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Design and development of an ejecting mechanism to remove clogged soil effectively from excavator buckets

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Abstract: *Excavators play a crucial role in construction, mining, and agricultural applications, but soil clogging in extended buckets often reduces efficiency and increases operational downtime. This research focuses on the design and development of an ejecting mechanism to effectively remove clogged soil from excavator buckets, improving productivity and reducing maintenance efforts.*

The study involves analyzing soil adhesion properties, bucket geometry, and force requirements for effective ejection. A mechanical and hydraulic-assisted ejector system is designed and simulated using Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD) to evaluate its performance. The proposed mechanism is tested under various soil conditions (wet, sticky, and compacted) to assess ejection efficiency, cycle time reduction, and energy consumption.

The results indicate that the ejector mechanism significantly reduces clogging, enhances continuous digging operations, and minimizes operator intervention. This research contributes to the advancement of excavator technology, making it more efficient and adaptable for challenging soil conditions in construction and earthmoving industries.

Keywords: *excavator, bucket, adhered, soil.*

I. Introduction

Although excavators are used mostly for construction purpose, they have various other applications also like digging and maintenance of rivers, canals, ponds, drainages, etc. Excavators used in such operations have longer arms so as to achieve greater area of approach. They are used for distant digging operations. Such machines are called as „Long-Reach Excavators". These have comparatively smaller capacity buckets and so soil compaction occurs more in them. While digging near riverside or canals, soil is mostly wet, forming lumps of about 1-1.5 kg. (See figure 1).

Figure 1: Bucket with adhered soil

Such lumps remain attached to inner-plates of bucket because of adhesion between soil and metal. M. Khan (2010), in his literature explains that soil adhesion increases with increase in moisture content [1]. These lumps are not easily removed during unloading stage of bucket. If this adhered soil is not removed, then it will reduce intake capacity of bucket during further digging operations. So, to remove this, mostly operators hit the bucket over its teeth against ground on some hard object like stone. This makes bucket teeth dull and sometimes they brake (See figure 2) [2].

Figure 2: Bucket with damaged teeth

Further due to such hitting (called as jerking), actuators of bucket damage. Operators maintenance cost and downtime increases and bucket needs earlier replacement. This reduces overall efficiency of bucket and machine (Vivek Ramsahai, 2011) [3].

This gives us the need for design and development of soil ejecting mechanism in buckets. Implementation of such mechanism will make bucket operations easy.

II. Literature Survey

Researchers have studied on this concept and developed some mechanisms [4]. Some of them are as below:

2.1 Excavator Bucket with Soil Ejector

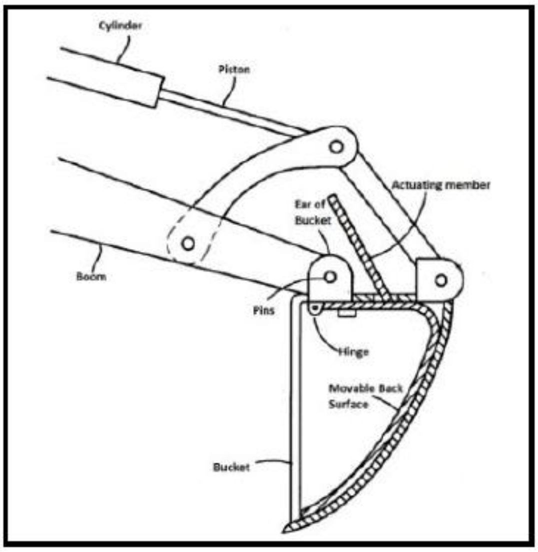

Figure 3: Mechanism

George W. King (2004), suggested this mechanism. See figure 3 [5].

Here movable back surface of the bucket defines the loading and unloading stages as shown. This movable surface is the soil ejecting plate here which is supported with bolt and spring arrangement. When it gets actuated with the actuating member, it removes soil by moving in between the front and back positions (see figure 4) [5]. When rod attached to ejecting plate gets locked at a certain position, the plate moves forward and so the dirt is removed.

