \( \mathbf{T} \) - the kinetic energy of the system’s generalized coordinates; \( \mathbf{q}_j \) - generalized coordinates; \( \dot{\mathbf{Q}}_j \) - \( \mathbf{q}_j \) direction broadness; \( \sum_{j=1}^{n} \lambda_j \frac{\partial \phi}{\partial \mathbf{q}_j} \) - \( \mathbf{q}_j \) directional constraint force. By further introducing generalized momentum:

\[
P_j = \frac{\partial \mathbf{T}}{\partial \dot{\mathbf{q}_j}}
\]

The simplified expression of the reaction force is:

\[
\mathbf{C}_j = \sum_{i=1}^{n} \lambda_i \frac{\partial \phi}{\partial \mathbf{q}_j}
\]

This equation (4-5) can be simplified as:

\[
\dot{P}_j - \frac{\partial \mathbf{T}}{\partial \mathbf{q}_i} = \dot{\mathbf{Q}}_i - \mathbf{C}_j
\]

Kinetic energy can be further expressed as:

\[
\mathbf{T} = \frac{1}{2} \dot{\mathbf{R}}^T \mathbf{M} \dot{\mathbf{R}} + \frac{1}{2} \dot{\gamma}^T \mathbf{B}^T \mathbf{J} \mathbf{B} \dot{\gamma}
\]

Where \( \mathbf{M} \) is the mass of the component and \( \mathbf{J} \) is the inertia of the component in the centroid coordinate system.
3.2 Establishment of Dynamic Model for Blowout Prevention Equipment

Although ADAMS / View comes with modeling tools, but only a few relatively simple structure of the model, and for some of the complex structure, more model of the operation of the model cumbersome, longer time, greatly reducing the efficiency, ADAMS The CAD model data interface can be used to import the model data from other professional solid modeling software (CATIA, Pro/E, etc.) through the corresponding data interface to obtain the required dynamic model.

The SimDesigner for CATIA V5 products product series developed specifically for CATIA enables MSC to quickly exchange data between ADMAS and CATIA and seamlessly link 3D models drawn with CATIA V5 to ADAMS. Therefore, the three-dimensional model of the flip mechanism is presented in CATIA, which fully exploits the three-dimensional solid modeling function of CATIA and the dynamic analysis function of ADAMS [8-10]. SimDesigner Generative Products can be used to output the required cmd format for ADAMS in the CATIA model, import it into the ADAMS / View function component, and then define the relevant parameters or component attribute values, such as grid model and size, component constraints, force size and direction, component name and color, etc. The ADAMS analysis model is shown in Figure 4.

![Figure 4 ADAMS dynamics model](image)

In ADAMS, there are six relative degrees of freedom in the space, including the degree of freedom of translation (3) and the degree of freedom of rotation (3), there are seven translational degrees of freedom in the mobile subcomponent, and there are five degrees of freedom in the rotation subcomponent.

After simplification of the model, remove the screws, nuts and locating pins and other components. The rest of the dynamic part of the road model by the 218 rigid body, seven mobile vice, five rotation vice, two fixed sub-composition. There are 12 degrees of freedom in the whole flipping mechanism, 6 on the body of the special vehicle and the flipping mechanism, where the turning mechanism is the degree of freedom of rotation.

The vehicle is in the flip work is to control the lift hydraulic cylinder through the hydraulic drive to achieve, so that the turning mechanism in the set time to do a uniform rollover movement, when the flip mechanism to flip to a predetermined position (flip to 95° position) to achieve anti- The workover equipment is docked up and down with the wellhead during the set time. In addition to the corresponding mobile vice and rotating vice, the rest of the components are fixed with the auxiliary, are fixed in the special transport vehicle pre-set on the ground.

3.3 Dynamic Simulation Analysis of Blowout Prevention Equipment

When using ADAMS/View to calculate the contact force, according to the different calculation model can be divided into impact function and compensation method two. It is worth noting that the contact force calculated by the impact function method not only includes the damping force caused by the
relative motion between the members, but also the elastic force caused by the mutual cutting of the members.

The dialog box for defining the contact force in ADAMS is shown in Figure 4-3. The values and units of each parameter are shown in Table 1.

**Table 1 Contact Force Parameter Table**

| Parameter name          | unit            | Value |
|-------------------------|-----------------|-------|
| Stiffness               | newton/mm       | 200   |
| Force Exponent          | newton·sec/m    | 2.2   |
| Damping                 |                 | 10.0  |
| Penetration Depth       | mm              | 0.1   |
| Static Coefficient      |                 | 0.3   |
| Dynamic Coefficient     |                 | 0.2   |
| Stiction Transition Velocity | mm/sec    | 100   |
| Friction Transition Velocity | mm/sec      | 1000  |

The finite element model of the special transport vehicle for jetting and repairing wells is added in ADAMS, and the effect of driving force is shown in Figure 5.

