The correction system for the direction of a locomotive spotlight’s luminous flux

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Abstract. In this article the authors propose their concept of a correction system for the direction of a locomotive spotlight’s luminous flux in the horizontal plane during train movement. This solution will keep the railway tracks well-lit while the locomotive moves on curved track during night time and in limited visibility conditions and drastically increase the railway traffic safety.

1. Introduction
Traffic safety is one of the key performance indicators of railway transport. Today a plethora of automated systems provide it [1, 2]. Nevertheless, making the most important decisions still falls to humans. The direct responsibility for accident-free train movement lies on the train driver’s shoulders, and freight and passenger transport safety depends on his correct actions [3, 4, 5]. During a large portion of working time, taking the geographic location of Russian railways and climate conditions into account, drivers operate their train during nighttime and in limited visibility condition (rain, snow, fog, etc.). To operate in such conditions all locomotives are outfitted with lighting devices [4]. One of the drawbacks of the optical system currently used with locomotives is the fact that during the movement on curved track the spotlight doesn’t light the way ahead of the locomotive and the driver keeps moving practically «blind» (fig. 1 a). Needless to say, this circumstance directly influences the train traffic safety and often serves as the cause of numerous emergency situations.

2. Methods
The authors propose a correction system for the locomotive spotlight’s luminous flux that will allow to keep the railroad tracks well-lit by the spotlight when the train moves on curved track (fig. 1 b).
Figure 1. The direction of a locomotive spotlight’s luminous flux a) no correction, b) using the automatic correction system.

The system consists of a locomotive spotlight, a gear mechanism, a stepper motor, a stepper motor driver, a central computer, and a dashboard camera (fig. 2). This equipment is located in the locomotive cabin and is protected from any atmospheric influences. Power is supplied by the on-board electrical network (DC voltage 12 V) with a step-down converter.

Figure 2. Structure and the operating principle of the correction system’s hardware.
The correction system for the direction of a locomotive spotlight’s luminous flux functions as follows. The spotlight is connected by the gear mechanism to the stepper motor’s crankshaft that is controlled by the CPU through the motor’s driver. The dashcam (set on the locomotive dashboard) records the rail tracks ahead of the locomotive. While the train moves in a straight direction, the rail tracks remain in the same position on the video, but once it reaches a curve the rails start moving to the right or to the left in the camera’s field of view (Fig. 3).

Figure 3. The image of railway tracks ahead of the locomotive, recorded by the dashcam

The system’s CPU constantly processes the video images. If the tracks on the image shift from their original position, a command is sent to the stepper motor’s driver to turn the motor’s crankshaft on a required number of steps (to an according angle on a horizontal plane) (Fig. 3). Similar solutions were discussed in concepts of the correction system for the direction of automobile headlights’ luminous flux [6, 7, 8].

While approaching a railroad station the correction system receives signals from automatic brake control system’s (ABCS) trackside assets and locks the spotlight, fixing it in the center position in the direction of the locomotive’s axis. After the train leaves the station the correction system still receives signals from ABCS trackside assets and unlocks the spotlight’s gear mechanism.

In case of software malfunctions the spotlight pivots to the central position automatically. The emergency manual control of the gear mechanism is also envisioned in this concept.

3. Results and Discussion
Currently there exists a working model of the correction system for the direction of a locomotive spotlight’s luminous flux (Fig. 4). Test drives are planned to take place in Transbaikal Railway testing area in 2019/2020. The video image processing and the stepper motor control are performed by means of original software developed for Raspberry Pi (a microcomputer used to analyze the video images) and Arduino (a microcontroller used to control the stepper motor) platforms. The Raspberry and Arduino platforms are used due to their small size, high reliability and low cost [9, 10].

The force transfer from the stepper motor to the locomotive spotlight is performed by a special gear mechanism developed by the authors that is compatible with any type of locomotive spotlights.
Figure 4. A locomotive spotlight outfitted with the gear mechanism

Figure 5. The gear mechanism's blueprint.
This mechanism is a round rotating base placed on a journal bearing. The spotlight is placed on the rotating base. Once the luminous flux correction system is active the stepper motor receives commands from the microcomputer. The motor's crankshaft is connected to the base with a screw-and-nut type drive and pivots the spotlight to a required angle by rotating.

4. Conclusion
The insufficient illumination of railway tracks ahead of the locomotive makes the driver strain their eyes and concentrate their attention, which leads to increased fatigability [11]. The correct rail track lighting in curves will improve the train drivers' working conditions and decrease their fatigue. In certain cases, curve tracks illumination will help prevent collisions with other objects or drop the train’s speed, minimizing the damage sustained by the locomotive.

The use of the correction system for the direction of a locomotive spotlight's luminous flux will raise the railway traffic safety during nighttime and in limited visibility conditions.

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