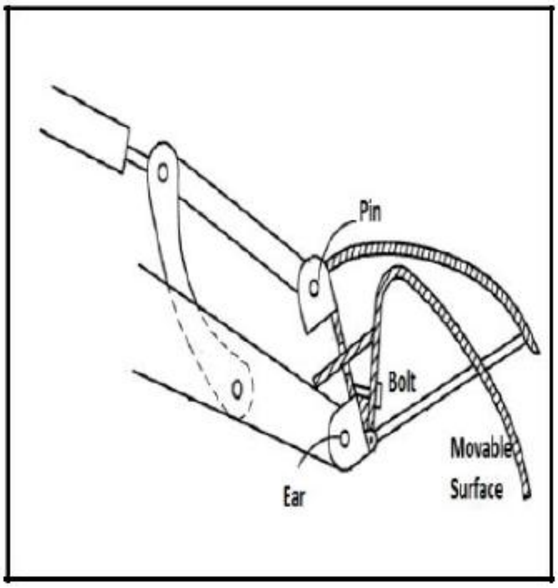

Figure 4: Working

2.2 Self Cleaning Bucket

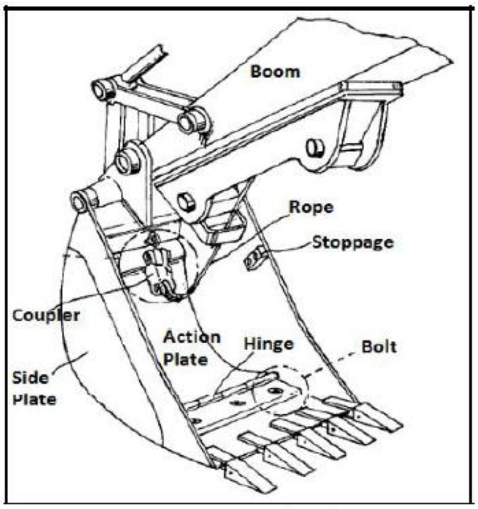

Figure 5: Mechanism

Daniel Ammons (2007) suggested this mechanism. See figure5 [6]:

Here bucket is accompanied with ejecting plate whose one part is fixed with bolts and other part is hinged and the swinging one. One end of rope is attached to swinging part with the coupler and other end is fixed on arm with bolts.

When rope tightens with the movement of arm, ejecting plate comes out and mud attached to it gets removed. Stopper is provided to control movement of ejecting plate (see figure 6) [6].

