

## Virtual Simulation of High Impact Shovel Loading Operation for Optimum Dumping Characterization

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The use of large machinery in surface mining operations has resulted in high-impact shovel loading operations (HISLO). When large capacity shovels dump 100+ tons of loads in a single pass, large impact forces are generated resulting in high frequency shock waves. These shock waves cause severe truck vibrations, and thus, expose dump truck operators to high levels of whole body vibrations (WBV) and impact the health and safety of operators. The operator's lower torso, lower back, legs, feet and hands are exposed to these WBV levels, which ultimately result in lower back injuries, musculoskeletal diseases and other long-term injuries. There exists no fundamental work to address this problem except a rigorous mathematical model for this impact force developed by previous researchers. This paper outlines a pioneering effort to develop a 3D virtual simulation model for a shovel dumping operation

**Abstract** 

rock materials. In any truck would consist of I will be a continuous material the dynamic impact for of shovel dumping pro another 100 tons of Material pass. e resulting impa because of the damping a phenomenon known of the truck body, cha accordingly (Figure 1).

is reduction in vibr human body. e cushio dynamic impact force have a similar magnitude considered during the evaluations [6]. erefo dynamic impact force simulation of the shove modelling (DEM) techn

\*Corresponding author: Frimpong S, Department of Mining and this paper. e virtua Engineering, Missouri S&T, Rolla MO, USA, Tel: (573) 341-768 7custionaing eect in frimpong@mst.edu /Span<</ActualText<FEF480A0>>> BDC 4.392%5hoo.ingTEAAC 30% of expertise and understanding about how to control the vibrationseduce the impulse ford generated within dump trucks in surface mining operations [1-3]. e HISLO vibrations are forced vibrations induced by the generated force from material impact. e available literature has allowed the authors to evaluate the contributions by researchers to the body of knowledge on impact force modelling. Studies from Iverson (2003) and Metz (2007) have focused on determining the impact force of a single body through impact test or using soware packages (e.g. PFC3D) [4,5]. However, none of these studies focused on determining the impact force generated by owing material under gravity. Impact forces from Aouad and Frimpong (2013) are a bit overestimated because the material was considered to have been dumped at once. In reality, the material is generally well fragmented either during the direct shovel

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\mathbf{u}tt\mathbf{v} \mathbf{v} and \mathbf{v}words, using the \mathbb{E}_{\kappa} in \mathbb{E}_{\kappa} in \mathbb{E}_{2}\mathbf{F} respectively the north \mathbf{F}anlyse the shovel dumping proces in detail for selcting optimu 
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     \mathbb{R} 73 december
\mathbf{E}_{\text{scat}}\epsilon the complete system based on the motion of \epsilon\mathbf{u}_nis Mith mean \sim\blacksquarein. (2016) and (2016)simulaton proces are compared for verication [7]. e per cent 
     die<br>Giernalmith
   0.03\%, 1.4 % _{1.11} in \blacksquare\mathbf{v}t_{\rm eff} mude (2013) under the same
  \piit, \mathbf{r}\mathbb{R}_{\geq 1} we added the (2013) . Expression in put
     force was used in the \sum_{i=1}^n \sum_{i=1}^n of \sum_{i=1}^nvar = \frac{1}{\sqrt{2}}s+isimbo\lfloor t\rfloor\prod_{i=1}^n \mathbb{E}_{\mathbb{P}^{(n_i)} \times \mathbb{P}^{(n_i)}}\mathbf{v}irt\mathbf{v}and 0.56\%, 7.02\%,
  which show a great show as a good agreement of the show a great show a great show a great show a great show as<br>Single show as a great show as<br>
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           As the rst step in seting up the virtual simulaton, a detail CAD 
   g/\Lambdah_{\text{c}} , h_{\text{c}} and h_{\text{c}}kand k for k\blacksquare \blacksquaret the relative components of components \sigmatthe derivative proces is control data to capture the actual process is control data to capture the actual method \alpha\mathbb{Z} 7.3 \mathcal{L}_1 & 4100\mathbb{Z}\mathbb{Z}, \mathcal{L}(\mathcal{L}_2).
     \sum_{s \in \mathbb{N}} is the CAT \sum_{s \in \mathbb{N}}(\xi, 3)\blacksquare. ender \& 4100\blacksquare\mathbf{S}_{\text{max}}is positned at a proe dumping heigt to mic the dumping 
  processes. \binom{6}{33}t_4, t_5 m) t_6 is \sqrt{17}\sim than H for \simprevnt jolting and to maint the eectivns and the ecieny of 
   \mathbf{u}the dumping \mathbf{v}\frac{1}{\sqrt{8}} \frac{1}{4100} \overline{8} \overline{8} \overline{9} \overline{2} dump to \overline{2}\mathbb{R} also ben used to the dumping \mathbb{R}\mathbf{r}_{\text{th, error}}geomtris of the dumping proces requi very ne mesh, whic 
     consume large CPU times in DEM. e simplcation of the shovel
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 $H$  model problems  $H$  $W_{\text{max}} = E$ ,  $(1, 4, 5)$ isometrc and the front views of the truck body asembly and the  $s_{\rm H4}$ rel  $\sim 33$  ,  $6.33$  $m_{\nu}$  ( $\epsilon$  6, **i**).  $t_{\rm s}$  $6.00, 5.50, 0.05$ .  $\sqrt{7}$  $\kappa$  is the the truck and show  $\kappa$ 5.33  $_{1}$  5.00  $_{2}$  (see in 10).  $t$  $m<sup>4</sup>$ ,  $\overrightarrow{M}$  are into  $5.0$  $\prod_{i=1}^{\infty}$  and the forces devlop in truck body. e shovel diper use a simple polygna meshing becaus ther is no coner for any of the forces from the dipers. e mesh for save a lot of computation diper save a lot of computation diper save a lot of computation d<br>En 1970, e mes save a lot of computation diper save a lot of computation diper save a lot of computation diper  $\mathbf{E}_n$  in  $\mathbb{R}^3$  in  $\mathbb{R}^3$  in  $\mathbb{R}^3$  $,\ldots$  , 5.0 (Fig. 11).



