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Dynamic analysis of gas permeable blasting mat as geometrically nonlinear system with unilateral constraints

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Abstract

Blasting mat is used to prevent flyrock accidents, decrease environmental impacts and expand the range of projects where blasting operations could be carried out. Transformable gas permeable blasting mat is made from worn out tires of heavy trucks bound together with chains, ropes or cables.
Dynamic model of blasting mat is proposed in this research. It is represented by concentrated masses interacting with unilateral foundation and by elastic weightless incompressible elements. The problem solving involves combination of two types of nonlinearity: geometrical nonlinearity associated with large displacements and contact nonlinearity which emanates from the fact that contact region changes due to deformation of the elements. Explosive loading is simulated by instantaneous impulses applied at different times to different masses. The system behavior under various sequences of explosions is of special interest.
Numerical experiments showed that axial forces in elastic elements and maximum flight height of the masses depend on detonation sequence of the blast holes. Employed mathematical model was verified by full-scale experiment.

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Keywords: Dynamics; Unilateral contact; Geometrical nonlinearity; Blasting mat; Flyrock

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1. Introduction

Rock fragmentation by blasting is commonly used in civil engineering and road construction. However blasting process is a potential source of numerous hazards to people and surrounding objects (Kecojevic and Radomsky, 2005) The usage of blasting mat is one of the possible ways to prevent flyrock accidents, decrease environmental impacts and expands the range of projects where blasting operations could be carried out (Leschinskiy et al., 2017).

A new mass explosions technology for destruction of semi-rocky and rocky soils preventing flyrock was developed at Pacific National University (Shevkun et al., 2007, 2008, Leschinskiy et al., 2009). It is based on the use of transformable gas permeable blasting mat made from worn out tires of heavy trucks bound together with chains, ropes or cables (Fig. 1, a). Tires cover each blast hole and additional “anchor” tires can be installed from the side of protected object. Proposed technology allows to cover blocks with a various configuration in plan and height to be blown up. Experiments on site (Fig. 1, b) proved predictability, effectiveness and estimated safety of the developed technology (Leschinskiy et al., 2009).

Currently, mining industry tends to point blasting instead of multiple row blasting. It was caused by two factors: technological development in blasting (shift from detonating chord to non-electric detonation system etc.) and new requirements implemented to reduce seismic impact on nearby settlements. The behavior of blasting mat under various sequences of explosions is the critical idea of the research. It requires estimation of such main variables as tensile strength of connecting elements and tires weight.

The dynamic model of blasting mat is represented by concentrated masses connected using elastic weightless incompressible elements. The problem solving involves the combination of two types of nonlinearity: geometrical nonlinearity associated with large displacements and unilateral contact problem which emanates from the fact that contact region changes due to deformation of the elements. Contact region is defined by a set of “switched on” elements: elastic elements under tensile stresses and supports with compressive interaction forces between unilateral foundation and tires.

Within the last years, computational contact mechanics has been a topic of intense research worldwide (Wriggers, 2006). The aim of these studies is to devise robust solution schemes and new discretization techniques that can be applied to different classes of problems. Displacement based Finite Element Method is widespread in nonlinear mechanics (Reddy, 2004, Lovtsov, 2013). Incremental procedures are commonly used for numerical solutions for geometrically nonlinear systems (Crisfield, 1991, Petrov, 2014). There are many papers on nonlinear dynamics of geometrically nonlinear systems. The conceptual bases are given by Crisfield (1997) and Oller (2014). During the last decades, several new discretization schemes for contact problems were developed (Rolf, 2012). Givoli and Doukhovni (1996) applied the Finite Element Method – Quadratic Programming method to problems solving involving frictionless contact and geometrical nonlinearity in statics. Fujii et al. (2003, 2004) introduced a compression-free material law for cable elements in the study of dynamical behavior of flexible and incompressible goal nets for soccer. A three-dimensional Finite Element Model of space web considering compression-free material, large displacements and impact problem was developed by Yu et al. (2011).

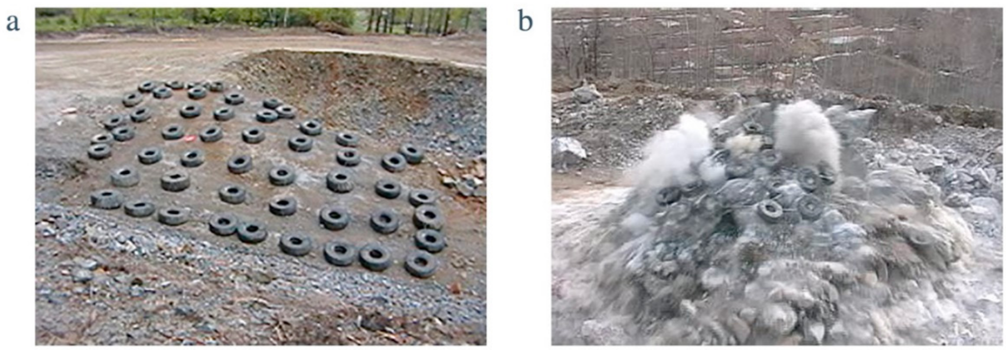

Fig. 1. (a) View of blasting mat; (b) View of detonation.