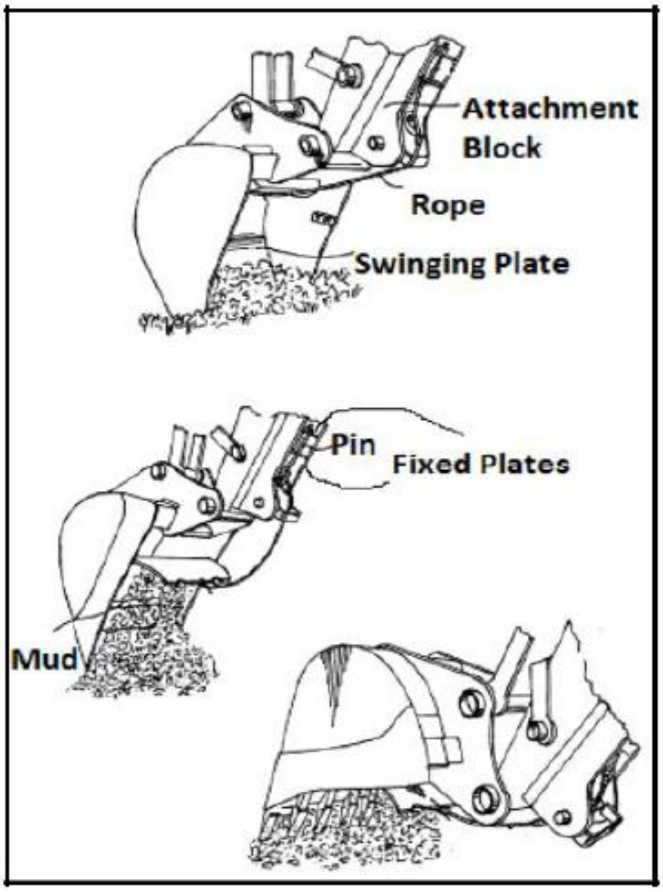

Figure 6: Working

2.3 Bucket with Soil Ejecting Plate as Wiper

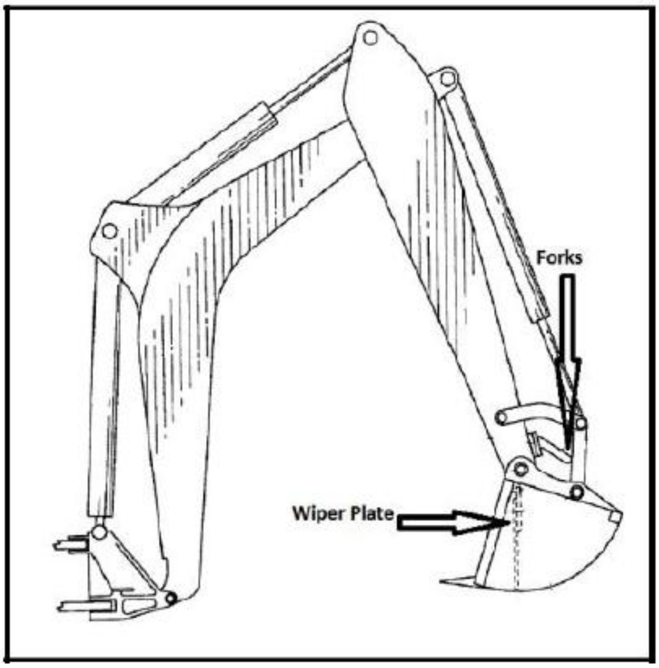

Figure 7: Mechanism

Gene Klager (2001), suggested this mechanism. See figure 7 [7].

Here, soil ejecting plate in the shape of wiper works with the fork attached to it as shown. Locking position of fork, moves wiper from back end to front position and so, the purpose is achieved (see figure 8) [7].

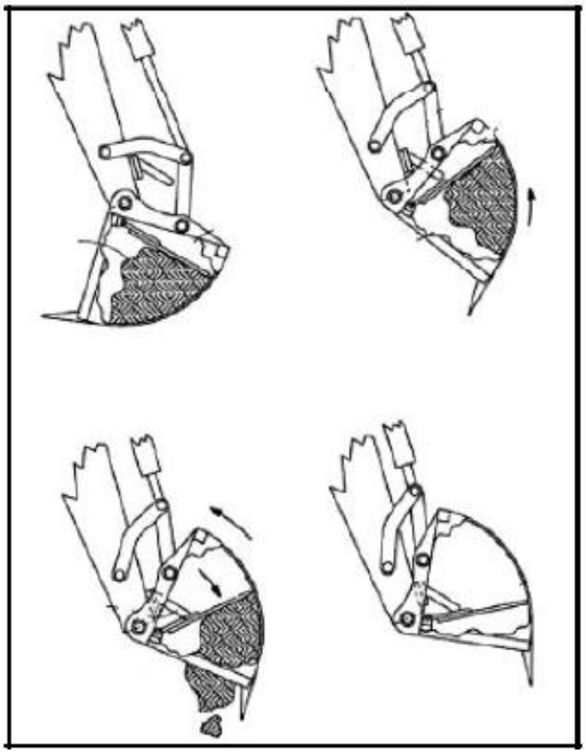

Figure 8: Working

III. Spring-Plunger Mechanism

3.1 Concept

Excavator bucket has two side plates and one curved plate. This mechanism consists of a soil ejecting plate in the shape of bucket"s curved plate (see figure 9).

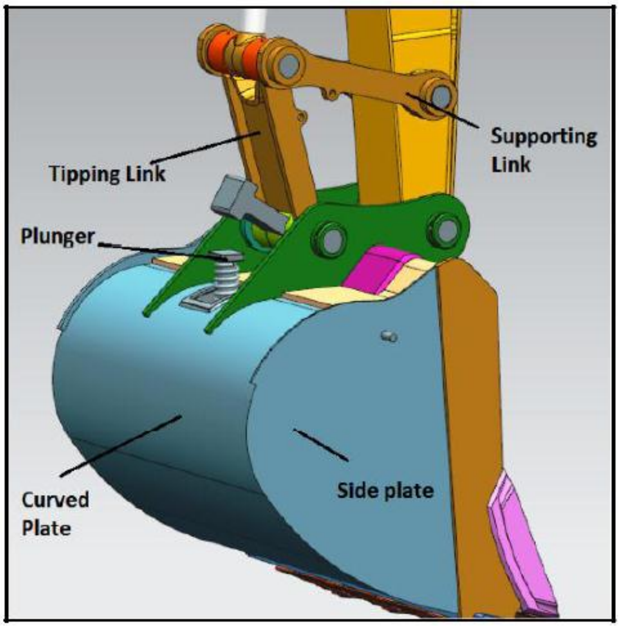

Figure 9: Concept

The plate is supported with one hinged rod. This rod moves plate within bucket‟s size. One bracket is made in bucket which is welded to bucket‟s surface. Ejecting plate is connected with plunger and spring. Bracket in the bucket is provided for resting of spring. A pusher is welded on tipping link of arm about which bucket rotates during curling-uncurling operation. This pusher forces the plunger head during the unloading operation of bucket (see figure 10). Force applied by pusher should be greater enough so as to rotate plate.When pusher applies force on plunger head, spring of plunger compresses and ejecting plate rotates about the hinged rod. Due to this, end of ejecting plate will go on shearing the soil attached to bucket. And so, all the mud will be removed. Again, when bucket moves in loading or digging position, spring extends back and so, the ejecting plate moves back and remains attached to bucket. For this arrangement

