DESIGN AND FABRICATION OF POWER SHOVEL

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ABSTRACT: Traditional methods have played an important role in energy saving of hydraulic power shovel. However, the Power shovels are still working with low fuel efficiency and bad exhaust. So, new technologies are urgently needed to further reduce fuel consumption and pollutant emissions .Researchers has begun to focus hybrid technology of hydraulic power shovel. This paper systematically analyzes the performance of motorized controlled power shovel. The use of automated technology results in reductions in fuel consumption (as a very low amount of fuel is used) and finishes working time. This also contributes to lower both environmental impact (i.e. global warming, acidification, ozone depletion and eco-toxicity) and the related cost. As power shovels are frequently used in construction sites, but this situation brings it significant health and safety hazards that often are not fully appreciated by stakeholders. So, Automation and Remote controlled arrangement help to overcome the problem of safety hazards.

Keywords: Energy saving; Hybrid technology; Automation; Earthwork; Remote controlled.

1. INTRODUCTION:

Material handling (MH) is a fundamental part of a Flexible manufacturing since it interconnects the different processes supplying and taking out raw material, workpieces, sub-products, parts and final products [2]. It relates to the movement, storage, *Corresponding author- Tanvi Verma, vtanvi13@gmail.com;

Control and protection of materials, goods, and products throughout the process of manufacturing, distribution, consumption and disposal. Material handling equipment is the mechanical equipment involved in the complete system. It is used in many ways such as digging of trenches, holes, foundations, material handling ,brush cutting with hydraulic attachments, Forestry work, demolition, general grading/landscaping, Heavy lift, e.g. lifting and placing of pipes, mining, especially, but not only open-pit mining, River dredging etc.[2]. With automation, mining companies can overcome problems of shortage of labor, improve productivity, efficiency and safety [1] [2] [3]. The control center to monitor the automated equipment may be located hundreds of kilometers away from the actual working area. It can be considered as a robot with a movable arm relative to the work piece. They are heavy-duty machines operated using simple control units to control the actuators manually [2]. Digging mechanism of hydraulic actuated excavator consists of three axes; boom, arm, and bucket. Each axis is set in motion using in order to follow the desired trajectory by the bucket tip.

Fig-1. Power Shovel

2. MATERIALS AND THEIR PROPERTIES [5] [6] [10]:

Material selection is the important part for the designing and manufacturing of the power shovel. All the components of the power shovel are made of different materials and have different important properties.

2.1 Arms (Aluminum) [6] [10]:

Aluminium and its alloys are the most important because of their excellent properties. Some of the properties of pure aluminium for which it is used engineering industries are:

1. Excellent thermal conductivity- (0.53 cal/cm/^{0}c).
2. Excellent electrical conductivity- (367,600/ohm/cm).
3. Low mass density- (2.7g/cm^3).
4. Low melting point- (658^{o}c).
5. Excellent corrosion resistance. Aluminium in fact has a greater affinity towards oxygen. As a result, when aluminium is exposed to air, the outer surface readily gets oxidized forming aluminium oxide. This oxide skin has a good bond with the parent metal and thus protects it from further oxidation.
6. It is not toxic.
7. It has got one of the highest reflectivity (85 to 95%) and very low emissivity (4to5%).

8. It is very soft and ductile as a result of which it has got very good manufacturing properties. Some of the applications where pure aluminium is generally used in electrical conductors, radiator fin materials, air conditioning units, optical and light reflectors, foil and packaging material.
9. Elasticmodulus-69,00MPa.

Limitation of Aluminium

1. Low tensile strength (65MPa) and hardness (20BHN).
2. It is very difficult to weld or solder. So, it is substantially improved by alloying. The elements use the principal of alloying elements are copper, manganese, silicon, nickel, zinc.

2.2 Gear (Nylon Polyamide) [5] [10]:

An important polymer family that forms characteristic amide linkages (CO-NH) during polymerization is the polyamides (PA). The most important member of PA family is nylons, of which the two principal grades are nylon-6 and nylon-6, 6 and both properties are similar .Nylon is strong, highly elastic, tough, abrasion resistance, and self-lubricating. It retains good mechanical properties at a temperature up to 125^0C (250^0F).The majorities of application of nylon (about 90%) are in fibers for carpets, apparel, and tire cord. The reminder (10%) in engineering components .Nylon is a good substitute for the metals in bearings, gears and similar parts where strength and low friction is needed.

