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Protective structures for construction and mining machine operators ☆

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Abstract

The paper presents selected problems concerning the passive safety of the operators of construction and mining machines. Such machines must be equipped with protective structures meeting the requirements of the relevant regulations and standards. Protective structures for engineering machines are described and classified. Requirements and ways of carrying out experimental investigations of protective structures: FOPS, TOPS, ROPS and RSPS are specified. The principles of constructing calculation models for numerical simulations in virtual space by the finite element method are given. A detailed example of FEM tests on a protective structure is provided.
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1. Introduction

Construction and mining machines operate in various environmental conditions, both above ground (construction and agricultural machines) and underground (mining machines). Since all kinds of engineering machines are operated by operators, a protective cabin (the operator's workplace) is an inseparable part of almost every such machine. The difficult conditions in which the machines work require that the cabin should ensure safety and be ergonomic.

Currently protective structures for construction and mining machines are required to provide safety in case of a rollover during engineering work (ROPS – Rollover Protective Structure – ISO 3471, EN 13510:2004) and protect construction machines against falling objects (FOPS – Falling Object Protective Structures – ISO 3449, EN 13627:2002). In the case of mining machines safety at much higher impact energies than the ones specified by ISO 3449 must be ensured. This is dictated by the operating conditions and the danger of rock slides. In Poland standard PN-92/G-59001: 'Rock slide protective structures (RSPS). Requirements and tests.' is binding for mining machines.

Protective structures significantly reduce the risk of an accident. In the KGHM Polska MiedŸ Holding Company there have been cases when operators of mining machinery have been saved by such structures in cave-ins, as shown in Fig. 1.

Another example is an excavator rollover (Fig. 2) during demolition of a building, where the protective structure, i.e. the cabin, saved the operator's life.

2. Protective cabins

Today protective cabins are used in all new construction machines and underground mining machines. Their main function is to protect the operator from impact (protection against rockbursts and rock or other object strikes) [5]. In addition, protective structures must provide vibration insulation, sound insulation (noise protection), thermal insulation and protection against harmful environmental chemical agents.

Cabins can be classified according to the site, the aim of the protective measures or the structure. A major criterion for classifying cabins is the consequences against which they must protect the operator and so one can distinguish:

- ROPS — a rollover protective structure (Fig. 3),
- FOPS — a falling object protective structure (Fig. 3),
- TOPS — a tip over protection structure (for compact excavators) (Fig. 4),
- RSPS— a rock slide protective structure (mining machines in Poland) (Fig. 5).

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Fig. 1. Protective structure saved mining machine operator's life in KGHM PM S.A. O/ZG LUBIN — rockburst on 04.08.2003, rockburst energy: $E = 190\,000$ kJ.

One should note that a protective structure can be an integral part of the operator's cabin or it can be an accessory (Fig. 3).

Cabins can be classified according to the site which may be [2]:

- a truck,
- a slow-speed (construction or agricultural) machine working on the ground's surface,
- a slow-speed (mining) machine working underground,
- any other self-propelled machine.

Cabins can be classified according to the aim of protective measures, which may be:

- mechanical impact protection,
- vibration insulation,
- sound insulation,
- thermal insulation,
- protection against harmful chemical environmental agents.

The most important and most clear-cut classification criterion is the kind of cabin structure (including load-bearing structure). And so one can distinguish cabins with:

- a surface load-bearing (shell) structure,
- a load-bearing beam structure,
- a load-bearing beam structure with sheathing.

A typical cabin usually has the form of a frame consisting of posts (made from box profiles) connected by crossbars, covered by a plate roof resting on the posts. The top plate preferably should be a space structure in the form of a frame with sheathing. The frame should be made from steel sections and the sheathing from thick tough plate metal. If the cabin receives a hit from above, the posts locally lose their stability. During the strike the box-profile posts should convert the impact energy into work of deformation [3,4].

Protective cabins have an open (Fig. 6) or closed structure, their height can be adjustable or not and they may differ in their support (the number of supports).

Fig. 2. Overturned excavator on building site.

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