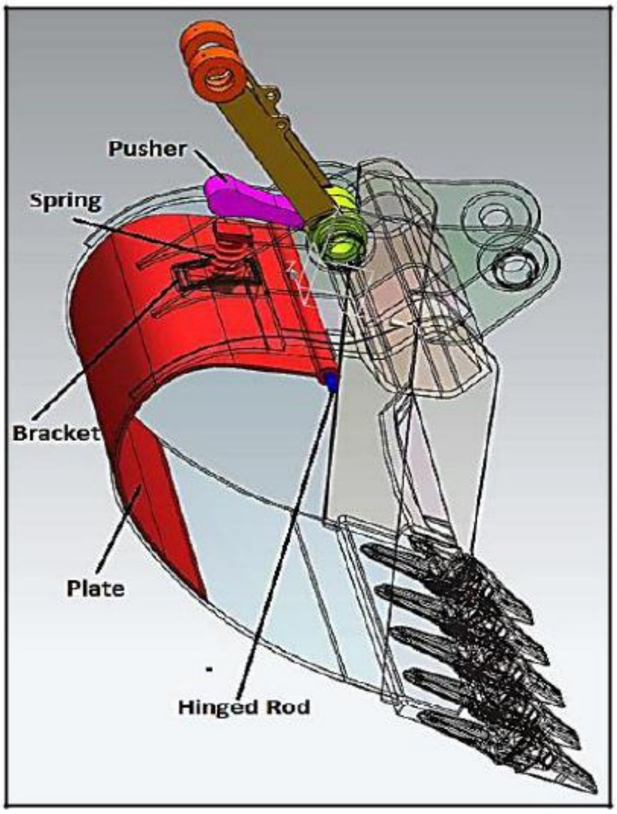

Figure 10: Mechanism

Hinged rod is utilised so as to give support to ejecting plate.

Ejecting plate thickness = 8 mm.

Mass of Mechanism = 90 Kg.

Bucket‟s capacity = 1100 Kg.

Volume Consumed by Mechanism = 1.8 %

Mass added on Bucket because of mechanism = 13.4 %

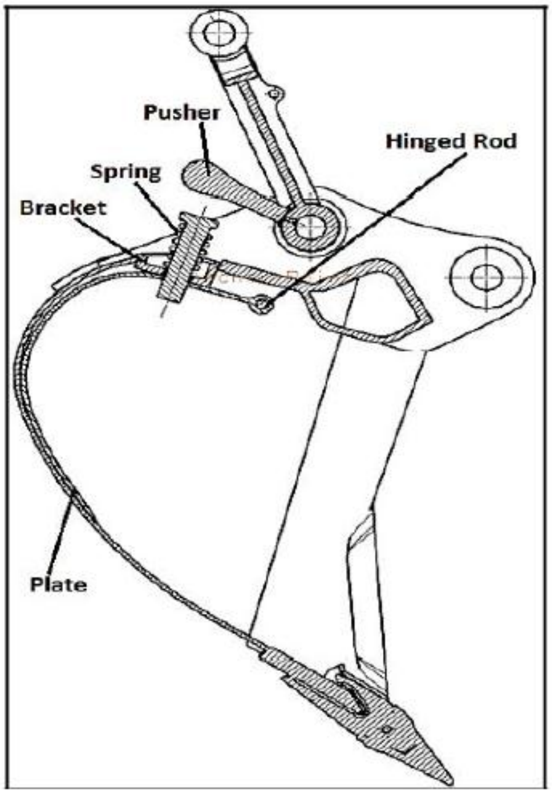

Figure 11: Sectional view

3.3 Theoretical Calculations

- **Force Required for Shearing Adhered Soil**

This is calculated from Mohr-Coulomb Equation:
$\tau = \alpha + \sigma \tan \mu$ (1) [8]

Where, τ is the shear stress required to eject adhered soil , σ is normal stress due to soil‟s weight, μ is external friction angle. Bowden and Tabor equation defines normal stress σ on friction plane as below (see table number 1 and 2):

$N = \sigma AR$ (2) [9]

Where, N is normal force due to soil‟s weight, AR is the real contact area between soil and metal.

