International Engineering Research Journal

Design and Analysis of Hydraulically Operated Dumper Placer Arm for Garbage Compactor

Priya Sen†, G. M. Dhanavade†, S. R. Patil†

†M.E. Automotive Engineering, Sinhagad Academy of Engineering, Pune, India.
†G.M. Design Dept., KAM-AVIDA Enviro Engineers Pvt. Ltd, Pune, India.
†M.E. Automotive Engineering, Sinhagad Academy of Engineering, Pune, India.

Abstract

The project deals with the design and analysis of a mechanism named dumper placer arm. This paper aids to comprehend the selection procedure and design of various building blocks of the assembly, its applications, analysis reports, etc. Dumper placer arm is a mounting on the rear end of a garbage compactor vehicle which would be used for lifting the bins containing domestic garbage viz., garden waste, market waste, domestic waste, commercial waste and others as generated in metropolitan cities and towns etc. The building blocks include leak proof hydraulic cylinders, pins, link chain, D-shackle, hook etc. This arm will lift the bin weighing 3600 Kgs approx. (including garbage weight) with the help of hydraulic cylinders, link chains and D-Shackle; tilt it at an angle of 45 degrees for emptying the bin; re-places it to its original position. Design iterations were carried on and the most preferable design was selected considering parameters like strength, machinability, cost, availability of materials, etc. Once the concept was finalized, the entire assembly was divided into number of sub-assemblies for simplification and then each assembly was worked out for its strength and design/ selection of its individual components. The assembly was further analyzed using CAE tool.

Keywords: **Garbage** *Compactor, Dumper placer arm, Solid Egde, Hypermesh, OptiStruct.*

1. INTRODUCTION

There are three types of wastes: solid, liquid, and Hazardous. This project comprehends solid waste management equipment. This particular equipment deal with solid waste that comprises standard domestic garbage (garden waste, market waste, domestic waste, commercial waste and others as generated in metropolitan cities and towns), and does not contain products of a flammable, corrosive or explosive nature.

In the early days waste collectors needed to pick/drop garbage with their hands which leaded to many serious health issues. Later on, in the year 2013 an act was passed known as Manual Scavengers Act, 2013, according to which manual cleaning, collection, disposal of any kind of garbage is strictly prohibited. With urbanisation, education, legislation and, awareness of health hazards, has in fact created a shortage of relevant man power, thereby compelling maintenance authorities to mechanize their cleaning & maintenance programs.

Urban areas in India generate more than 1, 00,000 MT of waste per day (CPHEEO, 2000). A large metropolis such as Mumbai generates about 7000 MT of waste per day (MCGM, 2014), Bangalore generates about 5000 MT (BBMP, 2014) and other large cities such as Pune and Ahmedabad generate waste in the range of 1600-3500 MT per day (PMC, 2014).

In order to handle such a huge quantity, solid waste management system has been divided into four steps:

1. Collection
2. Processing
3. Transportation and
4. Disposal

Hydraulically operated dumper placer arm performs the first step by enabling the arms to lift and tilt bins ranging from 1.1 cum to 4 cum capacity thereby eliminates human involvement.

It consists of two Skip Loader Arms with chains which is powered by two hydraulic cylinders in order to load the refuse in the bins with large Volume.

2. LITERATURE REVIEW

Suraj Gavali mentioned that the collection of waste is an essential work that ensures our communities remain in pleasant environments where they live. But major problem is transportation of the waste which can be reduced by compacting or reducing size of particular waste. A compactor can be used to reduce the volume of wastes. The waste weight will remain the same. However, savings will occur because waste volume will be reduced by approximately 80% which will decrease the number of times the dumpster will need to be emptied, therefore resulting in lower pick up fees.

O & M and Spare Parts Manual, Kampac Series Project Swachatha Corporation Equipment Kampac-Rel-14 UBL Project No. 2151600005-5214bl0010, Skipper Mobile Dual Dumper Placer for $3m^3$-$5m^3$ Bins, Tata Refuse Tech Specifications, Municipal Corporation Workshop Manual are the few industrial manuals by reviewing them following points are made.

Due to the traditional approach of cleaning in India, mechanized cleaning is kept at the bay by the government as well as by the private bodies.The idea behind the design of dumper placer arm arrangement is taken from a vehicle called Skip Loader vehicle which has a similar arrangement (as of dumper placer arm) called 'Skip Loader' and is already available in metropolitan cities which only lifts the bin, places it on the vehicle body and carries it along to the dump yard. The disadvantage with this system is that there is no provision for storing the garbage on the vehicle. Every time it is needed to carry the bins to the dump yard and bring it back to its initial location which eventually increases the travel distance, time consumption, fuel consumption and transportation cost.

