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DYNAMICS ANALYSIS AS RIGID BODY OF A 4-DOF HYDRAULIC EXCAVATOR-BACKHOE AS A MULTIBODY

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Abstract: *An excavator is an off-road vehicle or machine used for various types of construction work. It comes with an attachment called an excavator that is commonly used for excavation. During excavation, the force of the earth acts on the tip of the blade, causing deformation. In this paper, an attempt is made to quantify the values of the variables obtained while considering the backhoe loader as a multibody rotating at each joint and simulating it in Ansys. The results obtained show that the deformation obtained is small at low rotation and large at high rotation. Comparisons of deflections, joint forces, and velocities for each rotation set were aggregated in the x, y, and z directions, and total velocities, total joint forces, and deflections were also calculated. This white paper provides a foundation for researching and designing deformable multibody systems to achieve exactly the desired end result in precision tools and machines.*

Keywords- Design, simulation, deformation.

1. INTRODUCTION

Backhoe loaders are used for a variety of tasks including construction, demolition and simple moving of construction materials. Excavator backhoe loader includes hydraulic cylinder, boom, arm and bucket. Instead of pushing the material forward, the backhoe pulls the dirt back towards the machine body [1]. The working conditions of excavators put parts such as buckets, arms and booms under high stress. During drilling, there is an unknown resistance force with which the earth opposes the teeth of the bucket. Several studies have been conducted related to the design and performance of various parts of the excavator [2-6]. In this paper, we treat all attachments as individual bodies and consider the deformation process when the joints are rotated. Since the fastener material is flexible and stretchy, there should be some deformation due to its own weight and the center of gravity moment of each part. The excavator dynamics shows its efficiency. In order to improve excavator performance, excavator models are developed based on virtual prototyping technology, similar to building visual prototypes.

Fig 1 Backhoe Loader

Simulation process

The traditional design process involves laboratory testing that mimics a visual prototype to test excavator functionality. Ansys finite element analysis, the simulation of virtual prototypes for product design, has become an important tool. Modern design processes allow virtual simulation to test excavator performance prior to final design and deployment. Virtual prototype technology reduces the cost of the product development cycle, predicts product performance and provides a foundation for further product development. The following steps are used for the simulation.

Step 1-Building 3-D CAD model.

For this purpose, an excavator model of the excavator was actually measured on site by JCB-ECO Expert 3Dx and a composite CAD model was developed in Solidworks using the dimensions obtained in this way. The model was imported into Ansys 19.2 and saved. The simulation is run at different joints with different sets of rotation angles.

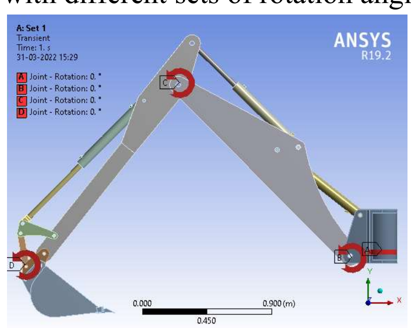

Fig 2 CAD model

Step 2- Adding the property of materials and constraints.

Material properties of parts are added according to actual working conditions. The assumed material is mild steel, which is ductile and can be used for both rigid and soft body dynamics analyses. Determine the bucket mass - 30.181 kg, the arm mass - 58.914 kg, and the boom mass - 102.06 kg

Object Name	Geometry
State	Fully Defined
Definition	
Source	E:\Alok Sir Analysis\ak_files\dp0\SYS-15\DM\SYS-15.agdb
Type	DesignModeler
Length Unit	Meters
Display Style	Body Color
Bounding Box	
Length X	2.6433 m
Length Y	1.962 m
Length Z	0.44467 m
Properties	
Volume	5.0007e-002 m³
Mass	392.55 kg

Fig 3 Material Properties

Step 3- The establishment of a rigid body

The assembly as a whole is assumed to be rigid and the desired stiffness properties are assumed to be rigid.

Object Name	STICK	BUCKET_18 BUCKET 2.29CU. FT.	PIVOT BUCKET LINK	BUCKET LINK_SHORT	2.5X30 X1.25 DA HYD CYL	2.5X30 X1.25 DA HYD CYL inner shaft	BOOM	2.5X20 X1.5 DA HYD CYL	2.5X20 X1.5 DA HYD CYL inner shaft	BOOM TURRET	BOOM TURRET
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Rigid										
Reference Temperature	By Environment										
Material											
Assignment	Structural Steel										

Fig 4 Establishment of Rigid body and meshing.

