Development of Backup Systems for an Automatic Boom Height Limit Changer for Road-Rail Backhoes

Abstract
Road-rail backhoes used in track maintenance are equipped with a boom height limiter that keeps the boom within a specified height to prevent electric shock when operated under overhead contact lines. Existing road-rail backhoes are used in two different modes—on-rail mode (traveling mode) and crawler mode (operation mode)—and boom height limit is set when in on-rail mode. Since distance between the boom and overhead contact lines is large enough when in crawler mode, an automatic boom height limit changer according to vehicle mode has been developed to effectively utilize the space up to the overhead contact lines. However, the automatic boom height limit changer changes boom height limit electrically, so, it cannot control the limit in the case of electric problem.

In light of that, we have developed backup systems where boom height limit is mechanically controlled in an electric problem. This article introduces the development of those.

Keywords: Road-rail backhoe, Height limit, Backup system

1. Introduction
Road-rail backhoes used in track maintenance are equipped with a boom height limiter that keeps the boom within a specified height to prevent electric shock when operated under overhead contact lines. Existing road-rail backhoes are used in two different modes—on-rail mode (traveling mode) and crawler mode (operation mode)—and boom height limit is set when in on-rail mode. Since distance between the boom and overhead contact lines is large enough when in crawler mode, an automatic boom height limit changer according to vehicle mode has been developed to effectively utilize the space up to the overhead contact lines. However, the automatic boom height limit changer changes boom height limit electrically, so, it cannot control the limit in the case of electric problem.

In light of that, we have developed backup systems where boom height limit is mechanically controlled in an electric problem. This article introduces the development.

2. Overview of Automatic Boom Height Limit Changer
2.1 Vehicle Mode Detection Method
A road-rail backhoe is structurally composed of an upper revolving body and a lower traveling device. As shown in Fig. 1, the upper revolving body remains the same even if the vehicle mode is changed. That is, change of mode means change of just the lower traveling device.

In order to detect the vehicle mode, we attached dogs (jigs for sensors) to the front and rear of the road-rail vehicle frame and proximity sensors to the front and rear of the upper rotating body. When a sensor detects a dog, it judges the vehicle to be in crawler mode, and when a sensor does not detect a dog, it judges the vehicle to be in on-rail mode (Fig. 3).
2.2 Method of Detecting Boom Height Using Boom Angle Detecting Sensor

Boom angle is detected using a potentiometer applied to the current boom height limiter and boom rising is suspended using a boom rise suspension electromagnetic valve. In either vehicle mode, boom height is detected using the boom angle detection potentiometer and only rising operation of the boom is suspended when the height exceeds the height limit.

2.3 Fixing of Maximum Boom Height

Taking into account separation of 500 mm from the lowest overhead contact line height of 4,400 mm, there are two boom height limits: “traveling 3,900” where the maximum boom height is 3,900 mm from the top of the rail in on-rail mode shown in Fig. 2 and “operation 3,900” where the maximum boom height is 3,900 mm from the top of the rail in crawler mode shown in Fig. 2. Those are automatically switched between each other according to the detected vehicle mode. Specifically, when the boom height limit is set to “operation 3,900”, operating the road-rail vehicle frame raises the vehicle and the separation between the overhead contact lines and the vehicle is reduced by the amount of rise. In order to prevent that, operating the road-rail frame automatically switches to the boom height limit of “traveling 3,900” to keep the distance to the overhead contact lines constant.

3. Overview of Backup Systems for Boom Height Limiter

The backup systems developed for two types of track maintenance road-rail backhoes manufactured by Kobelco Construction Machinery Co., Ltd. and by Komatsu Ltd. are as follows.

The automatic boom height limit changer explained in the previous section is controlled by oil flowing in a hydraulic circuit (hydraulic control). Rising and lowering of the boom is controlled by switching the oil flow direction. The switcher is the boom rise control valve; so, if a defect occurs with the valve, rising and lowering of the boom cannot be controlled. In order to overcome that, we have developed backup systems that enable mechanical control of the boom as well as electric control.
3.1 Backup System for Backhoes by Kobelco
Road-rail backhoes by Kobelco have a wire (Fig. 4) attached as a mechanical boom controller; however, the length of the wire is fixed, so it cannot change boom height to handle the height set by the automatic boom height limit changer (crawler or on-rail). We thus developed a new backup system aiming for the following development features.

- Development features
  1) Structure allows automatic change of boom height limit
  2) Structure allows control of boom height even if the boom is raised abnormally

- Control method using a backup cylinder
We decided to adopt a mechanism where the wire and a backup cylinder are connected in series and boom rise can be mechanically suspended as currently done using a wire alone. In this mechanism, the cylinder automatically extends and contracts to the length needed according to the height set by the automatic boom height limit changer. An extension/contraction detecting sensor attached to the cylinder prevents boom rise until the length of the cylinder length is that for the vehicle mode (Fig. 5).

3.2 Backup System for Backhoes by Komatsu
Road-rail backhoes by Komatsu too have a wire as a mechanical boom control backup; however, it cannot be equipped with a backup cylinder due to space constraints. We thus developed a backup system for those backhoes using hydraulic control, aiming for the following development features.

- Development features
  1) Control system is added to the circuit of the automatic boom height changer
  2) Usual operation of the automatic boom height changer is not affected when the automatic changer is not used
  3) Boom rise is suspended by controlling the boom operation when boom height exceeds the height limit due to situations such as a defect in the boom rise control valve

- Hydraulic circuit control method
When a defect in the boom rise control valve causes a malfunction of the boom with oil flowing on the boom rise side, the boom cannot be controlled. In order to forcibly suspend boom rise, we added a new backup circuit to the hydraulic circuit that shuts down oil flow to the boom rise side and suspends boom rise.

- Backup circuit and function check
Fig. 6 shows the backup circuit added. The backup operation principle can be explained as follows. To check backup operation, we attached an indicator lamp to the operator’s cab. That allows the operator to check if the backup system properly works (Fig. 7).
1) Abnormal rise past height limit releases the proximity switch (no detection).
2) The proximity switch being released turns the low voltage locking electromagnetic valve off.
3) The proximity switch being released turns the pilot electromagnetic valve off.
4) The boom rise control valve does not return to neutral due to failure.
5) Oil supply to the boom rise side continues (the boom rises without boom rise operation being made).
6) By turning the pilot electromagnetic valve off, the check valve is closed and oil supply to the boom rise side is stopped.
7) Boom rise is suspended.

4. Conclusion

For backhoes by Kobelco and Komatsu, we developed and checked performance of a backup system to mechanically control boom height in an electric failure and confirmed that the system can be put into practical use. The development results are as follows.
1) With the backup system using a backup cylinder, boom rise of road-rail backhoes by Kobelco can be suspended even in the case of abnormal rise of the boom due to failure of the boom rise control valve.
2) Using a backup circuit, boom rise of road-rail backhoes by Komatsu can be suspended even in the case where failure of the boom rise control valve causes abnormal rise of the boom.

In view of practical use of those backup systems, we will revise and improve the manual for maintenance vehicles. At the same time we will develop and verify new technologies with an aim of further improvement of safety in work using machinery.

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