FEA and Experimental Analysis of Packaging Separator Clip for Palletization of Steel wheel

Prashant Pharande, Prof. Parmeshwar Ritapure , Sunil Bhatamabrekar

***Abstract*—Packaging is the technology for protecting products to distribute, store, sale, customer and use. Packaging also refers to the process of designing, evaluating, and producing packages. Pallets are used for safety material handling and storage. Pallets are used mostly in storing heavy and large items in different industries across the globe. Now a day's returnable packaging schemes are preferred most for cost saving. Kalyani Maxion Wheels Ltd. Pune, is industry that uses pallet for packaging passenger-car wheels sized from 13" to 20", as well as drop-centre wheels sized 17.5", 19.5", 22.5" and tapered-bead-seat wheels sized 20" for trucks. For packaging this wheel pallets are used but considering returnable packaging schemes steel pallets are ultimate in their properties. In this research separators for palletization have been analyze by Hyper-mesh software and experimentation is carried out . This paper presents analysis of clip under uniform static conditions. To overcome metal to metal contact between wheels in palletization, separator clip is successfully analyzed and validate.**

***Keywords*— Finite Element Analysis, Packaging, Pallet, Separator, Static Analysis.**

I. INTRODUCTION

PACKAGING can be described as a coordinated system of preparing goods for transport, warehousing, logistics, sale, and end use. Packaging contains, protects, preserves, transports, informs, and sells. In many countries it is fully integrated into government, business, institutional, industrial, and personal use. Pallets are used for packaging and it has three main reasons: it protects the product, it improves storage and it makes distribution more efficient. Wooden pallets are cheap compared to non-wood pallets, such as metal and plastic pallets, they have some disadvantages, including: (i) degradation due to the environmental factors, (ii) unreliable performance of the pallet over a period of time due to the method of fastening members of the pallet, by nailing or screwing, and (iii) forest depletion due to the excessive use of trees. Due to these disadvantages, some pallet manufacturers use metals and plastics instead of wood, as the raw materials for pallet manufacturing [1]. Today, Kalyani Maxion Wheels Ltd. at Chakan MIDC, Pune; enjoy a worldwide presence and customer base with 20 facilities in 12 countries serving wheels to every major North American, Japanese, and European manufacturer of passenger cars and light trucks and commercial highway vehicle customers throughout the world. They uses steel pallets as they are strong and durable are now increasingly used in the material handling industry, replacing conventional wooden pallets. Number of trips and shipments that can be achieved with steel pallets compared to the wooden pallets are greater and is proffered for returnable packaging scheme. In company existing packaging scheme is as shown in fig.1

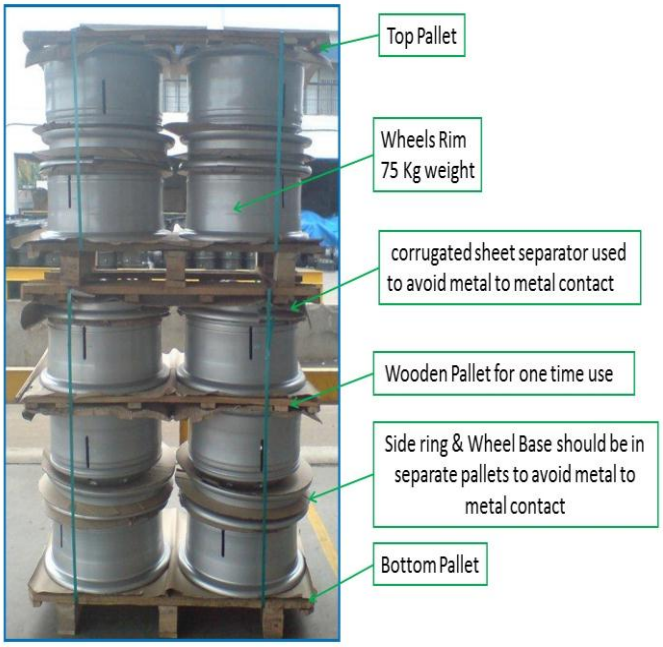

Fig. 1 Existing packaging scheme

Here we can see that corrugated sheets of 2 ply and 3 ply are used as separator while palletization of wheels. This corrugated sheets get wet and tear due to acid rain in container during transportation. So there is a scope to introduce new packaging schemes that can be overcome the drawbacks of exiting packaging schemes.