Step 4- Finite element meshing

The tetrahedral element is selected for meshing and meshing is performed.

Step 5- Simulation Results & Analysis After simulation, the Ansys post-processing module is used to continue the simulation results to obtain the system's laws of motion and dynamic curves. Finally, its dynamic performance is recorded.

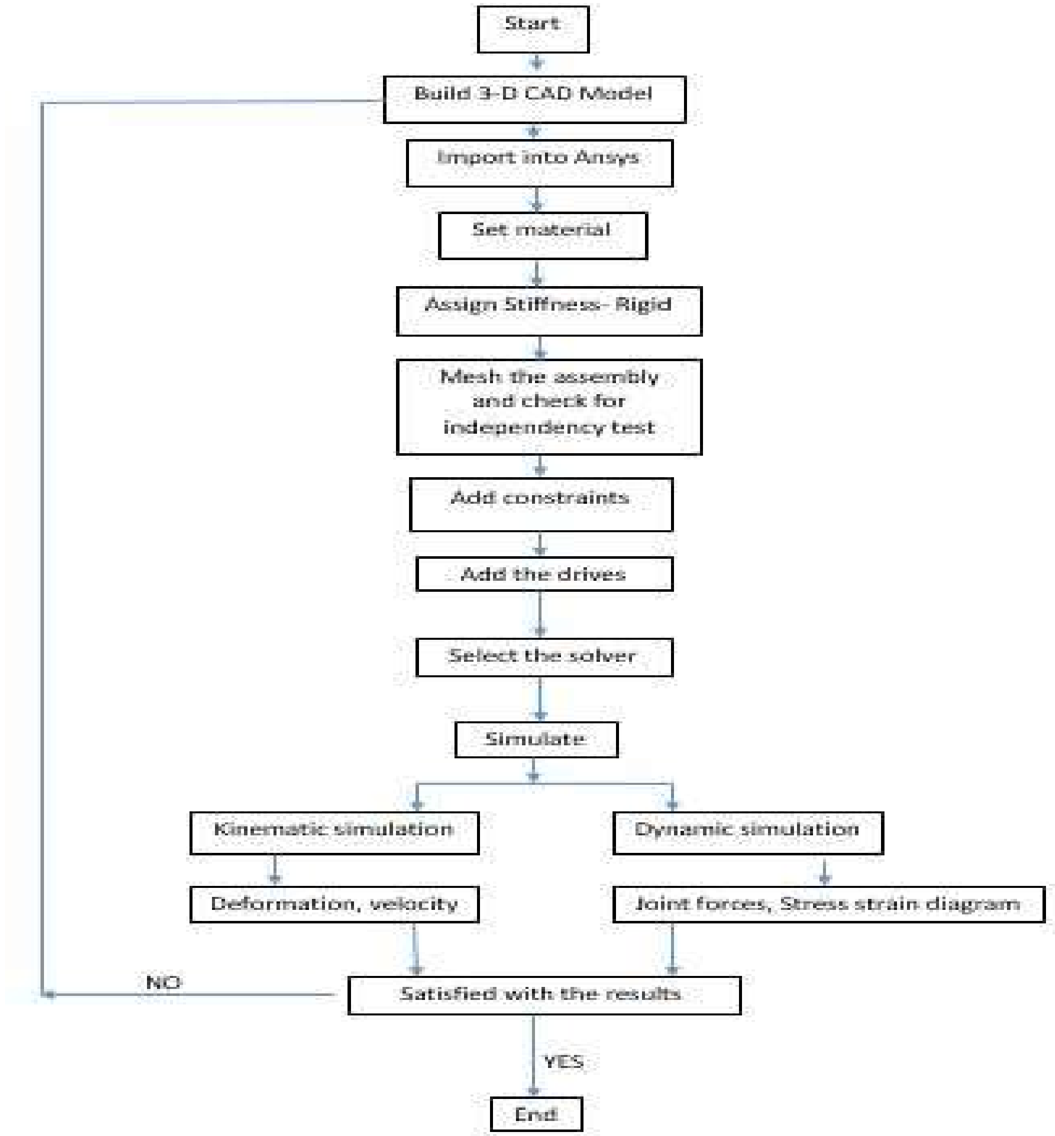

Fig 5 Block Diagram for Simulation Process.

