DYNAMIC ANALYSIS OF SOIL -TOOL INTERACTION IN HYDRAULIC EXCAVATION

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CERTIFICATION

This is to certify that the Thesis:

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is a record of original research carried out

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I declare that this thesis is a record of the research work carried out by me. I also certify that neither this nor the original work contained therein has been accepted in any previous application for a degree.

All sources of information are specifically acknowledged by means of references.

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DEDICATION

This research work is dedicated to the Almighty God for sustaining me throughout the course of this doctoral work from the beginning to the end.

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NOTATIONS

$\vec{\omega}_{A/O}$	- Angular velocity of point A relative to O
$\vec{\omega}_{B_1/O}$	- Angular velocity of point B_1 relative to O
$\vec{\omega}_{B_2/O}$	- Angular velocity of point B_2 relative to O
$\vec{\omega}_{E_1/O}$	- Angular velocity of point E_1 relative to O
$\vec{\omega}_{E_2/O}$	- Angular velocity of point E_2 relative to O
$\vec{\omega}_{C/O}$	- Angular velocity of point C relative to O
$\vec{\omega}_{D/O}$	- Angular velocity of point D relative to O
$\vec{\omega}_{B_1/A}$	- Angular velocity of point B_1 relative to A
$\vec{\omega}_{B_2/B_1}$	- Angular velocity of point B_2 relative to B_1
$\vec{\omega}_{E_1/B_2}$	- Angular velocity of point E_1 relative to B_2
$\vec{\omega}_{E_2/E_1}$	- Angular velocity of point E_2 relative to E_1
$\vec{\omega}_{C/B_1}$	- Angular velocity of point C relative to B_1
$\vec{\omega}_{D/C}$	- Angular velocity of point D relative to C
$\vec{\alpha}_{A/O}$	-Angular acceleration of point A relative to O
$\vec{\alpha}_{B_1/A}$	-Angular acceleration of point B_1 relative to A
$\vec{\alpha}_{B_2/B_1}$	-Angular acceleration of point B_2 relative to B_1
$\vec{\alpha}_{E_1/B_2}$	-Angular acceleration of point E_1 relative to B_2
$\vec{\alpha}_{E_2/E_1}$	-Angular acceleration of point E_2 relative to E_1
$\vec{r}_{O/A}$	-Displacement of point O relative to A
$\vec{r}_{A/B_1}$	-Displacement of point A relative to B_1
$\vec{r}_{B_1/B_2}$	-Displacement of point B_1 relative to B_2

$\vec{r}_{B_2/B_1}$	-Displacement of point B_2 relative to B_1
$\vec{r}_{E_1/B_2}$	-Displacement of point E_1 relative to B_2
$\vec{r}_{B_1/C}$	-Displacement of point B_1 relative to C
$\vec{r}_{B_2/E_1}$	-Displacement of point B_2 relative to E_1
$\vec{r}_{E_1/E_2}$	-Displacement of point E_1 relative to E_2
$\vec{r}_{C/D}$	-Displacement of point C relative to D
$\vec{r}_{D/E_2}$	-Displacement of point D relative to E_2
F_T	-Transmitted force due to the links
F_C	-Cutting force of the excavator bucket
m_b	-Mass of excavator bucket
a_L	-Acceleration due to the links
$\hat{e}_c$	-Unit vector
F_s	-Scooping force
R_s	-Resistance due to shear
τ_s	-Shear strength
A_b	-Area of excavator bucket
d	-Depth of cut
v_s	-Scooped volume
v_b	-Volume of excavator bucket
ρ_s	-Density of soil
W	-Weight of the moving soil wedge
L_t	-Length of the tool

L_f	-Length failure surface
ϕ	-Angle of soil-soil friction
c	-Cohesion of soil
c_a	- Adhesion between the soil and blade
δ	- Friction between the metal and the blade/the soil-tool friction angle
ρ	- The rake angle
ρ_{sl}	- Soil density
β	- The failure surface
Q	- Surcharge pressure
R	- Force resisting movement of the wedge
F	- Resistive force experienced at a blade
v_T	- Transmitted velocity
g	- Acceleration due to gravity
$a_{(h)T}$	- Transmitted acceleration in the horizontal plane
$a_{(v)T}$	- Transmitted acceleration in the vertical plane
v_y	- Velocity in the vertical plane
v_x	- Velocity in the horizontal plane
t	- Time
x	- Bucket displacement in x- axis
y	- Bucket displacement in y- axis
ρ_b	- Density of bucket
$F_{T(h)}$	-Transmitted force in the horizontal direction
η	-Cutting angle
θ_A	-Angle of unit vector $\hat{e}_{B_1/C}$

θ_B -Angle of unit vector $\widehat{e}_{B_1/B_2}$

θ_C -Angle of unit vector $\widehat{e}_{B_2/E_1}$

θ_D -Angle of unit vector $\widehat{e}_{C/D}$

θ_1 - $O\widehat{A}B_2$

θ_2 - $A\widehat{B}_2E_1$

α_1 - $B_2\widehat{A}B_1$

α_2 - $B_2\widehat{B}_1A$

α_3 - $E_1\widehat{B}_1C$

α_4 - $E_1\widehat{C}D$

α_5 - $D\widehat{E}_2E_1$

α_6 - $E_2\widehat{E}_1D$

ABSTRACT

This work improves upon earlier work in the literature concerning the motion of an excavator blade cutting through a medium with a flat surface. In particular, it involves the development of a robust analytical scheme for determining the motion of the various links of the excavator based on the geometrical parameters of the excavator and the transmitted and cutting forces of the excavator bucket. Furthermore, the scheme which involves the use of rigid body dynamics with analytical geometry and circular functions provides a generalized model from which the effect of various geometrical parameters on the cutting force for excavation can be captured in different scenarios. The study also examines the behaviour of the cutting force both in free swing and also when cutting through a medium with mitigating parameters of density, shear, cohesion and adhesion. Our model can also predict the volume of scooped material as well as the resulting bucket trajectory. As part of the validation exercise, simulations were carried out using MATLAB software in studying the various effects of the identified parameters in the excavation of granulated material such as dry sand. Use of the results obtained from our analysis can serve as a basis for enhancement of design parameters in the search for optimized excavation.

Keywords: dynamic analysis, soil-tool interaction, hydraulic excavation, cutting force.