The properties of the Nylon-6, 6 are-

1. Representative polymer- Nylon-6, 6$((CH_2)_6(CONH)_2(CH_2)_4)_n$
2. The degree of crystalline- highly crystalline.
3. Modulus of elasticity- 700MPa
4. Tensile strength- 70MPa.
5. Elongation- 300%.
6. Specific gravity -1.14.
7. Melting temperature- 260^0C (500^0F).

2.3. Nuts and Bolts (Mild Steel or Low Carbon Steel) [6] [10]:

Assembly of the prototype parts of the Power Shovel is done by using nut and bolts. All the arms (A, B, C and D) are joined together and the bucket and loader are joined to arms A and D respectively. Selection of material of nut and bolts is the important part in the design because the function and performance of power shovel depend on its capacity to resist deformation under the stress encountered in service. Nut and bolts are made of plain carbon steel or mild steel, the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel has a relatively low tensile strength, but it is cheap and malleable.

2.4. Bucket and Loader:

Selection of material for the Bucket and Loader of the power shovel is an important part of designing purpose. The material used for the bucket and loader is a tin sheet, provides greater protection against corrosion for iron or steel, it should be cheap, and low hardness because of the low percentage of carbon, easy in manufacturing.

Some important forms of Aluminium Alloy

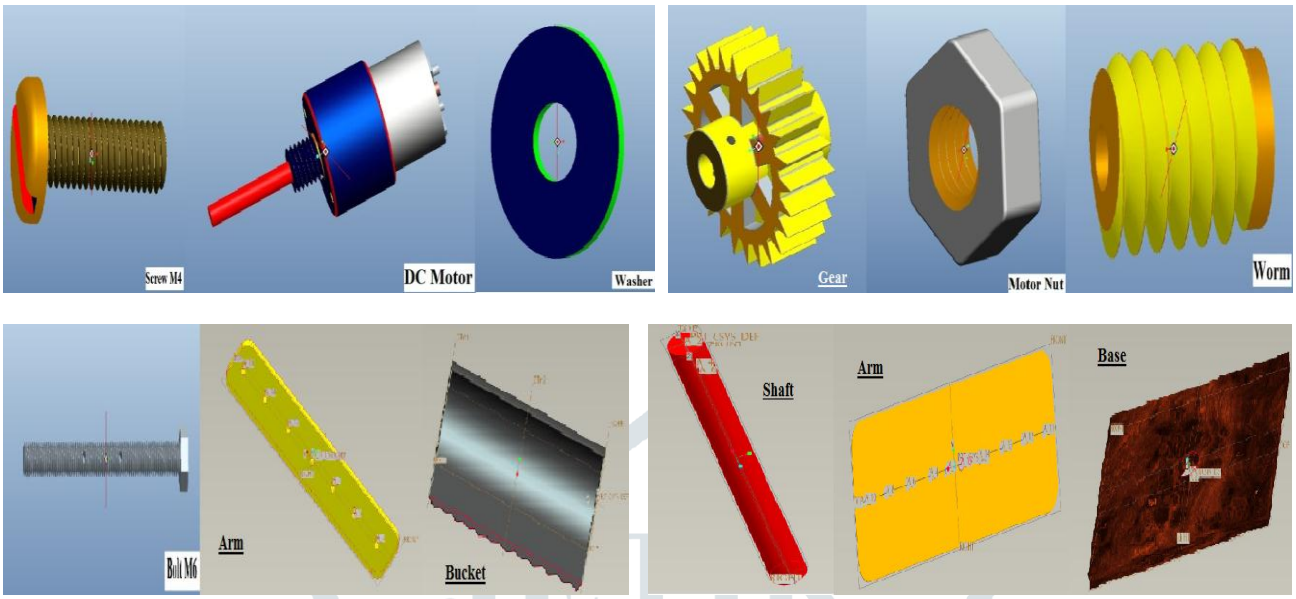
Table1. Some alloy of Aluminium

Alloy	Copper	Zinc	Magnesium	Manganese	Other	Applications
Duralumin	3.5-4.5	-----	0.4-0.7	0.4-0.7	----	Forged piston
Duralumin	2.2	5	3	-----	Ni=1	Generl purpose aerospace
LM5	0.1	0.10	3-6	0.3-0.7	Si=0.3 Ni=0.1	Marine applications
LM6	-----	-----	-----	-----	Si=12	Die casting
LM8	-----	-----	0.5	-----	Si=5	Die casting