Rigid-body dynamic simulation

(a) Pre-dynamic simulation-After meshing and independence testing of the assembled model, the initial positions of the parts are assigned and a user coordinate system is assigned to each joint.

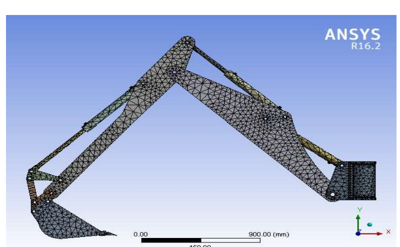

Fig 6 Assembled Model Meshed

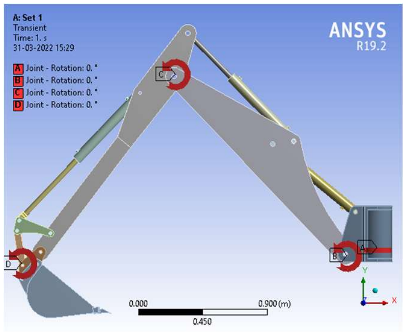

Fig 7 Initial user coordinate set at all 4 joints

(b) Set of Angles-

The simulation is performed at the following 15 sets of angles provided as input for different joints.

Joint A	**Joint B**	**Joint C**	**Joint D**
0	5	5	5
0	10	10	10
0	15	15	15
5	0	5	10
5	5	0	15
5	10	15	0
5	15	10	5
10	0	10	15
10	5	15	10
10	10	0	5
10	15	5	0
15	0	15	5
15	5	10	0
15	10	5	15
15	15	0	10

This paper chooses the simulation time as 25 sec and the step size is 1 sec.

(c) **Results obtained-**

Results for various sets of angles are compared via graphs.

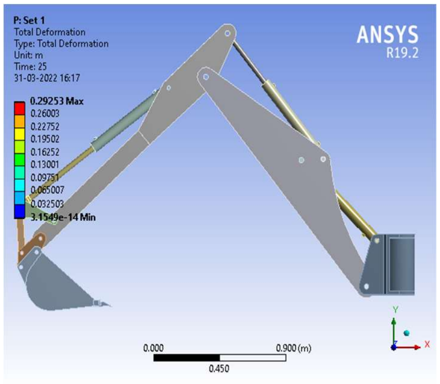

Fig 8 Deformation obtained for set 1.