In order to eliminate the above disadvantages Garbage compactors with DP arm is introduced which will make the garbage collection and transportation effective. The garbage collector vehicle depending on its garbage storage capacity can compress up to 6-7 bins of 1.1- 4 cum capacity at a time.

Companies like Palfinger, Singapore; SPV vehicles, Hong Kong; Technifab, USA; Ben Harvey, USA; Marrel, Europe are using advanced version of such arrangements with very high tensile steel material, light weight and optimized structure. [1, 2, 3]

Santosh Javalagi et al. stated in their paper that the selection of fluid depends on the working conditions of the hydraulic equipment. So to select a fluid one has to be clear about the operating conditions of hydraulic equipment and this can be achieved by testing the equipment with different fluids and select the fluid that gives the best performance. By further reading the paper, decision has been made to select ISO VG 68 Oil which is a mineral oil and has improved anti-wear additives. This fluid uses phosphorus, zinc and sulphur components to get its anti-wear properties. This fluid is mainly used in the high pressure hydraulic system. [5]

Navin Kumar Bansal et al. mentioned in their paper that there are two standard grades for lifting chain grade 80 lifting chain and grade 100 lifting chain. Based on the lifting load value and type of chain sling and angle between chains proper chain type is selected. Environmental condition also affects the life and capacity of chain so operating condition should also be taken into account while selecting chain. So, according to load lifting capacity of our project decision has been made to select Grade 80 link chain. [6]

According to an article published in a magazine named "Hydraulics and Pneumatics", adding a regenerative circuit speeds up the extending speed of a double-acting cylinder and reduces cycle operation time by half. [8]

3. SCOPE

1. Design of DP arm mechanism that can lift four different designs and weights of bin. Maximum capacity of bin it can lift is 4 Cum.
2. Design of Profile Plate on the rear end of tailgate.
3. Use of Regenerative Circuit for reducing the operation cycle time.
4. CAE Analysis.
5. Manufacturing of the final mechanism.
6. Validating the design on Vehicle.

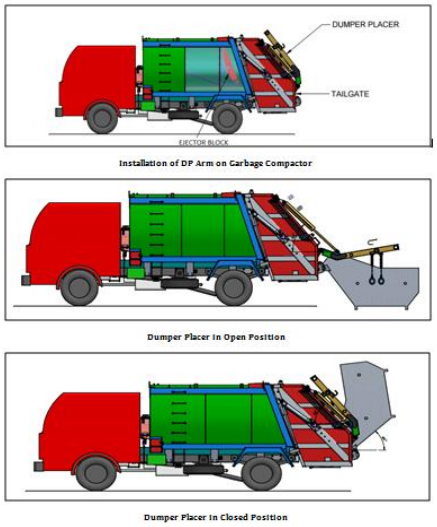

Fig. 1-Garbage compactor with DP arm arrangement

Fig. 2-Different types of bins which DP arm can lift
Capacity of the bins ranges from 1.1 – 4 Cum
Material of construction is M.S.

4. METHODOLOGY

Following steps are to be performed sequentially:-

1. Literature survey.
2. Setting the benchmark.
3. Design calculations for various sub assemblies like:-
   - Material selection for each part
   - Design of hydraulic cylinders
   - Design of pin, material selection etc.
   - Link chain design
   - D-shackle selection
   - Structural design
   - Hydraulic circuit study
4. Analysis using FEA tool.
5. Manufacturing.
6. Test data report compilation.

5. DESIGN

Design stage includes design of following components:-
For designing the following sub assemblies Solid Edge software is used.
Few of the advantages of Solid Edge software are as follows:-

1. Faster and flexible design.
2. Superior transition from 2D to 3D.
3. Best sheet metal modelling in its class.
4. Scalable design and failure analysis.

A. Design of DP arm arrangement: -

It consists of two Skip Loader Arms with chains which is powered by two hydraulic cylinders. The two arms are connected together with the help of a circular pipe.