During transportation of wheel with pallets, company faces problem such as metal to metal contact which damages wheel rim and its color which is unacceptable at customer end. Therefore to overcome the problems with separator there is need of redesign new separator. To find a suitable material from which we can easily manufacture separator with simple process. It should be economical, durable and must bear high

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Prashant Pharande is M.E. student with Zeal college of Engineering & Research, Narhe, Pune-41 (e-mail:prashantdpharande@gmail.com)

Prof. P. P. Ritapure is with Zeal College of Engineering & Research, Narhe, Pune. He is now P.G coordinator of Design department, Zeal college (e-mail: parameshwar.ritapure@zealeducation.com).

Sunil Bhatamabrekar is with the Research and Development Department, Kalyani Maxion Wheels, Chakan, Pune. He is now HOD in R&D Department (e-mail: sunil.bhatamabrekar@maxionwheels.com).

compressive loads. Separator should withstand high bearing load capacity.

II. MODELING

A. *Material Survey*

In company number of trials were conducted on separators such as use of foam, corrugated sheets, rubber and polypropylene (PP) sheets. From this trials it was observed that polypropylene sheets are good but not best for packaging. The research and development team came with an idea that they can developed a clip made of PP. Also PP is a low-cost polymer with versatile applications. In recent years, polymeric composites were widely used in the production of new engineering materials. The polymeric composites are promising, due to their economic versatile applicability and good mechanical properties[2]. A frequent goal of polymeric material research is the improvement of physical properties.

TABLE I
MATERIAL PROPERTIES OF POLYPROPYLENE MI3530

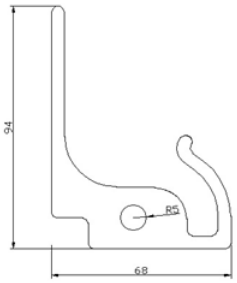
No	Material Properties	Value
1	Density	$1.16e^{-9}$ t/mm^3
2	Young's modulus (E)	1000 MPa
3	Tensile strength at yield	26 MPa
4	Poisson's ratio	0.3

GPa= Giga-Pascal, MPa= Mega-Pascal t = Tone, mm = millimeter.

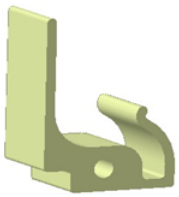
One of the most popular commercial technique for manufacturing polymers is injection moulding. In this study PP material is used for manufacturing clip, the required mechanical properties are shown in table 1.

B. *Modeling of Separator Clip For Steel Wheels*

Separator clip is designed in AutoCAD and then imported to Catia V5 for 3D modeling. Design is carried out by considering ease to manufacture at low cost and maintain sufficient space between wheels while staking. For each wheel four separator clips are used. The is hole provided at center of clip to avoid shrinking during injection molding processes as shown in figure.



AutoCAD Model



3d Catia Model

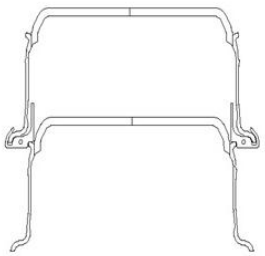


Fig. 2 Modeling for separator clip and cross-section

III. FINITE ELEMENT ANALYSIS

A. *Meshing and Boundary Conditions*

Hyper-mesh is software used for pre-processing. The separator clip has been meshed in Hyper-mesh software by quad element of size of 5mm. For simulating separator clip connectivity was maintained and element quality check were maintained according to software standards.

