ORIGINAL RESEARCH PAPER

Mechanical Engineering

3 DOF HYDRAULIC EXTRACTOR MINI JCB

KEY WORDS: Hydraulic Extractor, Mini JCB, Versatile construction, Kinematic modeling

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ABSTRACT

An excavator is a typical hydraulic heavy-duty human-operated machine used in general versatile construction operations, such as digging, ground leveling, carrying loads, dumping loads and straight traction. These operations require coordinated movement of boom, arm and bucket in order to control the bucket tip position to follow a desired trajectory. This paper focuses on review of a work carried out by researchers in the field of kinematic modeling of the backhoe attachment to understand relations between the position and orientation of the bucket and spatial positions of joint-links. Kinematic modeling is helpful for understanding and improving the operating performance of the backhoe excavation machine. There are many research work done by researchers in the same field but still there is a scope to develop kinematic modeling of backhoe attachment to predict the digging trajectory as well as better controlling of backhoe attachment to carry out required digging task at desired location.

(1) THEORY

Hydraulic extractors are of great use in various construction as well mining industries. Due to heavy duty use, these mechanisms need hydraulic pistons to work. This mechanism allows these heavy duty machines to lift heavy weights and work in rough environments with ease. Here proposed project provides a working hydraulic excavator mechanism used for digging, mining, and construction industry. We here demonstrate hydraulic piston mechanism by using syringes with liquid to achieve required hydraulic pressure for operating the excavator.

We use 3 syringes to operate the excavator in 3 degrees of freedom. One for operating the bucket, one for operating the excavator in vertical direction and one for the base forward and backward. This also system consists of a base where additional mechanism can be integrated with it to achieve 4th degree of freedom, to move it in horizontal directions.

The research concluded that tracked hydraulic excavators spent approximately 75% of their operating time performing an actual earth moving task, including 15% for grading and 60% for digging.

Further more, surveys conducted in this field suggested that the typical digging (digging and loading into a truck), trenching (trench diggingand loading onto a pile) and leveling operations are the three most common duty cycles performed by excavators .In this study, various types of operating cycles were performed to investigate the impact of the DDH with differing controllers on the system behavior (position tracking, energy consumption,

Regeneration, velocity, oscillations). The selected operating cycles include an example of a typical digging cycle with changing payload adopted from Ref. and a simulation cycle without payload, as defined by the Japan Construction Mechanization Association Standard (JCMAS) in 2007

Rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with complex mechanism and automation of construction activity. Backhoe excavators are widely used for most arduous earth moving work in engineering construction to excavate below the natural surface of the ground on which the machine rests. Hydraulic system is used for operation of the machine while digging or moving the material. An excavator is comprised of three planar implements connected through revolute joints known as the boom, arm, and bucket, and one vertical revolute joint known as the swing joint . Kinematics is the science of motion which treats motion without regard to the forces that cause it. Within the science of kinematics one studies the position, velocity, acceleration, and all higher order derivatives of the position variables (with respect to time or any other variables). The excavator linkage, however, is a complex link mechanism whose motion is controlled by hydraulic cylinders and actuators. To program the bucket motion and joint-link motion, a mathematical model of the link mechanism is required to refer to all geometrical and/or time-based properties of the motion. Kinematic model describes the spatial position of joints and links, and position and orientation of the bucket. The derivatives of kinematics deal with the mechanics of motion without considering the forces that cause it

(2) LITERATURE REVIEW

There are four major area of work say kinematics, dynamics, soil-tool interaction and FEA and optimization on which the literature review carried out for development of kinematic model, dynamic model, utilization of soil-tool interaction model for resistive force calculations, FEA for strength based design and to develop optimized design of backhoe excavator attachment.

P. K. Vaha and M. J. Skibniewski (1993), have described the kinematics of the excavator with the coordinate frame. To describe the position of the points on the mechanism of an excavator, coordinate systems are first defined. A fixed Cartesian coordinate system is assigned to the body of the excavator. The local coordinate frames are assigned to each link of the mechanism. A systematic method to define the local coordinate systems for the serially connected links (upper structure, boom, arm, and bucket) of the excavator is accomplished by applying the Denavit and Hartenberg procedure. [1]

M. Bodur, H. Zontul, A. Ersak, A. J. Koivo, H. O. Yurtseven, E. Kocaozlan, and G. Pqamehmetolu (1994), have control the cognitive force for the automation of the land excavation is developed to include the kinematics of the excavator arm. During digging at a certain point on the excavation trajectory, both the crawler and the rotational super-structure bodies are stationary, and thus the kinematic model is reduced to 3 degree of freedom. [2]

