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OPERATOR WORKPLACE VISIBILITY IN MOBILE MACHINES AS AN ERGONOMIC FACTOR FOR IMPROVING WORK EFFICIENCY

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Modern mobile machines, including tractors, combine harvesters, and trucks, are characterized by a high level of mechanization and automation of production processes. Under such conditions, the ergonomic organization of the operator's workplace plays a significant role. The productivity of work, operational safety of the machinery, and the operator's fatigue level depend on the quality of the cab and workplace design. An important ergonomic factor is workplace visibility [1], which ensures the operator's ability to receive timely information about the machine's working area and the surrounding environment. The visibility of the operator's workplace is determined by a combination of design and operational characteristics of the mobile machine cab. The main factors include the cab glazing area, the design of the pillars, the position of the operator's seat, the inclination and shape of the windshield, as well as the presence of auxiliary devices for monitoring the surrounding space. Insufficient visibility leads to reduced accuracy of technological operations, increased operator fatigue, and a higher risk of accidents and equipment damage.

The design of modern machinery cabs is carried out in accordance with international standards that regulate the operator's field-of-view requirements. One of the key regulatory documents is the international standard ISO 5721-1 [2], which establishes the requirements for the forward field of view of tractor operators. The standard defines the methodology for assessing visibility and the permissible values of field-of-view obstruction by structural elements of the cab. According to ISO 5721-1, visibility assessment is performed on a notional semicircle with a radius of 12 m around the machine, and the operator's eye position is determined relative to the so-called Seat Index Point, located approximately 680 mm below the operator's eye level. The standard also introduces the concept of "masking effects"—areas of space obstructed by cab structural elements (pillars, window frames, air intakes, etc.), which create so-called blind spots. The width of such obstructions must not exceed approximately 700 mm, as larger values significantly impair visibility and require modifications to the cab design. Similar field-of-view requirements for road-construction and other mobile machinery are established by ISO 5006 [3]. Both standards define methods for measuring the field of view and assessing blind spots, enabling manufacturers to ensure safe operating conditions for machinery.

To meet these standards, manufacturers implement various design solutions aimed at improving visibility. The most common approach is increasing the cab glazing area and using panoramic windows. In modern tractors and combine harvesters, the glazing area may exceed half of the cab surface, significantly expanding the operator's field of view. John Deere tractors are equipped with cabs featuring large panoramic front and side windows, providing excellent visibility of the machine's front and lateral working zones. These cabs also use thin front pillars, which reduce blind spots. Claas combine harvesters (e.g., the Lexion series) have similar cab designs with large panoramic windows and a significantly inclined windshield (Fig. 1), which improves visibility of the header and the working area in front of the machine—particularly important during harvesting. New Holland implements comparable solutions, using the concept of a panoramic cab with large glass surfaces and optimized pillar placement [4].

In addition to cab design, the proper positioning of the operator's workplace plays an important role in ensuring visibility. The seat must allow adjustment in height, longitudinal

position, and backrest inclination, enabling adaptation to the operator's anthropometric parameters and ensuring an optimal eye position relative to the control panel and the machine's working area. To enhance visibility, various auxiliary monitoring devices are widely used: rear-view mirrors, panoramic mirrors, and modern video surveillance systems. Rear-view cameras and 360-degree vision systems allow the operator to monitor areas outside the direct field of view, which is especially important for large machinery.

Thus, the visibility of the operator's workplace is an important ergonomic factor that directly affects the efficiency and safety of mobile machine operation. The use of international standards, improvements in cab design, and the application of modern technical solutions significantly enhance operator working conditions and increase machinery productivity.

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