TABLE III
LOADING CONDITION FOR SEPARATOR CLIP

No	Loading Conditions for single clip	Loads (N)
1	Static Single Stack Load	368
2	Static Double Stack Load	876
3	Dynamic Double Stack Load (TWO WHEELS ARE IN DITCH)	2628

The basic purpose of this software is to simulate the results of practical loading situations, to find out whether a specific material is strong enough to withstand a specific load or not. During analysis three load conditions are considered as single stacking load, Double stacking load and when two wheel of transporting vehicle in ditch load that is 3g (gravitational) load which are as shown in table 3.

The maximum load acts on separator clip. So this analysis is done for maximum load conditions. The hexahedral element is used to mesh the separator clip as shown in figure.

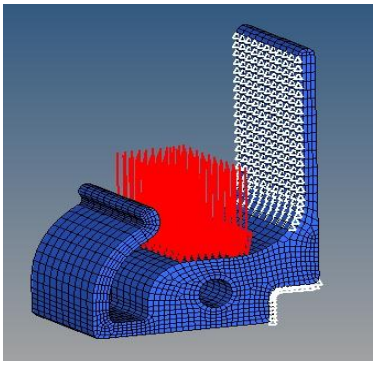


Fig. 3 Hyper-mesh meshing model for Separator Clip

For separator clip having dimensions 68mm×40mm×94mm, maximum compressive force of 2628N is applied in vertically download direction and constrain is as shown in figure with triangular symbol. A couple force is induced in clip and clip tends to bend in inward direction.

B. Analysis

Deformation due to applied forces causes bending moment in clockwise direction and it is about 0.87mm. As the displacement is too low it behaves elastically and regain its original position on removal of applied load. Due to this advantage it is able to use for returnable packing purpose.

The yield point for PP material is 26Mpa[10]. According to FEA, von Mises stresses induced in separator clip is approximately 18Mpa with an factor of safety 1.7, which is in safer side. As stress is below yield point it can sustain for worst load conditions.

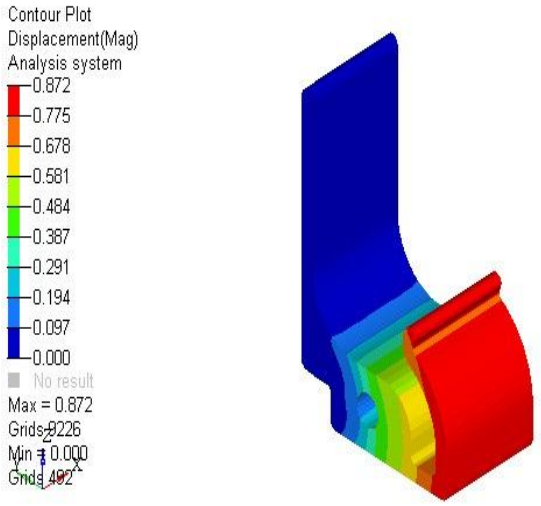


Fig. 4 Deformation for Separator Clip

Fig.4 presents the deformation of clip, the scale of values varies from minimum to maximum. The maximum deformation for clip is 5mm, considering it here deformation is negligible.