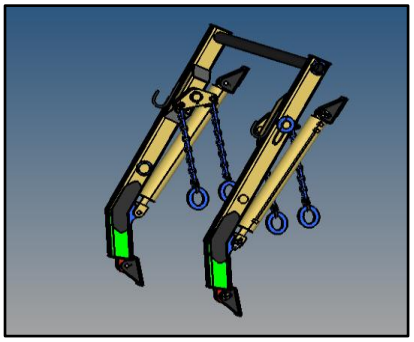

Fig.3-Design of DP arm arrangement

Table no.:1-Details of the components used in DP-Arm mechanism

Components	No.s	Material
DP- Arm	2	M.S
Cylinders	2	STD.
Pins	6	EN 24
Link Chain	4	Grade 80 Alloy
D-Shackle	4	M.S
Elliptical Hook	4	M.S
Hook for chain	2	M.S
Circular Pipe	1	M.S

B. Design of Profile Plate:-

It is a plate mounted on the tailgate on which the bin along with garbage weight rests during tilting operation.

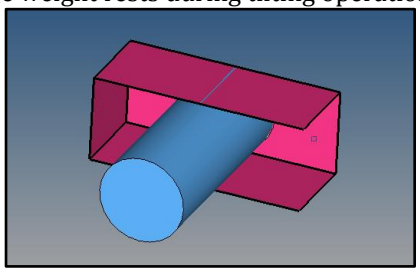

Fig. 4- Old Design

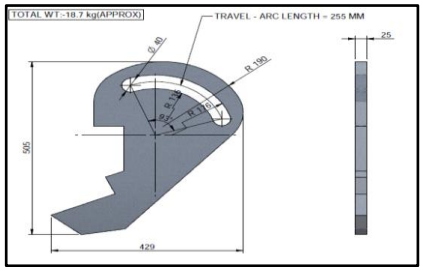

Fig. 5- New Design

Travel arc length = 255 mm
Travel angle = 93°

The earlier design was a male-female type of arrangement which failed to serve the purpose. So a new design has been generated by considering the maximum weight and tilt angle of the bin.

C. Hydraulic circuit arrangement:-

Regeneration circuits can double the extension speed of a single-rod cylinder without using a larger pump. This means that regeneration circuits save money because a smaller pump, motor, and tank can produce the desired cycle time.
The regenerative circuit consists of a hydraulic tank, breather, strainer, non return valve, PTO driven pump, pressure relief valve, direction control valve, flow divider and hydraulic cylinders.
The circuit used a standard equal-flow, two-section gear-type flow divider which is connected in the rod-end line of the cylinder. The normal inlet port of the flow divider is connected to the cylinder rod-end port. One outlet port is connected to the directional control valve, and the other outlet port is teed into the line from the cap-end cylinder port to the directional valve. When the cylinder extends (valve position a), oil from the rod end enters the flow divider. Half of the fluid flows to tank through the directional valve, while the other half mixes with the pump supply and flows to the cap end.
With the directional valve shifted to position b, pump flow into one outlet port of the flow divider and flows to the cylinder rod end. Oil from the cap end tries to return to tank, but mainly flows to the other outlet port of the flow divider and mixes with pump flow to increase cylinder speed about 95%.

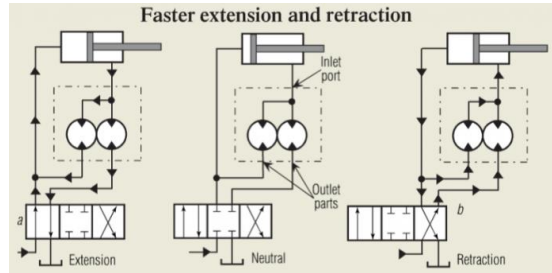

Fig. 6- Regenerative Circuit

6. ANALYSIS

As discussed earlier DP arm is an accessory of a garbage compactor and is subjected to following types of forces while working or at rest: - 1. Vertical load (bin with garbage weight). 2. Self-weight of the arm. 3. Cylinder forces while lifting and lowering of arm. 4. Forces while rotation of arm.

ANALYSIS TOOLS USED:
Pre-processor- Hypermesh 13.0
Solver- OpstriStruct 13.0
Post-processor- Hyperview 13.0
The stepwise procedure of analysis and results are discussed below:-

STEP-I: GEOMETRY IMPORT AND EDITING

The geometry for analysis is imported into Hypermesh in standard IGES format. The imported geometry is edited in Hypermesh to remove surfaces which are not going to take part in analysis, for example, cylinders, chains, hooks, edge fillets, etc. It is done to improve the mesh quality.

