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The rescue of people buried alive

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Introduction

A natural disaster means an event caused by natural forces which only becomes a catastrophe through its effects on the human civilization when extraordinarily powerful forces cause the partial or entire collapse of buildings. Persons trapped inside the buildings are referred to as "people buried alive".

When rescuing people buried alive the heads of operations are always confronted with the fundamental problem of selecting the appropriate equipment. Heavy, large equipment is very efficient, but through intervention in the static rubble structure it endangers the lives of buried people by uncontrolled slides. Smaller, more sensitive equipment permits a more sensitive procedure, but is less efficient and the time factor is of special importance in the rescue of people buried alive. The removal of all rubble by hand is not only too time-consuming but even impossible with bigger pieces of rubble. In addition, the rescue teams are put at risk by rubble falling down.

Especially in case of wide-area disasters, e.g. caused by earthquakes, often all available construction equipment of the surrounding is ordered and used as fast as possible. Because of this, the people buried alive have almost no chance to survive [1]. After the earthquake in Armenia, in 1988, many buried people located alive were later recovered dead due to the improper rescue operations [2]. In 1992, after the devastating earthquake in the Erzincan region, Turkey, heavy debris clearing equipment was used much too early, which probably caused the death of people buried alive [3]. To avoid this and to maximize the safety of people buried alive, the following process chain for the removal of rubble has been developed in the present work:

Uncovering – Crushing – Grabbing – Lifting away

For the processes of "crushing", "grabbing" and "lifting away" the market for construction equipment offers a wide range of machines, which however have to be used in an optimum environment. There is no standardized construction equipment for the first and most important process, the “uncovering”. An effective removal of small pieces of rubble on the one hand creates air gaps or keeps them free, so that buried people are supplied with air. On the other hand, the rescue teams are able to identify the debris structure, to assess the remaining load-carrying capacity, and to specifically search for people buried alive. After the uncovering it is possible to additionally use heavy construction equipment with attachments, such as grabs or shovels, since the dimensions of the building parts and the boundary conditions of their position can now be determined. At the same time, this eliminates the danger to people buried alive of being suffocated by small pieces of rubble trickling down (with an uncontrolled pulling or lifting out of larger pieces of rubble with grabs or buckets these small pieces are not grabbed or fall back through the claws of the grab onto the heap of rubble).

There is an interplay between uncovering, possibly also crushing, and grabbing the rubble. This process of uncovering, which, if at all, used to be carried out by hand and because of that very slowly, is now automated for the first time by an ultrasound-controlled suction dredge (cf. chapter 2). The rubble cone is scanned by ultrasonic sensors, and the suction pipe is automatically directed into an optimum position and slope. The whole suction device is designed as attachment for a hydraulic excavator and can simultaneously be used as supporting device for additional sensors, such as miniature cameras, sound detectors, or cameras for observing the movement of large pieces of rubble. The flow meter integrated into the suction pipe automatically informs the driver when a large piece of rubble has been sucked free and a grab or shovel can be used. Thus, the uncovering process is both automated and standardized, and the rescue team can keep to the engineering process chain without delay.

Furthermore, this project gives an overview of the suitable equipment for each rubble structure rubble cones, peripheral rubble, sliding areas, cavities, or layers and develops ideal combinations, such as suction dredge and demolition grab. In addition, various optimization suggestions are elaborated for the specified equipment. A sound basis for decision making is developed for the heads of rescue operations, because an “ideal” rescue operation can only be achieved through the use of several coordinated devices, where one device always has to create optimum conditions for the follow-up device.

The forecast of natural disasters, such as earthquakes, is still almost impossible. The more important it is to develop strategies which permit the immediate implementation of effective emergency measures after the occurrence of such an event. The most important aspect in this connection is the optimum use of rescue equipment for the extrication of people buried alive. Here, an automated suction system with simple dimensioning principles as well as the theoretical development of ideal equipment combinations for different rubble structures represent a substantial improvement.

2 Development of an attachment including control system for automation of the "uncovering" process through pneumatic extraction

2.1 Test installation and operation

The operating radius of standard suction systems or suction dredges is limited to a few meters. Due to the simple kinematics through which the suction pipe is moved by one or two hydraulic cylinders, the suction mouth always considerably pounds on the material to be extracted. Despite the controllable hydraulic cylinders the suction pipe has to be guided by two persons on-site.

Not only because of its limited operating radius but also because of the forces induced by the pounding of its suction mouth, which would be passed on to the rubble structure, the standard suction dredge is unsuitable for rescue operations. The deployment of personnel directly at the suction mouth is also unjustifiable in view of the dangers involved.