A. J. Koivo (1994), presented the kinematics of specific construction machines as excavators (backhoes and loaders). A systematic procedure is presented to assign Cartesian coordinate frames for the links (joints) of an excavator. If the lengths of the actuators or the joint variable angles are given, the position and orientation (pose) of the bucket are determined by the forward kinematic equations. If the position and orientation of the bucket are specified, the joint variable angles corresponding to this bucket pose and the lengths of the actuators are calculated from the backward (inverse) kinematic equations. The corresponding velocity relations are derived for the hydraulically driven excavator (backhoe and loader). [3]

David A Bradley and Derek W Seward (1995) the LUCIE system has demonstrated a number of novel concepts in its approach to automated and robotic excavation and in particular features such as the use of velocity vector control and software force feedback to control the motion of the bucket through ground. The equations for angular velocities of each joint were developed. This structure is implemented in real-time using a production rule based AI format. They have control the movement of the excavator or LUCIE through ground by implementation of a real-time Artificial intelligence based control system utilizing a novel form of motion control strategy. [4]

C.F. Hofstra, A. J. M. van Hemmen, S. A. Miedema and J. van Hulsteyn (1999) described the kinematics of the backhoe of Komatsu H245S with a 12 m boom and an 8.5 m stick. This kinematics of backhoe utilized by them for the development of dynamic model. They have determined the relation between the machine orientation and the desired trajectory. In order to do this effectively while describing the position and orientation of the bucket the Denavit-Hartenberg (DH) approach based on homogenous co-ordinates is utilized. [5]

S.S. Rao and P.K. Bhatti (2001), have developed a probabilistic model of the manipulator kinematics to account for the random errors in the kinematic parameters in 2001. Based on the probabilistic model, kinematic performance criteria are defined to provide measures of the behavior of the robotic end-effectors. Gaussian distributions are assumed for the various manipulator parameters, and the joint efforts are modeled as Markov stochastic processes. Indices called kinematic reliabilities are proposed as measures to assess the performance of a manipulator. The analytical approach is computationally more involved and the simulation technique is numerically more convenient to compute the performance measures of a Manipulator. [6]

(3) MODELING AND VALIDATION

This section introduces the modeling of DDH components and their validation. The multi-domain systems were modeled using MATLABS link and Biomechanics, consisting of electrical, mechanical, hydraulic and control systems.

Mechanical model the front hoe of the micro excavator was dissembled, and the dimensions and weights of each component were measured (Table 6).After that, a multimode model of the micro excavator was built in PTCCreo. The dimensions and weights of the selected hydraulic and me-chancel components were utilized in the mechanical model of DDHunits based on their specifications, including two pump/motors, one hydraulic accumulator, one electric motor, pipes and fittings, and structure for attaching them. The weight distribution of each DDH unities presented.

In the full model of the excavator's front attachment, the DDH units were mounted in the existing holes of the boom and arm structures.

The boom and arm DDH were symmetrically fixed to the lower part of the boom structure, and the bucket DDH was installed on the head part often arm structure.

(3.1) WORK SMART

(3.1.1) the new cabs are fully ROPS and FOPS compliant, for increased protection laminated glass is available as an option.

(3.1.2) all services, including tracking and dozer, are isolated when the control pod is raised as an additional safety precautionary measure.

(3.1.3) a lockable internal toolbox provides safe tool stowage on all models. Optional operator presence and seat belt isolation switches for increased on site safety.

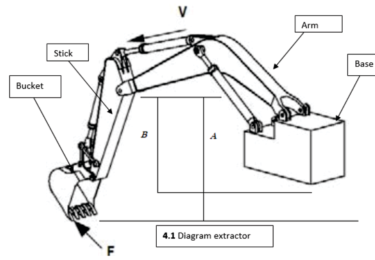
[3.2] SAFELY

(3.2.1) Optimum seat position with large glass area and bodywork design combine to give excellent all round visibility for increased on site safety. As a result, all models do not require mirrors to meet EU regulations.

(**3.2.2)** JCB's unique 2GO system gives an additional layer of safety meaning all controls are fully isolated unless the 2GO button is activated.

(3.2.3) a key benefit of the live link and immobilizer combination is the remote pin code management system.

(4) MATHEMATICAL FORMULATION



4.1 Diagram extractor

In the diagram(4.1) above, A represents the height to which the load is lifted before being released over the dump truck and B represents the distance the load falls before it hits the bed of the dump truck. In this exemplar, let us assume these values to be A = 2.5 m and B = 1.5 m. The bed of the dump truck can be considered as a mass spring-damper system where the mass of the truck bed, tm = 2000 kg, the effective stiffness, t k = 50,000 N/m and the effective damping, t c = 3500 Ns/m. The mass of the load can be taken to be, ml = 500 kg.