LM10	0.1	0.1	10	0.10	Si=0.25	Good shock resistance
LM14	4	-----	1.5	-----	Ni=2	Piston alloy
LM20	0. 4	0.2	0.2	0.5	Si=10-13 Fe=1	Die casting
LM24	3-4	3	0.1	0.5	Si=7.5-9.5 Fe=1.3	Die casting

3. DESIGN:

Designing of the fabricated parts is done in the Software Pro-E Wildfire 4.0.

Modeling of parts is as shown below:



After Assembling, the prototype looks like as in Fig.2

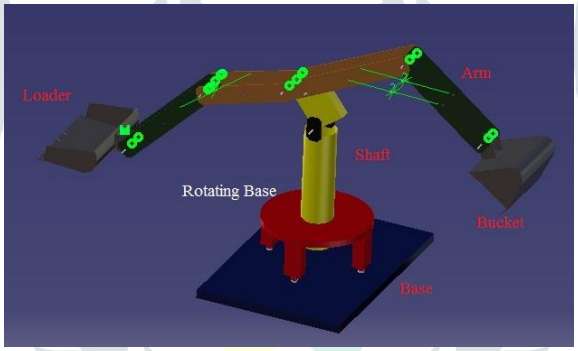


Fig.2 Prototype

4. CALCULATION:

4.3.1. Assumptions made in designing:-[8] [9] [10]

- Steady loading of members.
- Any minor deformation in components during operation is neglected.
- Any minor asymmetry, if any, is neglected.
- Calculations are done for extreme loading conditions.
- Internal defects or defects produced in the components during machining, if any, are neglected.
- Fastenings are assumed to be rigid and fastened parts are considered as a single piece.
- Project is used on plain ground level
- Aluminium used in project has mechanical properties as-
- Yield stress σ_y = 300MPa
- Ultimate strength σ_u = 483MPa
- Poisson's ratio Υ = 0.29

Nylon plastic of the gear pairs has mechanical properties as-

- Tensile strength σ_u = 78 MPa
- Young's modulus E = 2.8 GPa
- Poisson ratio Υ = 0.39
- Rockwell hardness M28
- Coefficient of friction μ = 0.2-0.3 (taken 0.3)
- Bolts & nuts used in project for fastening have high strength -
- Tensile strength σ_u = 830 MPa (min^m)
- Proof Load stress 600 MPa (min^m)

Table 2. Weight of components of prototype

Name of components	Weight(gms)
Arm "A"	140
Arm "B"	184
Arm "C"	116
Arm "D"	136
Bucket	220
Loader	100
Motor + bracket(bucket side)	180
Motor + Bracket(loader side)	224
Bolt M3	12
Bolt M4	14
Bolt M6	18
Spur gear with nut bolt	45

ANALYSIS OF ARM "A":

