Application of HAZOP Analysis Method in Roller Coaster of Amusement Facilities

Chen Wang¹ Shukun Cao¹ Zijian Cao¹ Yong Zhang² Lin Zhao¹

¹School of mechanical Engineering, University of Jinan, Jinan, Shandong 250022
²China Special Equipment Inspection & Research Institute, Beijing 100029

*Corresponding Author: Cao Shukun(1970-), male, Email: caoshukun@126.com

Abstract: Amusement facilities as a typical representative of special equipment, its safety has always been the most important issue in the design, construction and operation of recreational facilities, by all the parties concerned. The main research content of this paper is to use the HAZOP analysis method to analyse the deviations caused by human factors in the manipulation process of the roller coaster of typical amusement facilities.

1. Introduction

Security has become one of the most important issues nowadays, especially in special equipment, a small problem can lead to extremely serious consequences, it endangering the lives of people and causing serious economic losses.

Roller coaster as a typical example of special equipment has become one of the hottest projects in amusement parks, so the safety of roller coaster has become the most important issue in the process of design, installation and operation. In the process of roller coaster operation, because most of them are operated manually, so the operation deviation caused by human factors directly affects the safety of roller coaster operation. The roller coaster human factor HAZOP Analysis, so as to eliminate or decrease the effect of summarizing the result of the deviation measure.

2. HAZOP Analysis introduction

HAZOP Analysis is widely used by many chemical production enterprises, large-scale mechanical design companies and most construction units at home and abroad, and is applied to the whole life cycle of equipment and equipment. HAZOP Analysis is an important method and means to effectively prevent all kinds of dangerous accidents, It can effectively identify all kinds of potential risks and hazards caused by deviations caused by human factors in facilities, and achieve the purpose of eliminating or mitigating the possibility and consequences of accidents by putting forward reasonable and feasible measures, which is conducive to the safe operation of facilities[1].

The basic steps of HAZOP Analysis are shown in Figure 1: The analysis team first divides it into several nodes; In the analysis, you should first select a guiding word, identify the relevant error deviation, and write out the relevant description of the deviation in detail, and judge whether the deviation of the error occurs, and whether there is any consequence that needs attention; If attention is required, analyze the cause of the deviation, including the consequences of the deviation, conduct a risk assessment, and analyze measures that can eliminate or reduce the impact of the consequences[2]. In each node, all the guiding words need to be used once, until the analysis of all nodes is completed, the entire analysis process is completed.
3. Amusement facility roller coaster analysis

3.1. Roller Coaster Introduction
The roller coaster belongs to the special equipment related to life safety and danger as stipulated in the "Special Equipment Safety Law of the People's Republic of China", because of its high-speed and high-irritation experience on the human body, it is popular among the masses. The core of the roller coaster is the wheel set components. The wheel set consists of three parts: the walking wheel, the side guide wheel and the lower guide wheel, the role of the walking wheel is to support the weight of the entire body during the roller coaster stop and smooth running; The function of the side guide wheel is to keep the body of the car in the center of the track and guide the roller coaster in the whole process of steering and turning; The function of the lower guide wheel is to prevent the vehicle from falling and deviating from the track when the roller coaster makes a quick fall and reverses the movement[3].

3.2. Operating procedures

3.2.1. Passenger process.
(1) The operator of the operation room first puts the "safety valve" switch of the pneumatic safety pressure lever on the safety seat in the "off" position, and sets the "cross lock switch" of the safety seat to "on". Then press the “Lift” button of “Pressure Bar Lift” and the safety lever will be lifted for visitors to enter.
(2) After the visitors are seated smoothly, the staff of the platform informs the operation room with
the walkie-talkie or gestures. At this point, the operator of the operating room can press the "down"
button of the "pressure bar lift" until all the safety bars are lowered to the specified position, place the
"crossbar switch" of the safety seat in the "off" position, then the station staff will check whether each
safety bar cross lock is locked into the lock, after the inspection is correct, guide each passenger to fasten
the seat belt, and then check it again to avoid missing.

(3) After the station staff has checked the correctness, the “safety valve” handle on the platform is
turned to the on position, the “seat lock” indicator is illuminated, the station is exited and the operator
of the operation room is informed.

3.2.2. Start and stop.
(1) After the operator of the operation room receives the information of the station staff, check that the
equipment start conditions are all ready, and see if the "seat locked" indicator is lit. If it is lit, observe
whether there are any objects or other personnel on the platform that affect the operation of the
equipment. If everything is ready, set the power disconnect switch to the "off" position.

(2) After the above work is completed, the operator of the operation room presses the “bell” button,
and the station bell rings to inform the station staff and the tourist equipment that the device is about to
start. Then press the “Start” and “Electric Bell” buttons at the same time, the device starts and moves
according to the specified track. During the operation of the device, the staff should always pay attention
to the running status of the device.

(3) When the equipment runs to the last braking zone, slowly drive to the designated position of the
platform to stop, the “positioning” indicator on the console lights up, and the worker sets the power
isolation switch to the “on” position, and the station power is turned on.

3.2.3. Passenger process. The platform staff assisted the tourists to open the seat belt, then set the "safety
valve" switch to the "off" position, the safety seat "cross lock switch" to the "open" position, and finally
the "pressure bar lift" switch placed in the "up" position, the pneumatic safety lever is raised. Platform
staff guides visitors to leave in an orderly manner.