Table 1: Calculation for weight of adhered soil

Density of Wet Soil (ρ)	Volume of Soil (V) Considering c/s of Plate	Mass of Soil (m) = ρ × v	Weight of Soil (N) = m × 9.81
1905 kg/m^3	0.052 m^3	100 kg	1000 N

Calculating Normal Stress from equation (1).

Table 2: Calculation for Normal Stress

Weight of Soil (N) = m × 9.81	Contact Area (AR), Considering Inner Bucket Surfaces	Normal Stress (σ) =N/AR
1000 N	1.65 m^2	606 N/m^2

Calculating Shear Stress from equation (2). See table number 3.

Table 3: Calculation of Shear Stress

Adhesion Coefficient (α)	Normal Stress (σ)	External Friction Angle (μ)	Shear stress to avoid adhesion (τ) = α + σ tan μ
12020 N/m^2	606 N/m^2	23.5^0	12283 N/m^2

External Friction Angle (μ) = 23.5^0 [10].

(Shearing Force to be provided by Plate = σ × Area

to eject soil adhered of aroun 100 Kg .) **=** 12283 × 1.65

= 7444 N

Shearing Force on Plate-end = 7.4 KN (3)

- **Force to be applied by Pusher**

All the force will be applied by pusher when the piston of bucket cylinder will be fully retracted. Force applied by pusher should be greater than force required for shearing adhered soil.

Force applied by bucket cylinder in retraction is 113 KN.

So, calculating the force on pusher from force triangle law as below (see figure 12):

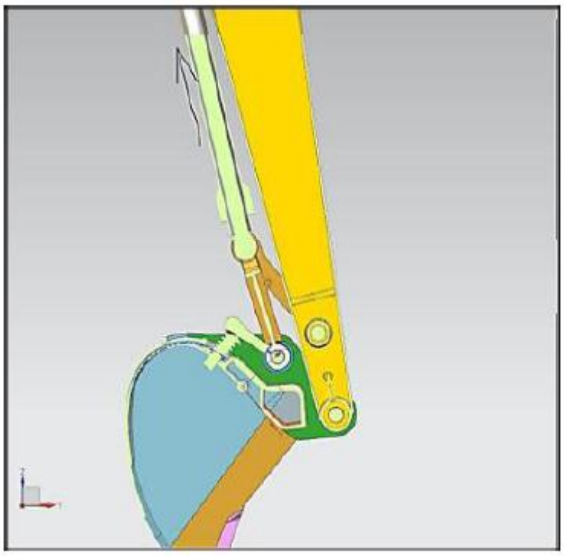

Figure 12: Force during retraction of cylinder piston

The direction in figure gives the force during retraction of piston of bucket cylinder. Now, calculating the force on pusher as below (see figures 13, 14):