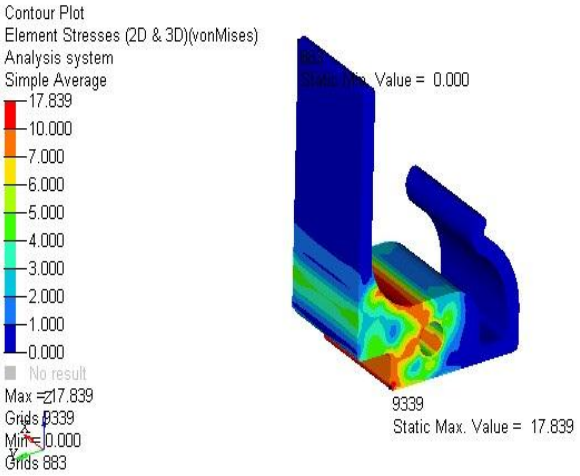


Fig. 5 von Mises stress for Separator Clip

Fig.5 presents the distribution of equivalent von Mises stress, the scale of values varies from minimum to maximum MPa. The maximum value recorded during this simulation of the Separator clip is very significant that obtained with the assistance in the mechanical analysis under the same conditions. One observes a strong constraint on the bottom of separator. Indeed, the separator is in sliding contact with wheel but due to heavy load there induce bending movement. This bending moment would be cause of slip of clip but due to increment in its height it restrict its motion.

IV. MATHEMATICAL MODELING

In this paper behavior of separator clip is considered as cantilever beams under a compressive load and stress ware calculated. To simplify model for calculation, model is assumed to be rectangular cross-section in shape and cantilever type beam.

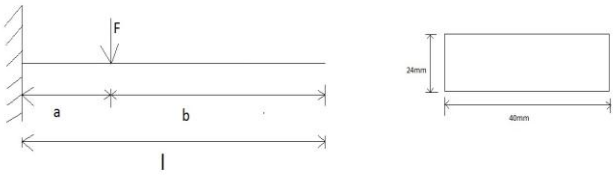


Fig. 6 Free body diagram for Separator Clip

so, let σb =Bending Stress induced in Separator clip
Bending stress induced in Separator clip given by following equation

$$\frac{M}{I}=\frac{\sigma}{y}=\frac{G\theta}{l}$$

Where,
M = bending moment (N-mm), I = Moment of inertia (mm4), σ = Bending stress (N/mm2), G = Modulus of rigidity (N/mm2),
Θ =Angular twist (rad/sec), l = Length of Separator (mm).

As per FEA data bending stress is induced at supports.[9]

where L=18mm and F= 2650N.

so

$$\sigma b=\frac{My}{I}=\frac{2650\times 18\times 12}{46080}$$

$$=12.42\,\text{MPa}$$

Deflection of beam: Maximum deflection of beam given by formula [10] [12], $\delta max=\frac{Fa^2}{6EI}(3l-a)$

Here a=18mm, l=54mm, we get δmax =0.44 mm

V. EXPERIMENTATION

The Universal Testing Machine (UTM) is used to measure the deflection of separator. The separator is mount on the sections of wheels in same position as that of in case of palletization of wheels. The Separator testing was conducted in company itself. The Separator is mounted on the designed fixture of UTM machine. The fixture is designed on AutoCAD and developed in Catia software as shown in figure.

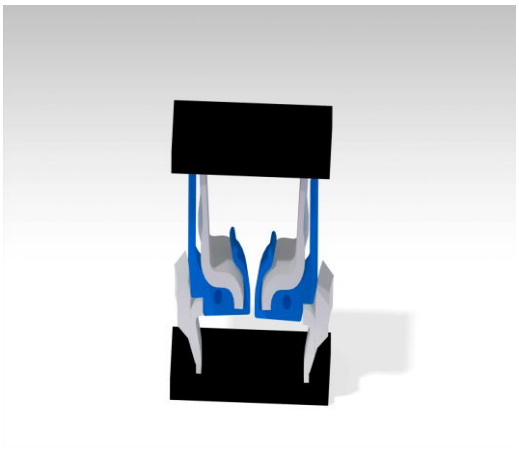


Fig. 7 Fixture for UTM Machine of 7.5" wheel cross-section

For 7.5-20 wheel rim we have we measure the point load with respect to maximum stress region and that load was applied on the Separator clip with factor of safety 2.

The testing procedure for is as follows:

- Fix the fixture to compression table of UTM.
- Place Separator clip on fixture.
- Separator clip should be tested in its normal shipping orientation.
- Apply pre-load to top surface.
- Calculate required load (LR).
- Apply LR at a maximum rate of 12.7 ± 2.5 mm [0.5 ± 0.1 in] per minute until required load is reached.