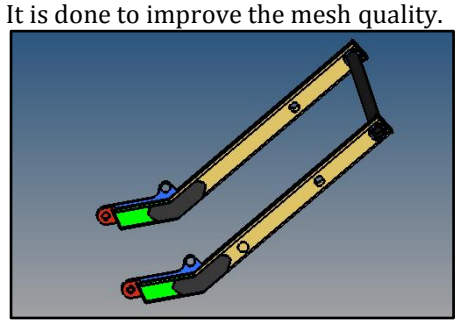

Fig. 7- Assembly of DP arm

STEP-II: MESHING

Once the geometry is in an appropriate state, a mesh is created to approximate the geometry. A solid 3D mesh is created; with element size of 10 mm is used. The specification of mesh is as follows: - element size: - 10mm; surface elements: - quad; solid elements: - hex 8

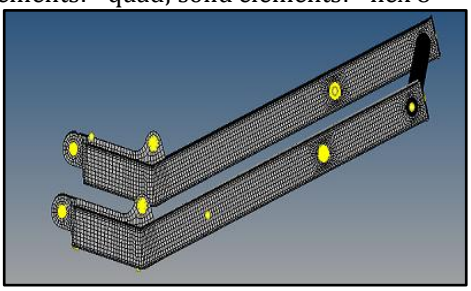

Fig. 8- DP arm mesh model

Table no.:2

DP Arm along with stiffeners					
Mass (Kgs)		**Nodes**		**Elements**	
Without Stiffener	**With Stiffener**	**Without Stiffener**	**With Stiffener**	**Without Stiffener**	**With Stiffener**
1.589 e-01	1.759e-01	46233	51340	22866	26706

STEP-III: MATERIAL AND PROPERTY INFORMATION

After meshing is completed, material (e.g. Young's Modulus) and property information (e.g. thickness values) are assigned to the elements. The following material properties were considered; Material selected:-Steel; density of steel:- 7850kg/m3; young's modulus: - 2.1e5 n/mm2; Poisson's ratio:- 0.3; Yield strength:- 247 Mpa.

STEP-IV: LOADS, CONSTRAINTS AND SOLVER IN-FORMATION

Various loads and constraints are added to the model to represent the loading conditions that the part(s) are subjected to. Solver information is also added to tell the solver what kind of analysis is being run, which results to export, etc. The lower arm pins are constrained, whereas the arm is subjected to loads at three different locations as shown in fig. 5. . The loading is done as follows: Weight of arm: - 1765.8 N acting at C.G of the arm; Weight of bin and garbage:- 17658 N; Cylinder force:-54823 N; and Factor of safety:- 04.

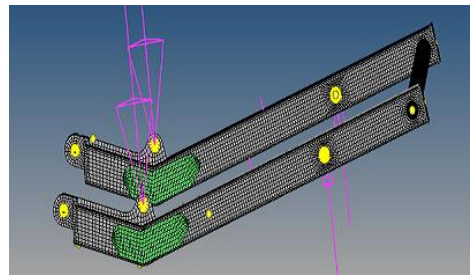

Fig. 9- Boundary Condition and Loading

STEP V: SOLUTION

During the solution phase of a simple linear static analysis or an Eigen frequency study, there is not much to do. The default settings of the Finite Element program do handle these classes of problems pretty well. If the solution process is aborted by an error, it is due to mistakes made during the model building phase. Just to mention a few typical errors: Element quality, Invalid material properties, Material property not assigned to the elements. Insufficiently constrained model (the model shows a rigid body motion due to external loads).

STEP VI: VISUALIZATION / POST-PROCESSING

Once the solution has ended successfully, post-processing (in HyperView for contour plots) of the simulation results is done next. Stresses, strains, and deformations are plotted and examined to see how the part responded to the various loading conditions. Based on the results, modifications may be made to the part and a new analysis may be run to examine how the modifications affected the part. This eventually completes the FEM process. The following are the results of analysis of arm.

1. *Following Stress and Displacement values are obtained:-*

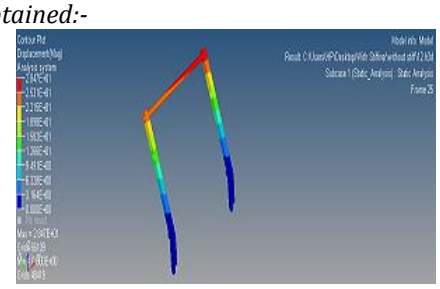

Fig. 10- Displacement Plot

Max. Displacement = 28.47 mm

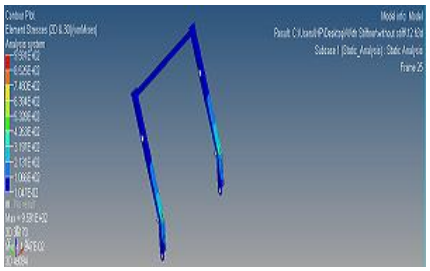

Fig. 11- Von-misses stress plot

Max. Stress = 959.1 N/mm^2

As per yield strength of M.S i.e. 247 N/mm^2 and considered FOS i.e. 4, Max. Stress value should come less than 988 N/mm^2.
959.1 N/mm^2 < 988 N/mm^2;
But a difference of 28.9 N/mm^2 is not permissible in practical condition.
So as to further reduce the stress value stiffeners are added at the stress concentration zone.