(i) Results for joint forces-

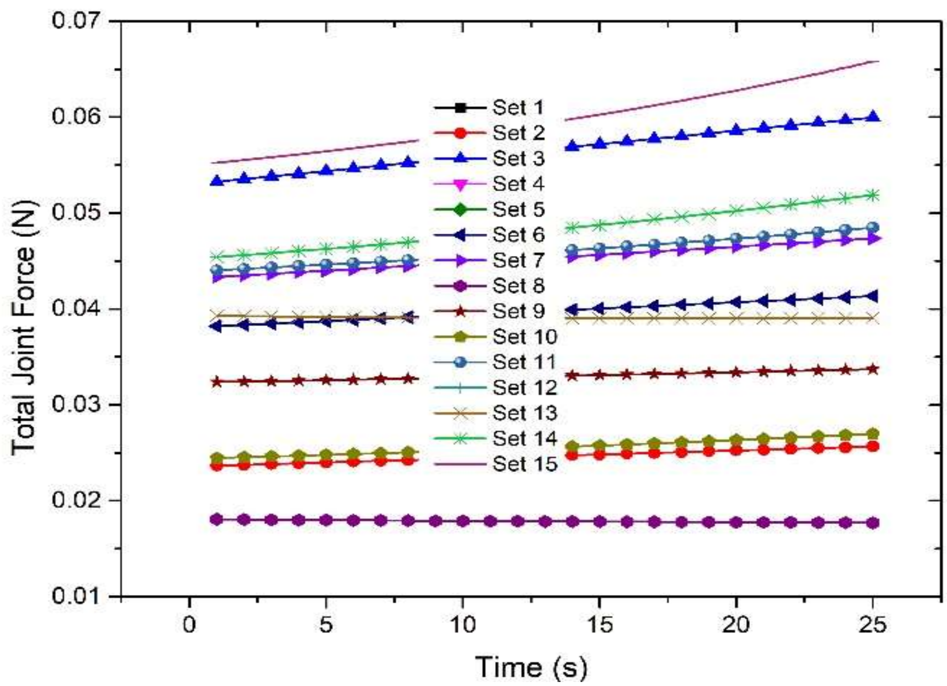

Fig 9 Total joint force

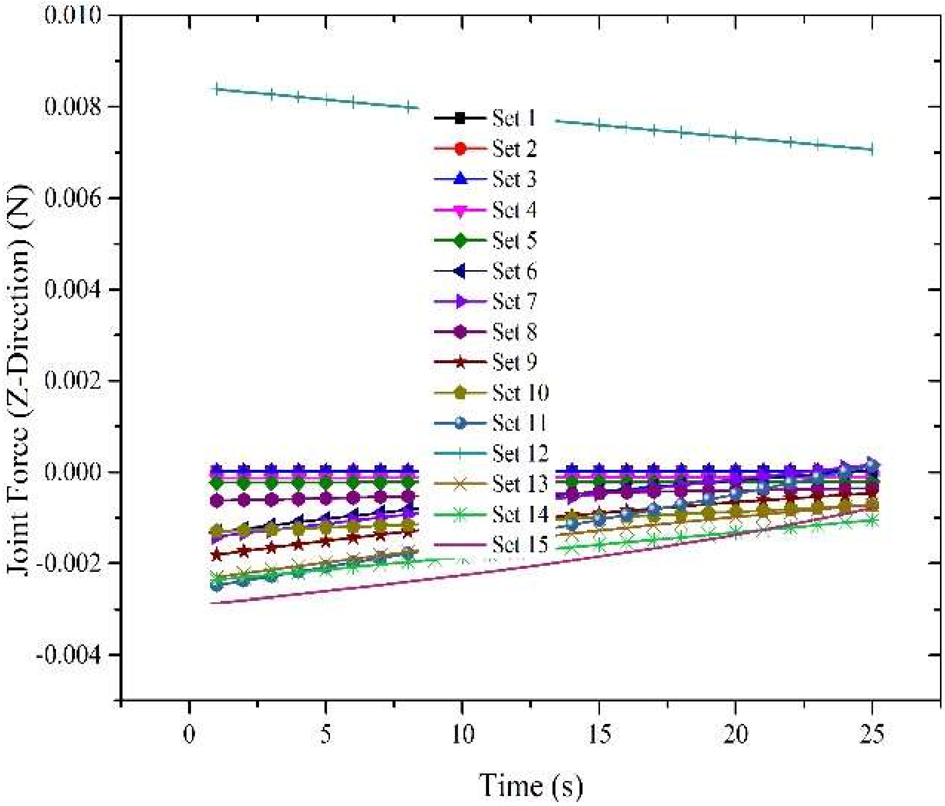

Fig 10 Joint force in Z- direction

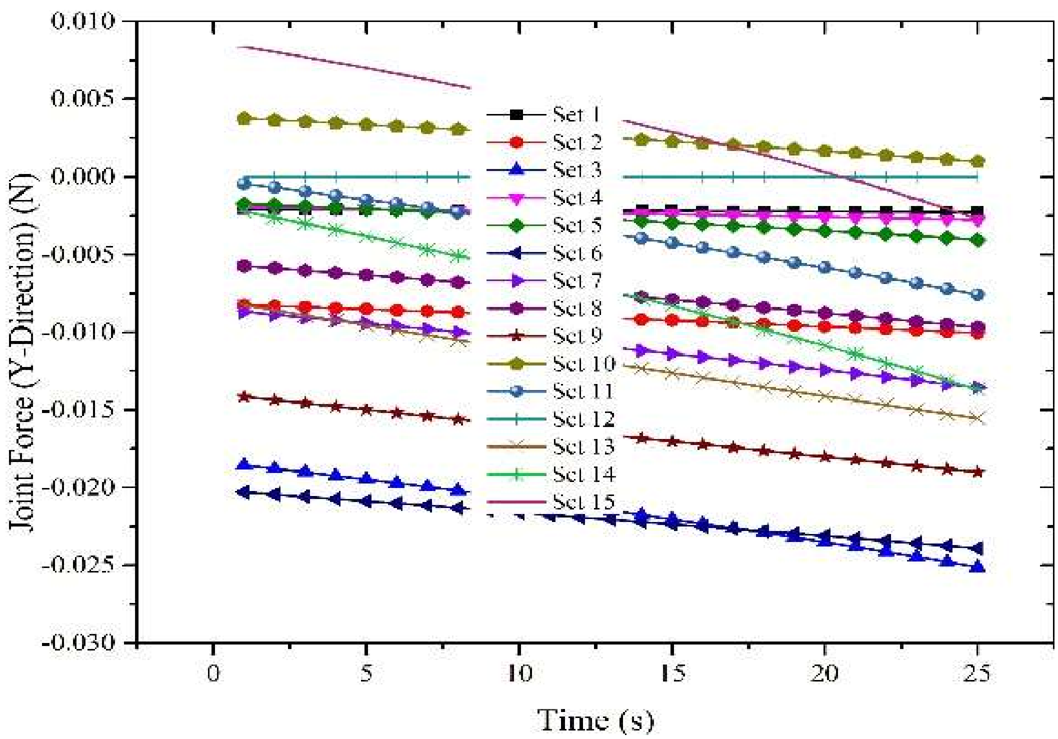

Fig 11 Joint force in Y- direction

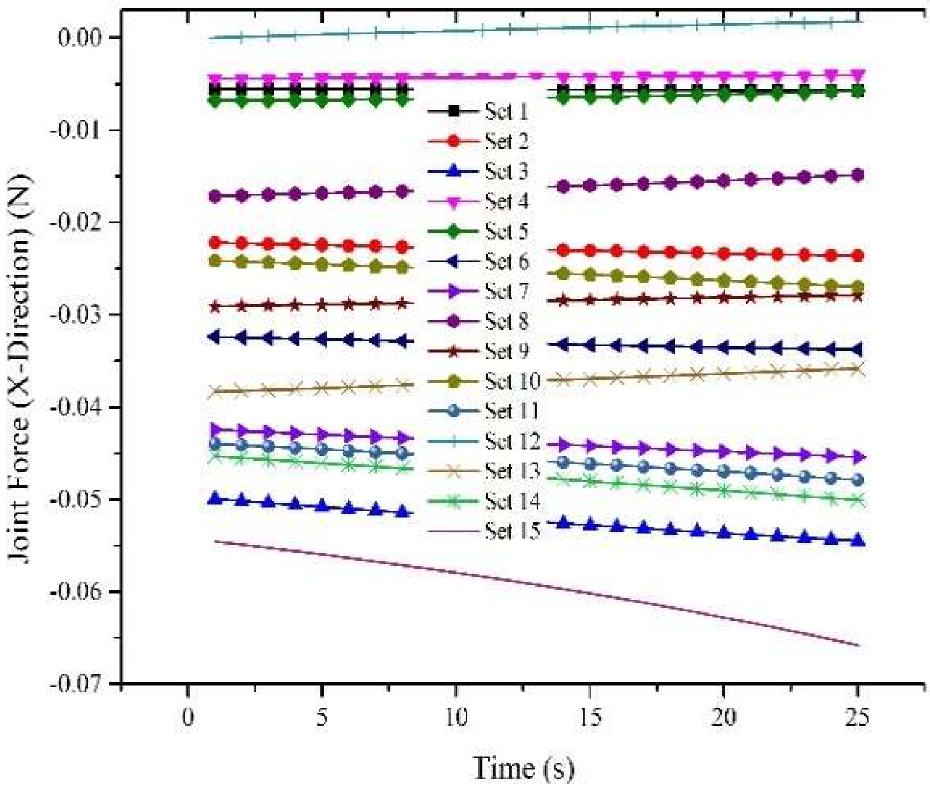

Fig 12 Joint force in X- direction

(ii) Results for Velocity-

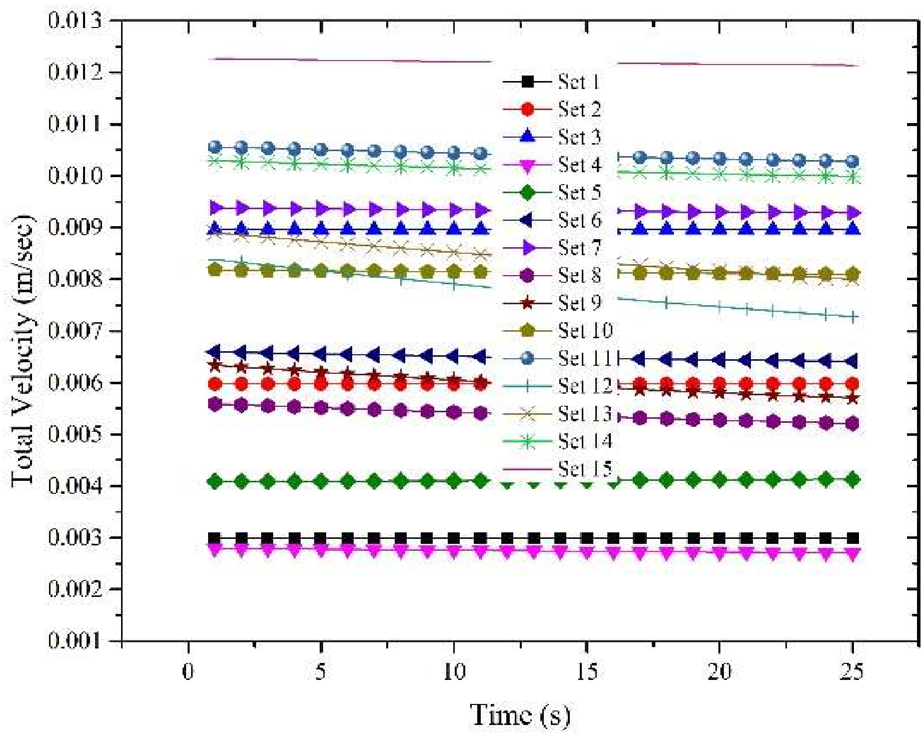