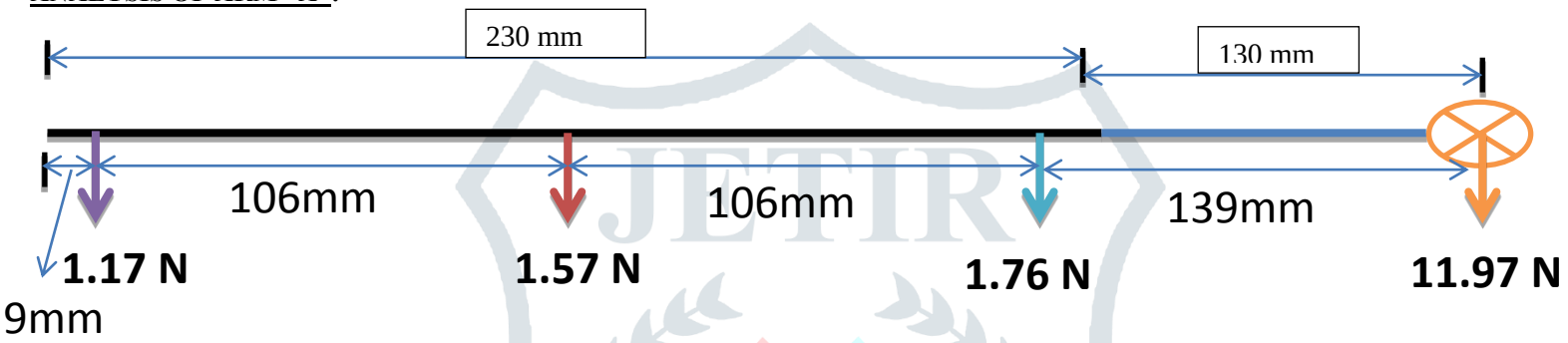


Fig.3 Free Body Diagram of Arm"A".

According to the free body diagram shown above, we can analyse force, bending moment and torque.

Force Analysis:-

$F_x = 0$ N

$\mathbf{F_y}$ = 1220+180+160+120=1680gm

=1.68kg = 16.48N

Bending-Moment Analysis:-

$\mathbf{M_x}$ = (1220 x 351) + (180 x 221) + (160x 106)

= 484960 gm*mm

= **484.96 kg*mm = 4757.46 N-mm**

M_y = 0 kg*mm

Stress Analysis:-

Applying Bending Moment equation;

$$\frac{\sigma}{y} = \frac{M}{I}$$

Where σ = Bending Stress (Mpa)

M = Bending Moment (N-mm)

I = Moment of Inertia ($mm^{4)}$

Y = Distance from neutral axis (mm)

y = 19 mm,

$I = (bh^3/12) = 5x\ 38^3/12 = 22863.33\ mm^4$

$\mathbf{\sigma_b}$ = **3.95 N/mm^2 3.95 MPa**

Theoretical yield strength σ_y = 300 N/mm^2 = 300 MPa (approx.)

As $\mathbf{\sigma_b < \sigma_y}$, thus Design is safe.

Factor of safety = 300/3.95 = **76** (f.o.s. is kept very high to avoiding buckling of the sheet plates.)

Similarly, we can easily calculate force, bending moment and corresponding torque of every arm.

Bucket Analysis:

The Bucket is designed in such a way that the center of gravity (C.G.) of the bucket, including the load (as sand), lies nearly below the Bucket joint. This helps in very low torque requirement and low load on bucket actuating motor in an idling condition.

Force Analysis:-

$F_x = 0$ N

F_y = (0.220 + 1.000)*g =**11.96 N** (**total weight** of bucket and specified load)

Torque Analysis-
Motor rated torque = T_1 = 32 kg*cm (max.)
Bucket teeth distance from wrist= 22.5 cm.
Net force applied by bucket teeth = 32/22.5 = 1.422 kg = 13.952 N
Approximate digging force exerted by bucket teeth $\mathbf{F_d}$ = **13.952 N**

Loader Analysis:
Force Analysis:-
F_x = 0 N
F_y = (0.100 + 1.000)*g =**10.79 N** (**total weight** of loader and specified load)
Torque Analysis-
Motor rated torque = T_1 = 1.8 kg*cm (max.)
Gear Ratio=1/25
Thus output torque (T_2) =25x1.8=45kg-cm
Bucket teeth distance from wrist= 12 cm.
Net force applied by bucket teeth = 45/12 = 3.75 kg = 36.7875 N
Approximate digging force exerted by loader teeth $\mathbf{F_d}$ = **36.8N**