2. *Following stress and displacement values are obtained after adding stiffners:-*

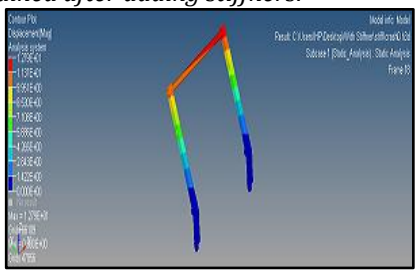

Fig. 12- Displacement Plot

Max. Displacement = 12.79 mm

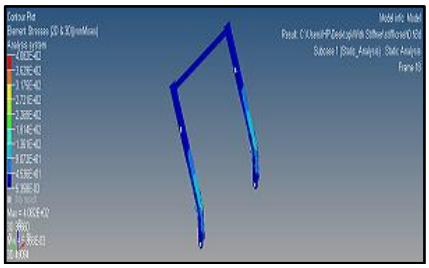

Fig. 13- Von-misses stress plot

Max. Stress = 408.2 N/mm^2

Here, 408.2 N/mm^2 < 988 N/mm^2
Hence, we can say that the values are within limit and the DP- Arm is safe static analysis.

7. MANUFACTURING AND IMPLEMENTATION

Prototype made after FEA analysis and eventually implemented on the vehicle.

Fig. 14- Prototype of DP arm

8. RESULTS

1. By using stiffeners of thickness 8 mm, value of stress has come within permissible limit. Hence DP arm is safe in static analysis.
2. The earlier bracket design was a male-female type of arrangement which failed to give controlled motion to the bin during tilting operation and resulted in improper evacuation and garbage spillage. So a new design has been generated by considering the maximum weight and travel angle of the bin. New profile plate design gave controlled motion to the bins during tilting operation without causing any spillage of garbage and resulted in 100 % evacuation.
3. By using regenerative circuit, cycle operation time (loading + unloading) is reduced by 50% i.e. from 150 sec to 75 sec.

9. CONCLUSIONS

1. Trials of first prototype garbage compactor KAMPAC 14 DP are taken at KMC
2. 4 Cum bin filled with garbage has been lifted by DP arm without any difficulty. The vehicle has been tested for continuous 8 hours with full load condition at KMC.
3. One prototype and three machines have been manufactured, tested at Kolhapur in the presence of Chief Executive Engineer of KMC and dispatched.
4. The project was successfully completed and commissioned, validated at KMC site.

5. KMC has issued satisfactory certificate to Kam-Avida Enviro Engineers Pvt. Ltd.

All the three machines are running successfully in Kolhapur area, thereby meeting the requirements of the customer.

10. REFERENCES

MANUALS

1. O & M and Spare parts manual, kampac series, (2015).
2. Manual- Specification for Vehicle Mounted Dumper Placer – SKIPPER, (Dec, 2015)
3. Manual- Specification of Solid Waste Management Equipment and Machinery, (2015).

RESEARCH PAPERS

4. Suraj gavali and Dr.R.J.Patil, (2015) Design, Analysis And Manufacturing of Garbage compactor- a Review, IJIERT /2394-3696, Volume 2, Issue 2, Feb, 2015.
5. Santosh Javalagi and Swaroop Reddy S., (2012), "Hydraulic fluid properties and its influence on system performance", Master's degree project, Dept. fluid and mechatronic systems, LIU-IEI-TEK-A--12/01284—SE.
6. Navin Kumar Bansal and Prof. U.V. Shah, (2014), "Selection Criteria and Design of a Chain used for Lifting Application", IJSRD, Vol. 2//2321-0613, Issue 09, 2014.
7. Ganesh Laxman Bhat, Srinivasa, Vignesh Ravichandran, (2013), "Design of Garbage Collecting System for Residential Application", MSRUAS-SASTech Journal, Vol. 14, Issue 1, 2013.

JOURNALS

8. Regenerative circuits made easy, Hydraulics and Pneumatics, (Nov, 2012).