Fig 13 Total velocity

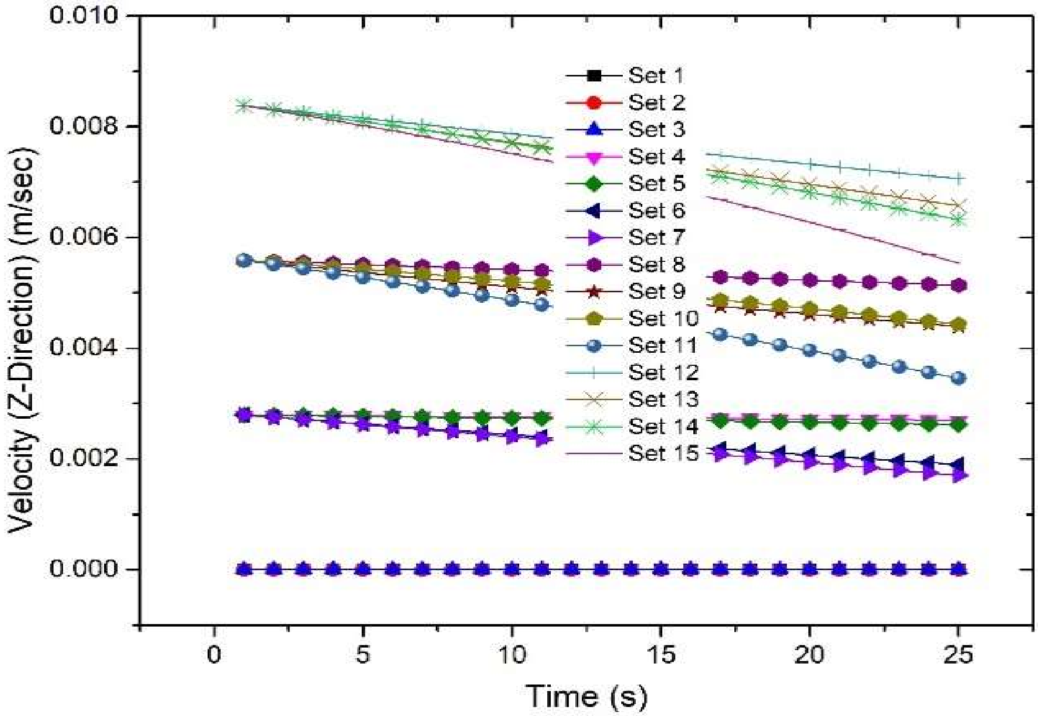

Fig 14 Velocity in Z-direction

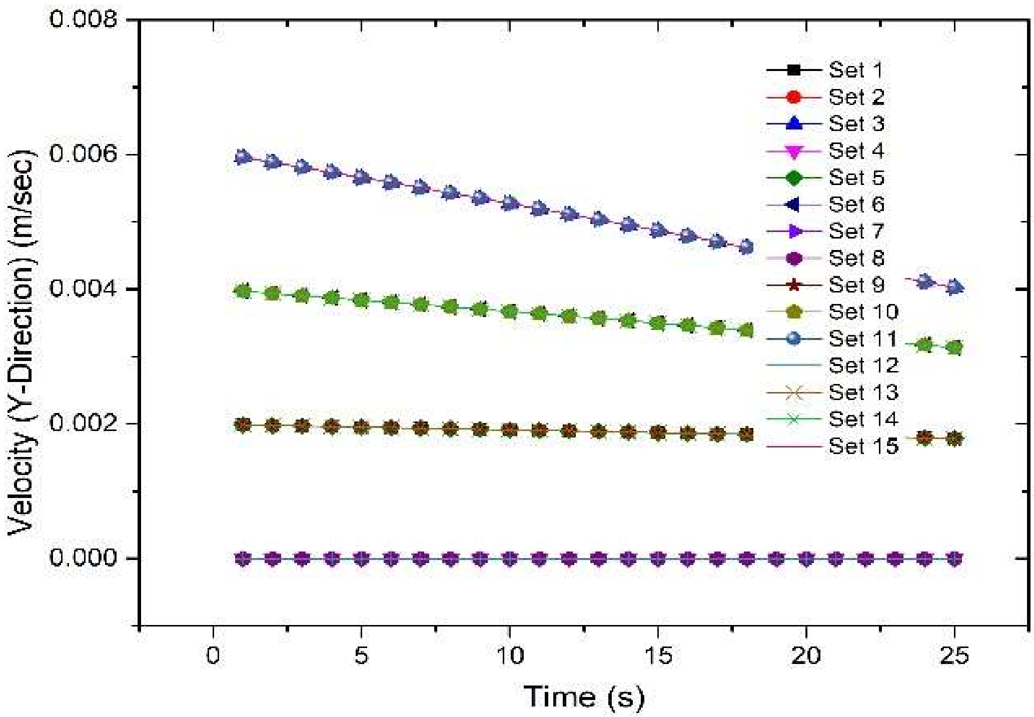

Fig 15 Velocity in Y-direction

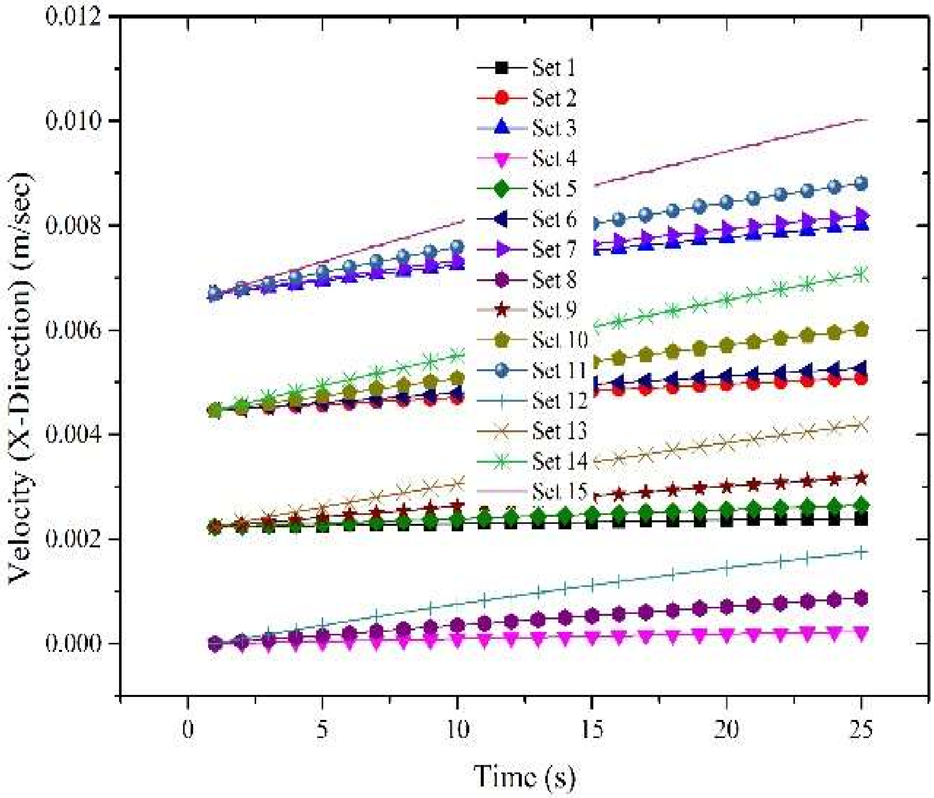

Fig 16 Velocity in X-direction

(iii) Results for deformation-

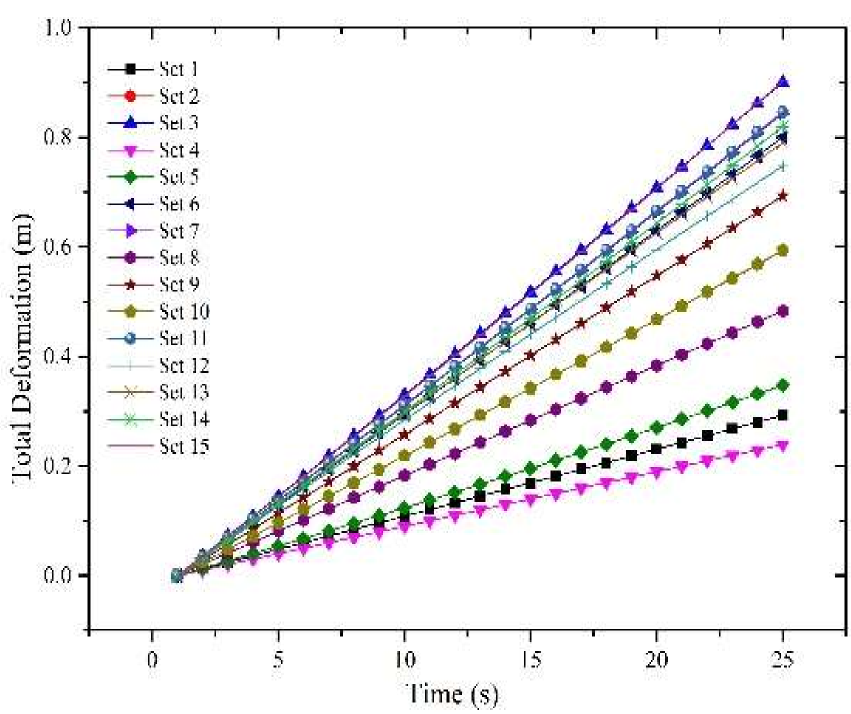

Fig 17 Total Deformation

Conclusion

This white paper uses virtual prototyping to validate the need for rigid dynamic simulation of excavators.

• First, the model was created in Solidworks and assumed to be a rigid body. The model is simultaneously simulated with a boom, dipper stick, and bucket.

• Second, the total joint force, velocity and deflection across the boom, dipperstick and bucket are determined.

• Third, by comparing the results at different sets of angles, we conclude that set 4 has the smallest total deformation and set 7 has the largest deformation. Also, the total joint force obtained was lowest in set 8 and highest in set 15. The velocity obtained was greatest in set 15 and least in set 4. Simulated

• minimum and maximum values at key locations were compared with mathematically calculated values obtained from the formulated equations of motion [7].

• If you consider the dipperstick and boom as flexible objects, you also get different forces. Again, comparisons can be made to further investigate the characteristic behavior of the materials. An overall comparison can then be made to find the difference between two conditions (stiffness and flexibility) that can predict material behavior.

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