Sensors Distribution Program in Health Monitoring of Side Forklift Steering Mechanism

Yang Jingjun¹, a, Liu Yimin², b, Huang Guojian¹, 3, 4, c, Wang Xinhua¹,d

¹Guangzhou Academy of SEI, Guangzhou, China
²School of Mechanical & Automotive Engineering of SCUT, Guangzhou, China
³School of Engineering of Sun Yat-sen University, Guangzhou, China
⁴Institute of Dongguan - Sun Yat-sen University, Dongguan, China

a1064667331@qq.com, b525351807@qq.com, cguojian.huang@gmail.com, dwangnewhua@163.com

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Abstract: In order to study the sensor distribution program in health monitoring of side forklift steering, we visited many ports and warehouses for inspection of side forklift steering safety in Huangpu district of Guangzhou, and summarized the most dangerous part of steering failure. Then we built a model of the steering mechanism which was simplified, and did motion simulation analysis. Then the dynamic simulation analysis was carried out on the ball pin. Finally, through the simulation calculation of maximum stress under various working conditions, we can determine the position of sensors stationing, and it provided with the train of thought of sensors distribution in health monitoring of side forklift steering mechanism.

Introduction

Structural health monitoring has been widely used in aviation[1], bridges[2] and roads[2] monitoring and the technology has gradually been improved. In general, there are mainly several directions that including, based on optical fiber acoustic emission health monitoring, based on structural vibration analysis structural health monitoring, based on digital graphics and image processing technologies structural health monitoring, based on structural stress and strain distribution structural health monitoring.

During the operation of the side forklift, the steering mechanism was prone to having failure. However, study on the structural health monitoring was relatively less. With low power consumption, long life cycle, flexible layout, etc, wireless sensor has gradually been widely used in on-line monitoring and detection.

Failure of Side Forklift Steering Mechanism

Through the inspection of the side forklift steering mechanism in Huangpu district of Guangzhou, we found that the ball head pin was the most typical part of steering failure. As shown in Fig.1.
While the steering wheel turning around, the ball head pin of both sides that marked on Fig.1 appeared to shake obviously. For the reason is the ball head pin wearing and tearing seriously, and fitting clearance overtop the standard. It also reflected that the load of the steering system of the side forklift was heavier, compared with other ordinary forklift.

Modelling and Simulation of Steering Mechanism

3.1 Structural Model

Simplified steering mechanism includes frame, tie rod, steering knuckle arm, steering drag link, wheels, trapezoid arms and steering wheel. First, the trapezoid arms should be positioned absolutely and followed by adding components of trapezoidal arms, tie rods, steering knuckle arm, drag link and steering wheel for assembly. Finally, the assembly drawing of the entire steering mechanism was worked out. As shown in Fig.2.

3.2 Motion Simulation

Using UG NX5.0 motion simulation module on the steering mechanism simplified kinematics simulation, this body is given METAL-Steel, material density $7.829 \times 10^{-6}$ Kg/mm³. Respectively, add “rotation pair” to the wheels and trapezoidal arms, frame and trapezoidal arms, tie rod arm and trapezoidal arms, steering knuckle arm and trapezoidal arms, steering knuckle arm and steering drag link, steering wheels and frame. Then add “sliding pair” to the steering drag link and frame. In order
to make the displacement of the steering drag link moved from the rotation angle of the steering wheel maintain constant, the steering wheel and steering drag link should be added with “gear rack pair”.

Set rotation function and add motion to the “rotation pair” of steering wheel and frame. In the “Function Manager”, create a new function and the specific function is as followed:

\[
\text{STEP}(\text{TIME},0,0,2,0) + \\
\text{STEP}(\text{TIME},2,0,4,-15) + \\
\text{STEP}(\text{TIME},6,0,8,15) + \\
\text{STEP}(\text{TIME},10,0,12,7) + \\
\text{STEP}(\text{TIME},14,0,16,-7) 
\]

Steering mechanism motion simulation process is shown in Fig.3.

![Fig.3 Motion Simulation of Steering Mechanism](image)

The simulation process of the steering mechanism includes the working condition of the steering wheel rotating both from the neutral to the extreme position and from one extreme position (right) to the other end of the extreme position (left). Therefore, it simulates the steering working conditions during the actual driving process. Ball pin is the ball hinge joint of the steering knuckle arm and tie rod and its kinematic pair is the “rotation pair” of spherical outside surface (ball pin) and inner surface (ball seat). Therefore, force simulation analysis will be performed mainly on the rotation pair of the ball pin and ball seat.

**Analysis of Simulation Results**

Importing the simulation model of the steering mechanism into “Adams” and we could get the swing angle and force curves of the left ball pin, which is shown in the Fig.4.
From the force curve in the Fig.4, we can get: ① The maximum load of the left ball pin can be up to 23.3KN, minimum of 18.8KN and average of 21.1K during the steering process; ② Stress mutation is prone to occurring in the extreme condition and the maximum value of the mutation is up to 0.746KN, occurs at a critical point of 12s when the wheel just turning from the right extreme condition to the left one; ③ The force distance of the left ball pin in the different extreme conditions is up to 4.5KN when the left steering wheel is as the outside and inside steering wheel. It is likely to cause uneven grinding and the other end worn badly.

Conclusion

1) Through the inspection of the forklifts in Huangpu District of Guangzhou, we found that the main part of the side forklift steering mechanism failure is the ball pin. The main failure modes include cracks, excessive wear and shaking.

2) Making a structural modeling of the steering mechanism to simulate the various working conditions of the side forklift steering, we found that the ball pin was prone to occurring stress mutations at the extreme position and the difference of the force between two extreme positions was up to 4.5KN, which resulted in uneven grinding.

3) Based on the calculation of modeling and simulation, 2 vibration wireless sensors and 2 torque wireless sensors would be taken on the left and right sides of the ball pin.

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