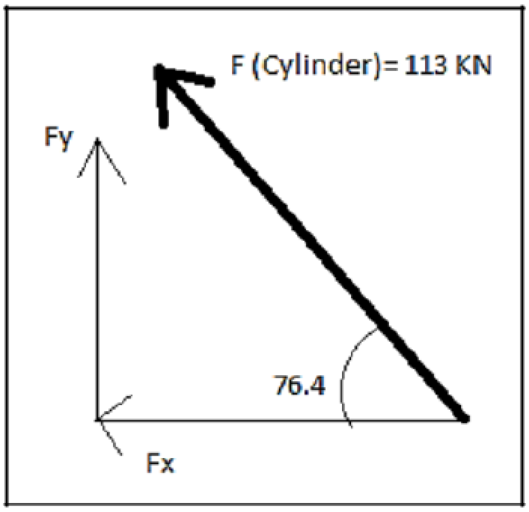

Figure 13: Force calculation

$$Fx = \cos(76.4) \times 113 \times 1000 = 26.5 \text{ KN}$$

$$Fy = \sin(76.4) \times 113 \times 1000 = 109.8 \text{ KN}$$

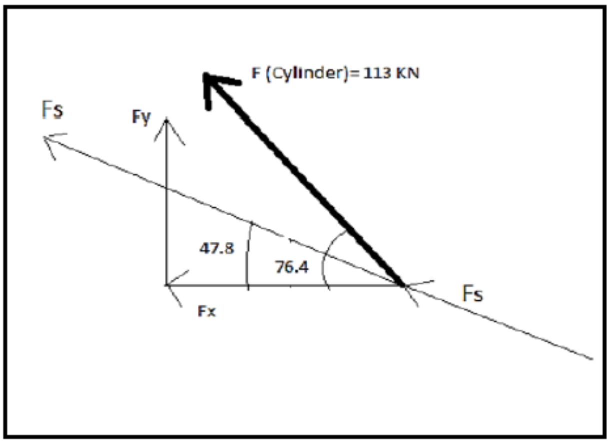

Figure 14: Force calculation

Fs = Force in supporting link
Fx= cos(47.8) × Fs , Fs= 26.5 / cos(47.8)= 39.4 KN
F(Cylinder) = F(Tipping Link) + F(Supporting Link)
F(Tipping Link) = 113 – 39.4 = 73.6 KN = 7.36 Tons
F (theoretical) = 7.36 Tons (4)
So, around 7.36 Tons of force is to be applied by pusher.
From (3) & (4), it is clear that pusher force is greater than shearing force. So, theoretically mechanism is correct.

- **Spring Design**

Spring being attached to the plunger should be sufficiently stiff enough to absorb impact of pusher.

Load which spring has to carry during compression = mass of adhered soil + mass of plate + mass of hinged rod and spring itself with plunger.
Considering wet soil density as 1905 kg/m^3 [11]:
And mass of adhered soil as 100 Kg., this load comes to be 3838 N.

See Figure 15.

So, Spring Force = 4000 N

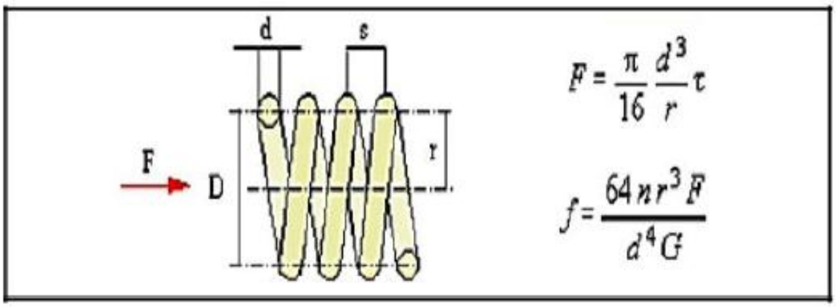

Figure 15: Spring Formula

D = Mean Coil Diameter = 62 mm
d = wire diameter = 10 mm
Number of active coils = 5
Deflection = 48 mm

3.4 Finite Element Analysis

- **Validating Force on Pusher**

Calculation of force on pusher by applying force on cylinder in retraction as 113 KN (see figure 16):