First define the coordinate system, set the length of the direction of the transport vehicle for the x-axis, the front to the rear of the direction is positive, and the special transport vehicle placed on the ground perpendicular to the direction of the z axis, pointing to the sky direction is positive, y axis is also parallel to the The direction of the truck body, the acceleration of gravity $Z = -9806.65\text{mm/s}^2$, the direction of the negative direction along the z axis.

In the simulation experiment of this process, because the parts of the special transport vehicle are rigid, the contact form can be defined as the contact between the entities, and the contact force can be obtained by the Impact function, set the special vehicle and the ground were solid 1, 2, the relative slip between the two when the friction coefficient shown in Figure 6 curve, so the friction can be obtained by the Coulomb method.

![Figure 5 ADAMS simulation software to add motion pairs, constraints, driving force renderings](image1)

![Figure 6 Friction coefficient and sliding velocity curve](image2)

In the ADAMS software dynamics simulation, the four auxiliary hydraulic cylinders of the special vehicle are set to the corresponding contact constraints (Solid-Solid between the support cylinder block and the piston rod) and the friction coefficient ($\mu = 1$) The fixed cylinder and the piston rod of the truck are fixed with a downward freedom, and the start time and the starting position of the driving force function are set to zero, and the end time and the ending position are set to 10 s and 303 mm, respectively. Lifting hydraulic cylinders Cylinders and special transport vehicles Fixed lifting joints.
(contact-constrained Solid-Solid) with a certain angle of rotation, lift the hydraulic cylinder of the piston rod and the special transport vehicle rollover mechanism of the lifting support Contact-bound Solid-Solid) Rotary pair with an angle, lift cylinder block and piston rod (contact constraint Solid-Solid) with upward freedom of the movement of the vice. Set the start dialog box to set the start time and start position of the drive force function dialog box to 10s and 0mm respectively, and set the end time and the ending position to 30s and 2300mm respectively. (Contact constraint Solid-Solid) has an upward movement pair, set the movement pair dialog box, set the start time and starting position of the driving force function dialog box to 30s and 0mm respectively, and set the movement counter dialog box, Set the end time and the end position to 60s and 700mm, respectively. And then change the cylinder and the piston rod of the lift cylinder to the movement of the downward freedom, and set the additional end time and the ending position of the mobile sub dialog box to 90s and 0mm respectively. The support cylinder and the piston rod are changed upward The degree of freedom of the movement of the vice, set the mobile sub-dialog box additional end time and termination position were set to 100s and 0mm.

Through the simulation analysis of the actual working condition, the simulation curve is obtained under the condition of lifting and loading a complete operation. Figure 7, 8, 9, 10 are the curves of the lift cylinders x, y, z and the resultant moment, Figure 11, 12, 13,14 is the x, y, z direction and the resultant torque change curve of the articulated position of the hydraulic cylinder and the flip frame.

![Figure 7](image1.png)

**Figure 7** Lift the hydraulic cylinder x direction torque change map

![Figure 8](image2.png)

**Figure 8** Lift the hydraulic cylinder y direction torque change map
Figure 9 Lift the hydraulic cylinder z direction torque change map

Figure 10 Lifting of hydraulic cylinder

Figure 11 Hinge position x direction torque change map
Figure 12 Hinge position y direction torque change map

Figure 13 Hinge position z direction torque change map

Figure 14 Rotation position of the joint
From the simulation results can be seen throughout the operating cycle of the hinge and lift the hydraulic cylinder of the force changes. When the lifting mechanism is in the initial position, lift the hydraulic cylinder thrust is the largest, hinge at the force is also the largest, the maximum contact force of 352KN. When the time is 30s, that is, when the flip frame is turned to 71°, the center of gravity of the flip frame and the anti-scratch workover device will be turned to the vertical direction. The contact force between the lifting hinge and the hydraulic cylinder is the smallest, close to 0N. When the flip frame from 71° gradually increased to 95°, due to the center of gravity to move back, lift the hydraulic cylinder from the thrust into the tension, then lift the triangular block hinge A contact force and gradually increased to 258KN. 45s after the flip for the process of return, is the reverse phase of the lifting process.

4. Summary
After the establishment of the three-dimensional simulation model for the special maintenance vehicle, the ADAMS simulation software is used to limit the contact and the contact load, and finally the torque curve of the lifting cylinder and its articulated position is obtained. Through the simulation of the actual work, the analysis of the force curve of the lifting mechanism is carried out to verify the rationality of the loading structure and the stability of the special transport vehicle, thus ensuring the safety and reliability of the working process of the overturning mechanism. The actual application of the structure, design and further improve the reference provided.

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