HAZOP analysis of human factors in combine harvesters

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Abstract: In recent years, agricultural machinery accidents have remained high, and in addition to the reasons for the lack of machinery itself, human factors account for a large proportion. This paper mainly introduces some accident classification and operation specifications of harvesters, divides the operation specifications into nodes, and then uses the keywords in HAZOP analysis method to conduct guided analysis, analyzes the causes, consequences and existing protection measures of deviations. Under the condition that the existing protection measures are in normal operation, the risk level is still beyond the acceptable level, and the recommended measures are further given, which is of great significance for the further promotion of the harvester.

1. Introduction
The promotion of combine harvesters has greatly improved the efficiency of harvesting, reduced the labor force of farmers, and freed farmers from heavy farming. However, due to the large size of the harvester, the inflexibility of movement, the large blind area of vision, and improper handling of faults, the incidence of harvester accidents has remained high. Data analysis shows that many times the accident is not caused by the machine itself, but by the human factors. In order to reduce the impact of human factors on the accident, HAZOP (Hazard and Operability Study) analysis method is used to firstly divide the operation process of the combine harvester, and then use the guiding words to analyze each node separately, identify potential dangers and propose solutions, which can effectively reduce the occurrence of accidents rate.

2. Material and Methods
2.1. Introduction to HAZOP analysis method
The HAZOP analysis method is a technology developed by Imperial Chemical Industries PLC (hereinafter referred to as ICI). HAZOP analysis is a systematic and structured qualitative risk assessment tool, which is mainly used in the design stage to determine the hazards and operational problems in engineering design[1]. HAZOP is an analysis method centered on guide words. Table 1 shows the basic meanings of each guide word and each guide word to examine the safety of the design and the causal relationship of the hazard. In 1974, ICI officially released the HAZOP technology. Kletz et al. gave a detailed account of the history and methods of HAZOP development in the book[2]. The basic steps of HAZOP analysis: first select the node or operation step to be analyzed, explain the process index or operation steps of the node; then use the guiding words to establish meaningful deviation, analyze the consequences of the deviation, and list the reasons for the deviation; Estimate the risk level by identifying measures that have been avoided to avoid deviations; finally propose a
solution and repeat the above steps[3]. This paper mainly describes the specific application of HAZOP analysis in the combine harvester, and it is of great significance to the promotion of HAZOP analysis in the agricultural machinery industry.

| Guide word | Basic meaning |  |
|------------|---------------|---|
| No         | The design intent was not implemented, or the operation was 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    | Only partially meets the design intent requirements |  |
| Reverse    | There is a situation opposite to the design intent |  |
| Other Than | Unexpected situation |  |

2.2. Basic principles of harvesters
The combined harvester mainly includes the harvesting platform structure, the threshing mechanism, the grain clearing mechanism, the conveying mechanism, the walking mechanism and the grain storage mechanism. In the harvesting work, the mature grain is firstly held and the necessary clamping is carried out[4]. The reel is used to position the grain to the position of the cutter, and the grain is cut at the cutter. After the grain is cut, the reel immediately pushes the cut grain to the inside of the header. After the grain reaches the inside of the header, the header transports the auger to concentrate the grain to one side, and quickly delivers it to the finger mechanism, and then dials. The mechanism transports the grain to the trough. After the grain reaches the trough, the caries grab the grain and transport it from the bottom of the trough to the threshing mechanism. The grain that has matured through such a process is smoothly cut and transported to the threshing mechanism[5-6]. After the grain reaches the threshing mechanism, the separation of the grain and straw of the grain is completed. After the granules of the grain are separated from the straw, the granules and the straw are further separated by the gravure screen, and the grain obtained at this time is passed through the subsequent grain cleaning mechanism to further pass the grain through the dithered sieve plate, and finally the cleaned clean. The grain is pushed to the Yanggu and passed to the granary by the agglomerate[7]. When the granary is full of grain, it is concentrated on other transport vehicles, which completes the entire grain harvesting task.