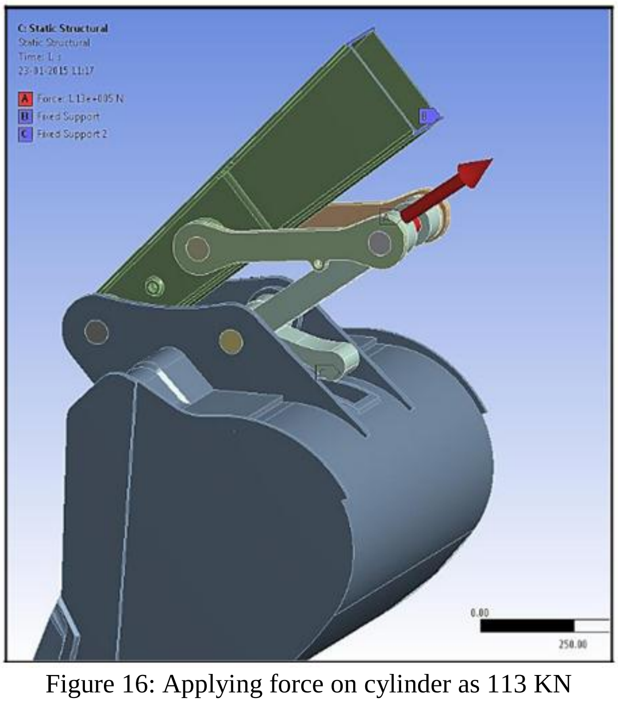

Figure 16: Applying force on cylinder as 113 KN

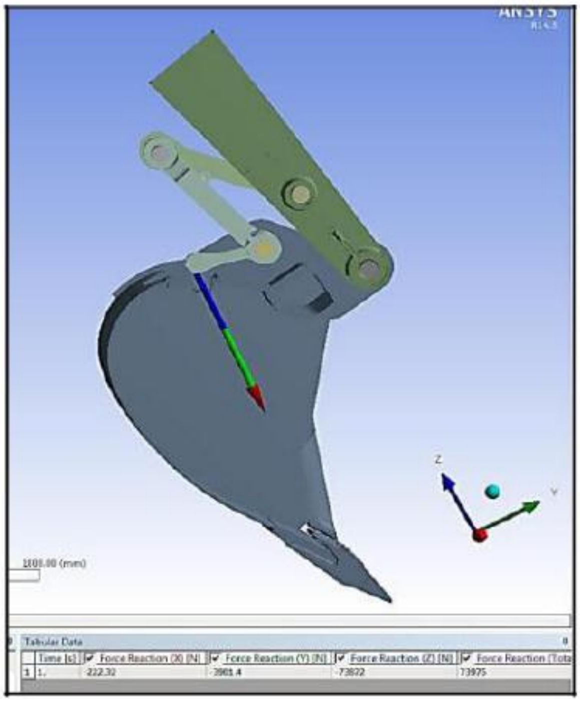

Figure 17: Force on Pusher as 7.5 Tons

This comes to be 7.5 Tons (see figure 17).

These are the suggested material for pusher (see table no. 4) and ejecting plate (see table no. 5).

Table 4: Material for Pusher

Material for Pusher	Tensile Strength	Minimum Yield Strength
S355	470-630 Mpa	355 Mpa

Table 5: Material for Plate

Material for Plate	Tensile Strength	Minimum Yield strength
S275	370-530 Mpa	275 Mpa

Below Figure shows stresses on pusher when this much force is applied on it (see figure 18).

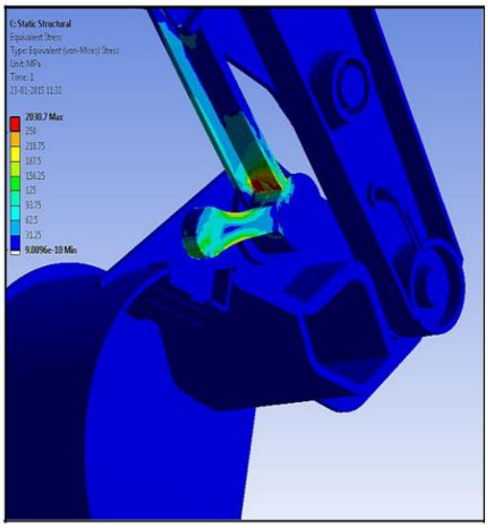

Figure 18: Stress on Pusher

Validating Force on Bracket

The same force applied by pusher, is applied on stud head and resulting effect is analyzed as under (see figure 19):