4. HAZOP node division
According to the above-mentioned roller coaster operation flow analysis, the HAZOP node is divided,
which provides the basis for the subsequent HAZOP analysis[4]. Table 1 shows the divided HAZOP
analysis nodes.

| Serial number | Node type            | Serial number | Node type            |
|---------------|----------------------|---------------|----------------------|
| 1             | No-load operation    | 11            | Platform situation   |
| 2             | Horizontal Lock ON   | 12            | Ringing the bell     |
| 3             | Safety bar up        | 13            | Press start and ring |
| 4             | Passengers sit       | 14            | Boot device          |
| 5             | Safety bar down      | 15            | Observation device operation |
| 6             | Horizontal Lock OFF  | 16            | End of operation     |
| 7             | Close the seat belt  | 17            | Open the seat belt   |
8  Switch on the safety valve  18  Closing the safety valve
9  Inform the operation room  19  Check visitor status
10  Ready  20  Tourists leaving

5. HAZOP Analysis
After the above node division is completed, it is necessary to determine the application guidance words, and analyze each node one by one until all nodes are analyzed. Table 2 shows the basic meaning of the guiding words.

| Guide word | Basic meaning |
|------------|---------------|
| No         | The design intent is not implemented or the operation is not in place |
| Less       | Insufficient in quantity or time compared to the requirements of design intent |
| More       | Exceeded in quantity or time compared to the requirements of the design intent |
| As Well As | Based on the design intent, something is extra |
| Part Of    | Just satisfied the requirements of the design intent |
| Reverse    | There is a situation opposite to the design intent |
| Other Than | There is a situation other than medical treatment |

Combine the comprehensive guiding words and the deviation matrix to perform HAZOP Analysis on each node to determine the possible deviation of each node, analyze the relevant solutions for each deviation and make an analysis record table, as shown in Table 3.

| Node | Guide word         | Element          | Deviation          | possible reason | Aftermath                                      | Existing measures | Recommended measures |
|------|--------------------|------------------|--------------------|------------------|------------------------------------------------|-------------------|----------------------|
| 1    | Comprehensive      | No-load operation| No-load running deviation | Staff did not start | It is easy to cause failures during operation and increase the probability of failures. | Staff confirmed many times | Establish a reminder mechanism to establish a no-load operation reminder on the console |
|      | guiding words      |                  |                    |                  |                                                 |                   |                      |
| 3    | Comprehensive      | Safety bar up    | Safety bar up deviation | Safety bar open fault | Passengers can't be seated; increase the chance of failure during operation | The station staff confirmed several times; manually open |                      |
|      | guiding words      |                  |                    |                  |                                                 |                   |                      |
| 7    | Comprehensive      | Close the seat belt | Close the seat belt deviation | The seat belt cannot be fastened properly; the seat belt is aging | May cause visitors to be thrown out during the operation of the equipment | The staff confirmed many times; often repaired the seat belt |                      |
|      | guiding words      |                  |                    |                  |                                                 |                   |                      |
The cause of the accident analyzed by HAZOP is the direct cause of the direct deviation. For a deviation, there may be more than one cause. Therefore, the accident caused by different causes should be analyzed independently. In the process of HAZOP Analysis, only concern is caused. The direct cause of the deviation does not involve the root cause of the accident\textsuperscript{[6]}.

6. Conclusion
In this paper, the HAZOP analysis method is used to analyze one of the typical roller coasters in the amusement facilities, because the current HAZOP analysis method is widely used in the petroleum and chemical fields, and the application in the amusement facilities is very small, therefore, the paper uses the HAZOP analysis method to analyze the deviation of the roller coaster due to human factors, which will play a certain role in the promotion of the method in the future, and can be used to solve some roller coaster operations some problems that have arisen.

Acknowledgements
Thanks Professor Cao Shukun of University of Jinan for guiding thesis writing, and thanked Dr. Zhang Yong of Beijing Institute of Special Equipment Testing for his valuable comments on the revision of the paper.

Fund project:
National key R&D project "Study on the whole life cycle monitoring and integrity assessment technology of manned equipment in amusement parks and scenic spots" (2016YFF0203100), Topic 5 "Research on the Integrity Evaluation Technology of Manned Equipment and Construction of Dynamic Quality Management Platform" (2016YFF0203105)

About the author:
Wang Chen(1996-),male,Jining,Shandong Province,master’s degree, research direction: safety research on amusement facilities.

References:
[1] Zang Zhensheng. Analysis of HAZOP Analysis Method[J]. Chinese Instrumentation,2018,(6):49–53.
[2] Yang Liu. Application of HAZOP Technology in Fine Chemical Equipment[J]. Instrumentation Standardization and Measurement,2018,(6):33–35.
[3] Wu Chunjun. Three-dimensional Design and Simulation of Three-ring Roller Coaster Car Body[D].Anhui: Anhui University of Technology,2016:7–16.
[4] Wang Wei. Cold Storage Refrigeration Project HAZOP Analysis[J]. Xinjiang Nonferrous Metals,2017;40(6):79–82.
[5] Su Zhenyu. HAZOP Analysis Method and Practice[M].Beijing: Chemical Industry Press,2017:62–64.