The static deflection (i.e. where the bed will rest when equilibrium is established) can be calculated by assuming that the additional weight due to the load is equal to the stiffness of the system k , multiplied by the deflection of the truck bed x , hence:

$F = kx$

$\Rightarrow mg = kx$

Rearranging the terms and substituting the known values, we get:

$$x_{t,static} = \frac{m_l g}{k_t} = \frac{500 \times 9.81}{50{,}000} = 0.0981\text{m} = 9.81\text{cm}$$

However, in order to calculate the maximum displacement of the system when the load is released onto the truck bed, we need to use the following equation involving the displacement of the bed of the dump truck (please note that the derivation of this equation involves complex engineering dynamics which is beyond the scope of your syllabus, but the application of the result is all that is being considered here):

$$x(t) = \frac{\sqrt{\left(v_t + \xi \omega x_{t,static}\right)^2 + \left(x_{t,static}\omega_d\right)^2}}{\omega_d} e^{-\xi \omega t} \sin(\omega_d t) \quad \ldots (1)$$

where:

$x(t)$: displacement of the truck at time t (m)

v_t : velocity of the truck bed on impact (m/sec)

ω : natural frequency of the truck bed (radians/sec)

ξ : damping coefficient

ω_d : damped natural frequency (radians/sec)

These variables are related through the following relationships:

$$\omega = \sqrt{\frac{k_t}{m_t}} \quad \ldots (2a)$$

$$\xi = \frac{c_t}{2\omega m_t} \quad \ldots (2b)$$

$$\omega_d = \omega\left(1 - \xi^2\right) \quad \ldots (2c)$$

Substituting all the known values and using the calculated values as soon as they are available, we get:

$\omega = 5$ radians/sec,

$\xi = 0.175$, and

$\omega_d = 4.847$ radians/sec.

Since the dropping of the load, and hence the impact on the bed of the truck is very quick, the transfer of momentum as the load strike the truck bed can be treated as an impulse. The momentum of any moving object can be defined as: Momentum = mass × velocity ... (3) In the case under discussion, the impulse sue to the load is therefore:

$$I_l = m_l \times v_l$$

Here, I_l represents the momentum of the load and v_l is the velocity of the load on impact which can be found by assuming that all the potential energy $PE = m \times g \times h$ lost as it falls through the height $h_l = B = 1.5$ is converted into kinetic energy $KE = \frac{1}{2}mv^2$, i.e.

$$PE = KE$$

$$\Rightarrow m_l \times g \times h_l = \frac{1}{2} m_l v_l^2$$

Rearranging the terms and substituting the known values, we get:

$$v_l = \sqrt{2 \times g \times h_l} = \sqrt{2 \times 9.81 \times 1.5} = 5.425\text{m/sec}$$

Furthermore, to find the velocity of the bed of the dump truck, we can apply the principle of conservation of momentum, which states that the momentum of the mass just before impact is completely transferred to the momentum of the object under collision. Using this principle for load and truck bed, we can write:

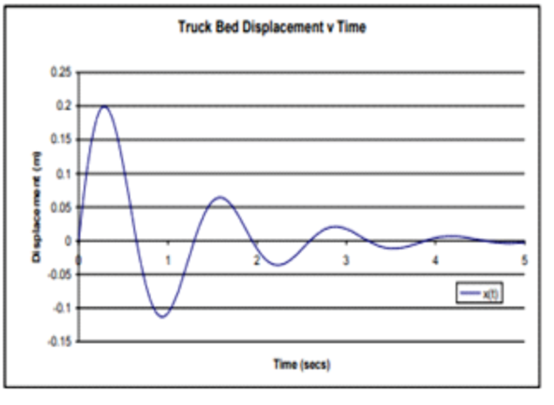
$$m_l v_l = m_{t,loaded} v_t \quad \ldots (4)$$

Here, $m_{t,loaded} = m_t + m_l$, of course.

Rearranging the terms and substituting the known values, we get:

$$v_t = \frac{m_l v_l}{m_{t,loaded}} = \frac{500 \times 5.425}{2000 + 500} = \frac{500 \times 5.425}{2500} = 1.085\text{m/sec}$$

The maximum displacement of the truck bed can now be calculated using equation (1). The right-hand side of equation (1) contains the product of the sine function and an exponential function where both vary with time. A graph of the resulting variation of the displacement x_t with time is shown in the following figure:



(5.1) Useful in construction and mining industries.
(5.2) Lift heavy weights and work in rough environments with easy.

(5.3) Capable of moving in horizontal directions.

(6) DISADVANTAGES:
(6.1) Expense
(6.2) Oil Problems
(6.3) Filters
(6.4) Leaks

(7) APPLICATION

(7.1) These heavy duty machines to lift heavy weights and work in rough environments with ease.

(7.2) Here proposed project provides a working hydraulic excavator mechanism used for digging, mining, and construction industry.

(7.3) It is also use in commercial work.

(8)EXPECTED OUTCOME

(8.1) the presented work concentrated on analyzing the possible improvements in an electro-hydraulic micro excavator with the application of zonal hydraulics.

(8.2) the efficiency behavior for electro-hydraulic zonal system components and the cycle efficiencies of the DDH systems were determined.

(9) REFERENCES

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