5. ANALYSIS ON PROE:

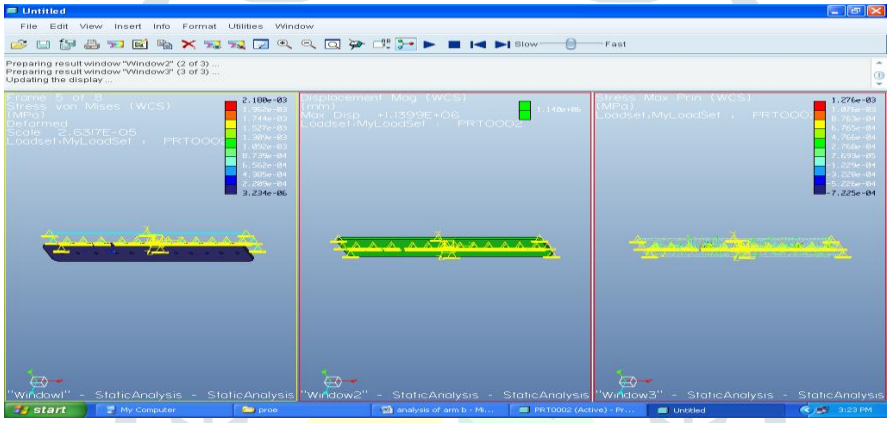


Fig.4 Analysis of Arms.

After doing analysis of arms on ProE (Mechanica), we conclude that the arms are designed and manufactured as per the specifications required. Very high factor of safety is achieved._

6. FABRICATION PROCESS[7]:

1. Fabrication of Bucket:-

Firstly 22 gauge (0.40mm) TIN sheets is cut into specific shape and size on cutting machine, then teeth are made using the shearing machine. Further those pieces are rolled on sheet rolling. Obtained parts are interlocked to achieve the desired shape (bucket). Finally, the edges are trimmed to have a good finish, thereafter bucket is painted with black paint.

2. Fabrication of Motor mountings:-

Starting with the cutting of Aluminium stripe (2.5mm thick) of required dimension. Followed by its bending in "U" shape by hammering along its edges. Now the bent portions are drilled to have holes of 2 mm& 4 mm diameter at the specific spot in order to fix the bucket and motor. Finally, the motor mounting thus obtained are filed and painted.

3. Fabrication of Arms:-

Step-in order to manufacture arm, the Aluminium strips are (2.5mm thick) cut into required dimension on the shearing machine. After that, the strips are drilled to have holes of 2.5mm and 4mm at the specific spot. Now the obtained arms are grounded and then painted with yellow color.

4. Fabrication of Main Shaft:-

This paper includes cutting of PVC pipe having diameter 65mm and of length 250mm.then this pipe is fitted with a circular wooden block at its both ends, then a motor is attached at the bottom end. In order to balance and have 360^0 rotation this pipe is fixed in circular wooden plywood (220mm dia& 13mm thick), which have 3 free wheels at its bottom.

5. Fabrication of Base:-

Finally, the plywood base is fabricated of the required dimension (430mmX305mmX13mm) Further wheels and motor are attached to it and the base is laminated with blue mica.

6. Automation:

We control the movement of the arms with the help of wireless radio frequency control logic. We control the base for all the direction. We use two circuits, one as a transmitter and second as a receiver. In the transmitter circuit, we use ten switches as a transmitter and in the receiver we use five DC motors to drive the arm with all the movement.

CONCLUSION:

As material handling is a part of flexible manufacturing, accordingly it is important to add automation of the system. So, it provides safety, increases productivity and accuracy. Keeping the system work on radio frequency, it can be controlled and operated by the control room. Introducing the hybrid technology in the system, we can save a huge amount of fuel and reduce pollution to a large extent.

ACKNOWLEDGEMENT:

We would like to acknowledge Director Prof. Arvind Datye and HOD(ME) Prof. A.K. Moudgil to give us a platform to write a technical paper on our project. We would like to give thanks to our guide Associate Prof. Abhishek Pandey for his encouraging guidance throughout the project. We would like to thank all the project members for their excessive cooperation. We would like to thank all the classmates for their positive critics which really help to complete the technical paper writing successfully.

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