3. Results

3.1. Untrained before taking up
Some drivers were not trained, did not carefully or did not look at the operating instructions, and went directly to the post; what's more, they did not get the driving qualification certificate to drive the vehicle, illegally driving the vehicle, and taking safety as a play, laying a hidden danger for the accident.

3.2. Fatigue driving
During the harvest season, the grain harvest is concentrated, and in order to obtain a large profit, the driver ignores the physical fatigue, has no day and night work, no other workers work shifts, especially at night, poor line of sight, physical sleepiness, and prone to accidents.

3.3. Poor security awareness
Some agricultural operators have a weak sense of safety. When they do not separate the threshing clutch, turn off the engine and remove the key, they are close to the header and remove obstacles.
When unloading grain, use the hand and iron shovel to push the grain in the grain bin, or climb into the grain bin to boost the grain; when the harvester is working, the front side and the left and right sides are too close to the machine; on the grain combine harvester Smoke is ripened by mature crops; fuel is added to the fields being harvested, which is likely to cause accidents.

3.4. Poor operating environment
The harvester itself is bulky and has many blind spots. The driver can't observe the surrounding environment clearly. When starting, turning, and reversing, the line of sight is not good. During the busy season, the field of dry farmer activities is frequent, and farmers' awareness of safety is weak. Farmers are too close to the locomotive to tear weeds by hand, farmers are standing on the locomotives that are working, and the obstacles such as poles and wires in the field are added. It is prone to accidental accidents.

3.5. Maintenance is not timely
The driver does not repair in time when the machine is faulty. Some users are unwilling to invest. The fire extinguisher is not replaced or fire extinguisher is not replaced in time. The fire hood is not installed. The debris and crop debris accumulated in the engine and running parts are not cleaned up in time. There is no heatstroke prevention measure for high temperature operation, which may cause fire and cause accidents.

4. Discussion
When working, the driver should concentrate and observe the operation of listening and its various components. If it is found that the blockage is stopped, stop the engine and remove it. If the engine load is too large, it should be suspended, and the threshing load should be suspended. Continue work after normal.

In wet and dry land operations, when the crop yield is above 6000 kg per hectare, low-speed operation should be adopted; when it is less than 6000 kg per hectare, higher-speed operation can be used. When working in mud and harvesting crops, low-speed operation should be used.

Use a brush to clean the air filter before working. The dust and hull on the engine radiator cover are removed once every 0.7 hectares. After every 5 hectares of harvest, the engine shroud must be opened to clean the dust from the engine's cooling water tank.

When the operation is terminated, all the grain is sent to the granary, and then the working clutch operating handle is moved backward to the "off" position to cut off the working power; when the machine is stopped, the handles should be adjusted to the neutral or "off" position. The throttle is in the idle position; by turning the starter key on the steering gear in the opposite direction, the engine can be turned off; then the main power switch is turned to the "off" position. When the combine harvester does not work or shift a long distance, the working clutch operating handle should also be pulled back to the "off" position to cut the working power.

In the early harvest, due to the high moisture content of the stalk and the high viscosity, it is easy to block the auger and paste the clear sieve. Therefore, it is necessary to clean the sieve and transport the auger before the end of the daily harvest.

When moving on a flat road, the speed of the combine harvester should not exceed 8 km/h; when the road is not good, it must be decelerated. When transporting for long distances, the header should be fixed and must not be in a floating state.

According to the operation specification of the grain harvester, HAZOP analysis is carried out. Firstly, the operation specification is divided into nodes (as shown in Table 2 for the division of nodes), and the guiding words and deviations are discussed, and the causes, consequences and existing protection measures of the deviation are discussed. Analysis, in the case of the normal operation of the existing protection measures, the risk level is still beyond the acceptable level, further recommendations should be given, and the person will track the rectification. The deviation matrix is collated, and then the guidance word and the deviation matrix are combined to
determine the deviations that may occur in each process. Table 3 shows the HAZOP analysis record table.