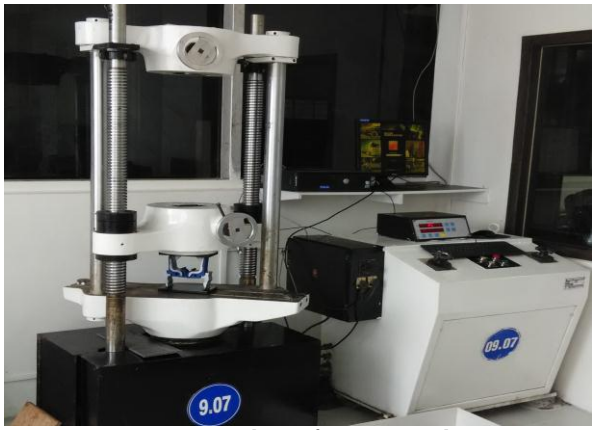


Fig. 8 Experimental setup for Separator Clip

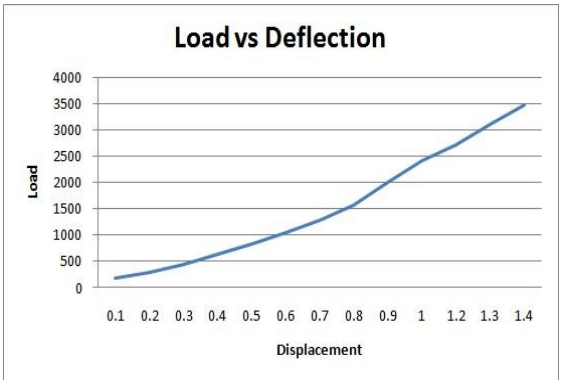


Fig. 8 Experimental Graph of Load vs Displacement

TABLE IV
RESULT TABLE FOR SEPARATOR CLIP

No	Procedure	Deflection in mm	Stress (MPa)
1	FEA	0.87	17.83
2	Mathematical	0.44	12.42
3	Experimental Value	1.07	

mm= millimeter, MPa= Mega-Pascal.

Fig. 9 Modified Packaging Scheme with Separator Clip

VI. RESULTS AND DISCUSSIONS

During packaging the maximum load is on bottom pallet. So we consider the total load on bottom pallet due to stacking with intermediate ant top pallet loads. The FEA, Experimental and mathematical are as shown in table 4.

From the result table 4 it is observed that the design and experimental vales are well within the specifications and acceptable. As by FEA result we can say that material under compressive loading shows stress of 17.83MPa where as its yield strength is 26MPa. So by this we can say that for durable and returnable packaging we can have separator clip at its lowest cost. The initial manufacturing cost of separator clip can be compensated by number of trips and shipments that can be achieved through palletization.

Conclusion

In this publication, we presented the static of behaviour of the separator clip under compressive load and its effect during the stacking process; the modelling is based on the Hypermesh 13.0. We have shown that the separator clip can be successfully used as an alternate packaging material that can withstand for durable time period.

The analysis results showed that, deformation and stress field in the process of stacking phase were fully loaded. The von Mises stress and the total deformations of the separator

clip increases as the load increases and stresses are additional which causes the crack propagation and fracture to the separator clip. Regarding the calculation results, we can say that they are satisfactory commonly found in the literature investigations. It would be interesting to solve the problem in packaging with an experimental study to validate the numerical results.

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Prashant Dilip Pharande is currently pursuing M.E (Design) from Department of Mechanical Engineering, Zeal College of Engineering and Research, Pune, India at Savitribai Phule Pune University. He received his B.E (Mechanical) Degree from Satara College of Engineering, Limb, Satara, India at Shivaji University Kolhapur. His area of interest is Design and Packaging.