From these considerations the idea developed to lead the suction pipe over the boom of a hydraulic excavator and to integrate the suction mouth separately into an attachment that automates all necessary movements. Optionally, a mobile suction dredge can be connected or a stationary suction system can be attached to the rear of the excavator. This modification also permits to drive over rubble and smaller obstacles, and makes the unit very flexible.

The actual attachment contains ultrasonic sensors for scanning the surface of the debris cone or heap of rubble. Controlling the suction mouth through the hydraulic cylinders of the boom would imply considerable disadvantages. On the one hand, they are not sensitive enough. This means that a centimeter-precise control of the suction mouth, which is necessary to avoid collisions with rubble and to optimize the suction performance, is impossible. On the other hand, the PC control would have to be adapted to each type of excavator. Therefore, the vertical movement of the suction mouth was completely separated from the boom and integrated into the attachment. The movements are executed through commensurate hydraulic cylinders equipped with a position measuring system. According to the surface structure and the composition of the suction material the user or driver can enter a distance to be kept between suction mouth and surface. The control system then adjusts the hydraulic valves according to the online values supplied by the ultrasonic sensors and the position measuring system of the cylinders.

Contrary to the conventional rigid design of the suction mouth, the innovation presented here includes an additional hydraulic cylinder that also allows slope adjustment of the suction mouth to the rubble surface. The adjustment process is completely automated; the surface slope is calculated from the distance values measured by the ultrasonic sensors. The system thus controls the air volume flow as a surface normal of the rubble surface.

Additional sensors also scan the environment of the suction mouth, so that suction operations can also be performed in areas which cannot be viewed by the driver of the excavator. Any obstacles will be detected by the control system and crossed over with the predefined distance. A flow measurement is used to control whether a place has been sucked free and the position has to be changed accordingly or whether a follow-up device (grab, shovel) has to be employed.

2.2 Analysis of the mass flows

Comprehensive studies and experiments were carried out with a stationary prototype of the attachment. Different rubble-specific types of grain were analyzed. They were arranged at different surface slopes to quantify the effectiveness of slope adjustment of the suction mouth. Table 1 shows the achieved mass flow rates depending on the set distances and slope adjustment at slopes of 10˚ and 25˚ for two different types of grain.

The diagram shows that the efficiency can be increased by more than 100% with slope adjustment. The effectiveness and superiority of the automated control is apparent at all slopes and distances.

In further experiments, complete rubble structures were set up to examine the adjustability of the control system. The maximum piece size that can be sucked off depends on the diameter of the suction pipe and the given air volume flow and vacuum. In the present case, a suction pipe of 150 mm in diameter was used. In combination with the available suction dredge, rubble pieces up to approx. 110 mm in diameter could be sucked off. One crossing of the heap with the suction pipe is already sufficient to uncover previously non-recognizable pieces of rubble, so that a follow-up device can grab and remove it. This sensitive removal of rubble ensures maximum safety for people buried alive.

3 Application of the fluidic analysis

Since all flow-relevant data were recorded during the series of experiments, characteristic values which can be used to exactly dimension pneumatic extraction systems for rubble could be obtained by regression. The determined parameters can also be used for other dimensioning tasks, e.g. for dimensioning pneumatic systems in combination with size reduction and demolition machinery, such as crushers, milling machines, or concrete pulverizers. These systems easily comminute reinforced concrete, but their disadvantages are a high dust generation and a large share of fine-grained crushed material. Therefore, these systems often cannot be employed in rescue operations, since the danger of suffocation would tremendously increase for buried people. However, if these devices are encapsulated or combined with pneumatic extraction systems, all dust and a major part of the crushed material can be immediately sucked off.

As an example, a pneumatic extraction system was designed for a mini-crusher, and this combination was tested with reinforced concrete and masonry. Four suction pipes were attached to the teeth of the crusher through appropriate fixtures, so that both the comminuted material and the generated dust could be sucked off immediately on the spot. The crusher was attached to the shovel of a hydraulic excavator, and the suction pipe was led over the boom. Thus, rubble can be comminuted without any vibrations or shocks within the whole operating range of the hydraulic excavator, and the material can be sucked off simultaneously.

With the modified crusher and the appropriately dimensioned suction system it was possible to comminute both reinforced concrete and masonry as well as to collect and remove the resulting problematic demolition material and dust.

With the obtained parameters basically any crushing machine can be modified in a similar way, provided that the crushed material to be sucked off has a maximum piece size of about 200 mm. A further step is to encapsulate milling machines and concrete pulverizers which have a much higher capacity compared to mini-crushers and which can also crush reinforcements.

4 References

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