Figure 1: High Impact Shovel Loading Operation (HISLO) (Harnischfeger, 2003).



Figure 2: CAT793D Model: a) Back Isometric; b) Front Isometric; c) Front; d) Side Views.

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**3D Virtual Simulation in PFC3D**

e diper paylod is eithr fragmentd or so materil. In eithr case, the diper paylod normaly consit of large amount

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 $\frac{116 \times 10^{-4} \text{ s}^{-3} \text{ s}^{2} \text{ s}^{-3} \text{ s}^{2} \text{ s}^{2}}{100 \times 10^{-4} \text{ s}^{-3} \text{ s}^{2} \text{ s}^{-3} \text$ mon mondo  $\frac{1}{2} \int_{\mathcal{C}} \frac{1}{2} \, d\mu$  $\begin{array}{c} \begin{array}{c} \begin{array}{c} \end{array} \\ \begin{array}{c} \end{array} \end{array} \begin{array}{c} \begin{array}{c} \end{array} \\ \begin{array}{c} \end{array} \end{array} \begin{array}{c} \begin{array}{c} \end{array} \\ \begin{array}{c} \end{array} \end{array} \begin{array}{c} \begin{array}{c} \end{array} \\ \begin{array}{c} \end{array} \end{array}$ 



 $\alpha$  is the particle come in contact  $\mu$ few particles  $\mathcal{A}_\text{c}$  is curve goes above the consta gravitonl force. Aer the rst pas,  $t_{\pi}t_{\pi+}100_{\pi\pi}30$  $\frac{1}{\sqrt{2}}$  $p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8, p_9, p_1, p_2, p_3, p_4, p_6, p_7, p_8, p_9, p_9, p_{10}, p_{11}, p_{12}, p_{13}, p_{14}, p_{15}, p_{16}, p_{17}, p_{18}, p_{19}, p_{10}, p_{11}, p_{12}, p_{13}, p_{14}, p_{15}, p_{16}, p_{17}, p_{18}, p_{19}, p_{10}, p_{11}, p_{12}, p_{16}, p_{17}, p_{18}, p_{19}, p_{10}, p_{11}, p_{1$  $\blacksquare$ second passection.  $45$  $\kappa_{\rm e}$ 57 M $\blacksquare$ 

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