### Table 2. Node division

| Serial number | Node type                          | Element                        | Guiding words | Deviation | Possible Causes                                                                 |
|---------------|------------------------------------|--------------------------------|---------------|-----------|---------------------------------------------------------------------------------|
| 1             | Integrated guiding words           | concentrate                    | 1             |          | After the grain enters the granary, the power is cut off.                         |
| 2             | Integrated guiding words           | Stop parking after finding blockage | 2             |          | Downtime is the handle is adjusted to neutral                                    |
| 3             | Integrated guiding words           | When overloading, wait for the load to work normally and continue working | 3             |          | The harvester does not work and moves over long distances, cutting off the work power |
| 4             | Low gear operation at heavy load   | Slow operation deviation at high load | 4             |          | Clearing the clearing screen and conveying the auger before the end of the harvest |
| 5             | Low-speed operation when sludge is used to collect fallen crops | Slow down when the road is not good | 5             |          | Flat inside moving speed is no more than 80 kilometers per hour                   |
| 6             | Cleaning the air filter            | Cleaning the air filter deviation | 6             |          | Slow down when the road is not good                                               |
| 7             | Cleaning the radiator              |                                | 7             |          | When moving over long distances, the header must not be in a floating state.       |

### Table 3. HAZOP analysis of nodes

| Serial number | Guide word | Element | deviation | Possible Causes                                                                 | as a result of | Existing measures | Recommended measures |
|---------------|------------|---------|-----------|---------------------------------------------------------------------------------|---------------|-------------------|----------------------|
| 1             | Integrated guiding words           | concentrate | Concentrated attention bias | Staff safety awareness is not in place; staff fatigue driving | Increasing accident rate | –                 | Strengthening safety awareness education |
| 2             | Integrated guiding words           | Stop in time after blockage | Timely parking deviation after blockage | Not found in time; not processed | –             | –                 | –                    |
| 3             | Integrated guiding words           | When overloading, wait for the load to work normally and continue working | Fast travel speed; machine failure | – | – | – | – |
| 4             | Low-speed operation at heavy load  | Low-speed operation deviation during heavy load | Deviation in low speed operation when muddy land is harvested | The driver has poor driving experience; knows that he needs to slow down but does not slow down | – | Increase the speed | Increase overload reminder |
| 5             | Low-speed operation when sludge is used to collect fallen crops | Deviation in low speed operation when muddy land is harvested | The driver has poor driving experience; knows that he needs to slow down but does not slow down | – | – | – | – |
| 6             | Integrated guiding words           | Cleaning the air filter | Cleaning the air filter deviation | The machine can't dissipate heat in time, increasing the machine failure rate | – | – | Increase the temperature monitoring device and alert in case of overheating |
| 7             | Integrated guiding words           | After the grain enters the granary | After the grain enters the granary, the dynamic deviation is cut off | Lack of professional knowledge of the operator; direct power cut off due to forgetting | – | Caring food losses | – |
| 8             | Integrated guiding words           | Cleaning the clearing screen and conveying the auger before the end of the harvest | Cleaning the clearing screen and conveying the auger deviation before the end of the harvest | Lack of professional knowledge of the operator; uncleaned due to being lazy, forgotten by the operator | – | – | – |
| 9             | Integrated guiding words           | When moving over long distances, the header must not be in a floating state. | Job staff lacks expertise; operator forgets | Increase accident rate | – | – | – |

### 5. Conclusion

With the large-scale promotion of harvesters, users are gradually increasing, and safety issues cannot
be underestimated. It is necessary not only to reduce the occurrence of accidents from the problems existing in the machine itself, but also to analyze the causes from the human factors and strive to minimize the incidence of accidents. The HAZOP analysis of human accidents is a good way to solve the harm caused by human deviation. It is found that the potential danger of the workers in the process of participation, timely discovery and propose solutions to prevent problems before they occur, further for the harvester Promotion provides a strong guarantee.

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