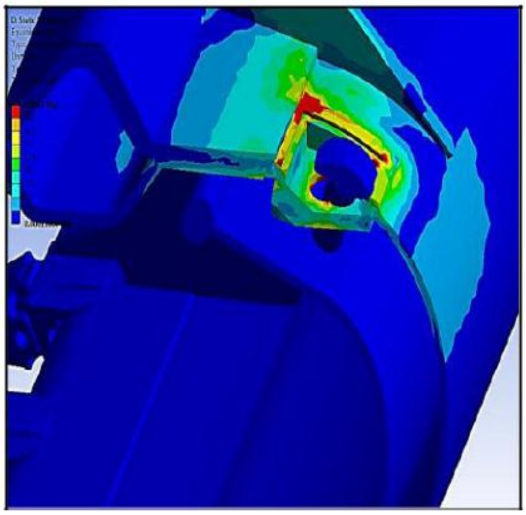

Figure 19: Stress on Bracket

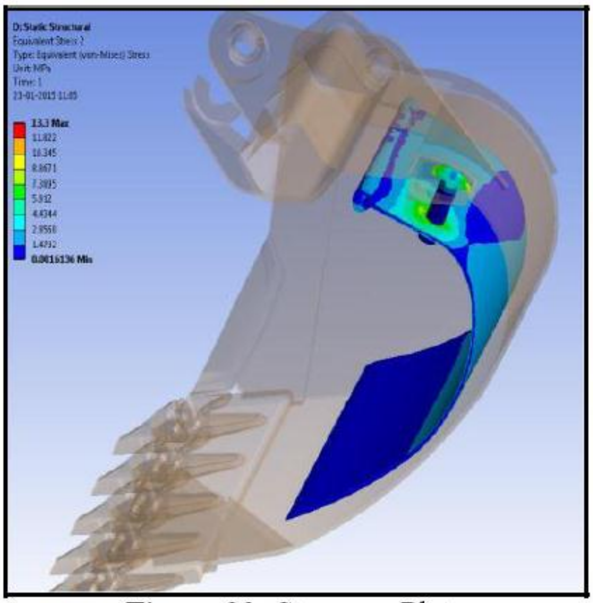

Figure 20: Stress on Plate

Above figures show that von-Mises stresses induced are within permissible limit (see figure 20). Also force on pusher is greater enough to shear the soil. Stress limit given while checking are well above prescribed values. Furthermore we can correct these by proper welding to give sufficient strength to bracket.

IV. Conclusion

The design and analysis of the model shows the basic concept for development of such attachment. Implementation of such mechanism on actual bucket will reduce need for jerking. Also it will increase bucket capacity. The mechanism may be replicated on excavator bucket of any size. Furthermore it may be actuated hydraulically to improve its functioning.

V. Future Scope

Further validation and actual test field results are needed for this model to measure the ejection forces and to commercialize the product. In addition additional testing is required to check the feasibility of the attachment for larger excavators.

References

[1]. Muhammad Azam Khan, Rashid Qaisrani, LI Jian-qiao, "The Techniques of Reducing Adhesion and Scouring Soil by Bionic-Review of Literature," Advances in

[2]. Natural Science, Proceeding of 3rd International Conference of Bionic Engineering, Vol. 3, No. 2, 2010. Pp. 41-50 http://www.google.com.sg/search?q=bucket+with+dama ged+teeth&safe=active&biw=1164&bih=853&source=l nms&tbm=isch&sa=X&ei=I5cKVcGODJC9uAT1voCYAw&ved=0CAYQ_AUoAQ#imgdii=_&imgrc=XXJZ ivaWJj7VUM%253A%3BaK2vo9GehDaTpM%3Bhttp%253A%252F%252Fd323w7klwy72q3.cloudfront.net %252Fi%252Fa%252F2014%252F20140731const%252FF4917.JPG%3Bhttp%253A%252F%252Fauctionser vices.com%252Fauction%252F234327%252Fconstruct ion-equipment-auction%3B404%3B420

[3]. Vivek Ramsahai, April Bryan and Robert A. Birch, "Backhoe Bucket Mechanism for Ejecting Adhered Soil," The Journal of Association of Professional Engineers of Trinidad and Tobago, Vol.40, No.2, October/November 2011, pp. 26-36.

[4]. Abhay k. Pande, Rajkumar B. Chadge and Sachin Kharat, "A Review on Soil Ejecting Techniques in Excavatorbuckets,"(ConferenceProceeding), International Conference on Emerging trends in Manufacturing, Engines and Modelling (ICEMEM), 27-28 April, 2015.

[5]. George William King, "Excavator bucket with retainage ejector," U.S. Patent, US 2005/0193601 A1, Sep. 8, 2005.

[6]. Daniel Ammons, "Bucket Cleaning Apparatus," U.S. Patent, US 7,624,522 B1, Dec.1, 2009.

[7]. Gene Klager, "Self-cleaning hydraulic clam bucket," U.S. Patent, US 6658769 B2, Dec. 9,2003.

[8]. Kooistra, A, Verhoef, P.N.W., Broere, W., Ngan- Tillard, D.J.M. and van Tol, A.F. (1998), "Appraisal of soil stickiness of natural clays from laboratory tests," *Proceedings of the 25 Years National Symposium of Engineering Geology in the Netherlands*, Delft, Netherlands, Available at: <http://www.geo.citg.tudelft.nl/broere/pdf/kooistra_app raisal_1998.pdf.>[accessed Sep. 15, 2010].

[9]. Bowden, F.P. and Tabor, D. (1964), "*The Friction and Lubrication of Solids," Part I*, Clarenden Press, Oxford, UK.

[10]. Bhaveshkumar P. Patel, Dr. J.M. Prajapati, Bhargav J. Gadhvi, "An Excavation Force Calculations and Applications: An Analytical Approach," International Journal of Engineering Science and Technology (IJEST), Vol. 3, No. 5, May 2011.

[11]. http://www.engineeringtoolbox.com/dirt-mud-densities-d_1727.html