International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 03 | June-2015 www.irjet.net p-ISSN: 2395-0072

CRASHWORTHINESS AND EVALUATION OF WASHING MACHINE IN TWO PRODUCT CLAMPING SIMULATION

Sangam Patil[1], Dr. M. A. Kamoji[2]

[1] M.Tech Student (Design Engineering), KLE. Dr. M.S Sheshgiri College of Engg & Tech, Belgaum, Karnataka, India

[2] Professor, Department of Mechanical Engineering, KLE. Dr. M.S Sheshgiri College of Engg & Tech, Belgaum, Karnataka, India

---***---

Abstract - *A washing machine comes under the category of white goods and is intended for industrial and household use. During the transportation and handling of washing machine using clamp truck at warehouse environment, various unavoidable accidents occur which greatly affects the critical components of washing machine such as U-shaped cabinet, rear panel, channels etc. Analysis of these components becomes mandatory so as to evaluate the damages caused by the clamping. Packaging elements are employed to avoid damages and ensure their safety. The aim of this study is to evaluate the crashworthiness and robustness of the washing machine components and packaging elements by performing crash analysis. Geometric model was created using SOLID WORKS V14 and meshed using HYPERMESH V11. Appropriate boundary conditions, load conditions, material properties were assigned to the model and crash analysis was done using Ls-Dyna. Stress-strain plots and energy plots are obtained for the main components of washing machine. Major risk was observed on the U-shaped cabinet and rear panel. Therefore packaging system was modified with X-braces, results were plotted and compared with existing model. The modified packaging design was better than existing one and no major risk was observed on the parts of washing machine. The washing machine was safe inside the modified packaging system during clamping scenarios. Experimental test was performed and displacement results were obtained. The results obtained from experiment are compared with simulation results and are in co-relation with one another.*

Key Words: Packaging system, Clamp truck, Warehouse, SOLID WORKS V14, HYPERMESH V11, Ls-Dyna.

1. INTRODUCTION

A washing machine is a white good product used to wash laundry, such as clothes and sheets. The most important utility a customer can derive from a washing machine is that he/she saves the effort and time to be put in brushing, agitating and washing the cloth. In white good industries once the washing machine is manufactured it is properly packed and sent to factory distribution center (FDC) for storage. From FDC the washing machine is then transported to regional distribution center (RDC) and then shipped to local distribution center (LDC) from where the customers buy the product. A distribution center is warehouse were the products are stored before they are shipped to next distribution center. During this process of distribution at FDC and RDC the loading and unloading of the product from trailer and moving the product from one place to other in warehouse for stacking is performed by clamp truck [1]. Various types of unavoidable accidents occur during handling of washing machine using clamp truck in warehouse environment.

In this paper, a top load washing machine along with its packaging is subjected to two product clamping simulation and its crashworthiness and robustness is evaluated.

1.1 Packaging system of washing machine

Packaging of washing machine plays a very important role in preventing the damages that can occur during to two product clamping scenario [2]. Fig-1 shows packaging system of washing machine which is currently followed in the industries to avoid the damages. In the figure only single product is shown for two product clamping simulation two units of washing machine packaged in the similar way are used.

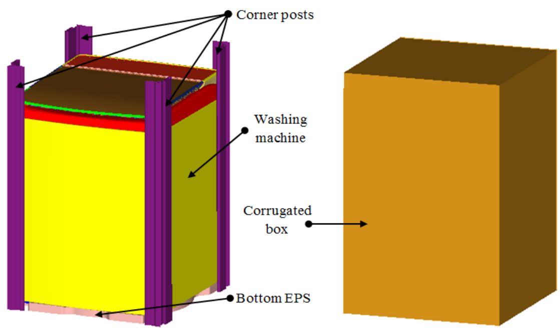

Fig -1: Packaging system of washing machine

It consists corner post, bottom expanded polystyrene (EPS) and corrugated box. Corner post and bottom EPS are primary packaging system and corrugated box is secondary packaging system. Corner posts are used to cushion the corners of washing machine and to provide resistance against axially directed compressive loads during storage and transportation [3]. Bottom EPS are used to protect lower parts of washing machine while the corrugated box holds the washing machine and primary packaging unit (corner post and Bottom EPS) together.

2. FINITE ELEMENT METHOD

Crash analysis was performed using Ls-Dyna to check the crashworthiness and robustness of the structural components of the washing machine. A brief description of the model created and meshed is explained in the following section.

2.1 Geometric Modeling

A complete geometric model consisting of washing machine, packaging unit and articulating clamps was developed in SOLID WORKS V14. Fig-2 shows geometric model of two units of washing machine with primary packaging unit wrapped inside the corrugated box and held with articulating clamp.

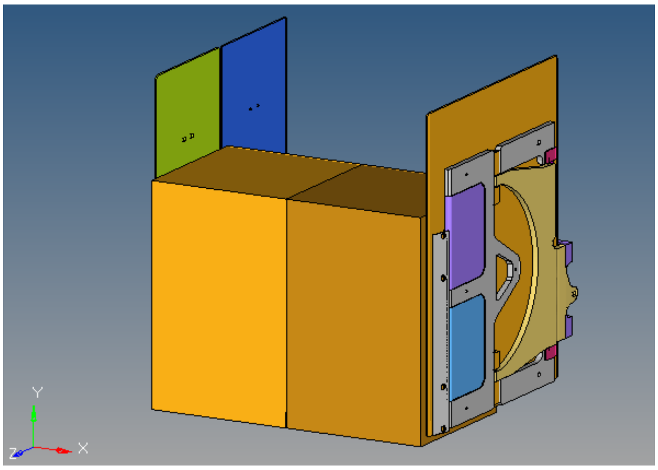

Fig -2: Geometric model

2.2 Meshing

The model consists of infinite number of points hence it should be discretized to some finite number of divisions on which analysis is to be carried out. So we mesh this model in HYPERMESH V11 to divide it into finite number of divisions called as nodes and elements. Shell meshing was performed on washing machine, corrugated box and corner posts while hexa meshing was performed on Bottom EPS and articulating clamps. Fig-3 shows rear view of meshed model.

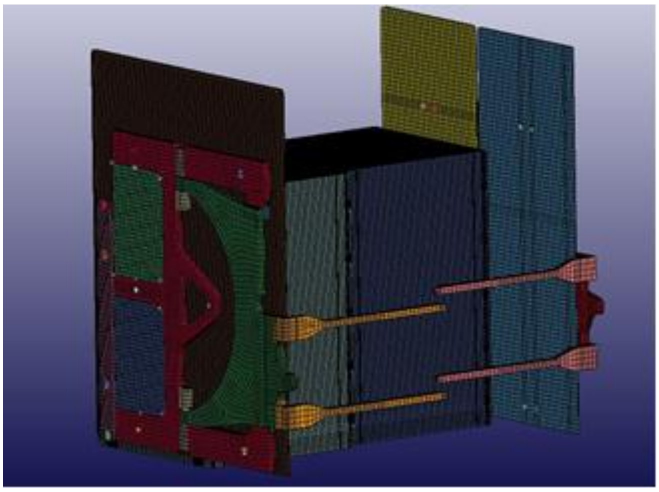
Fig -3: Rear view of meshed model

2.3. Crash Analysis

The ability of the component to absorb energy to prevent the damages in the event of an accident is referred to as crashworthiness and its analysis is called crash analysis. In this study the two units of washing machine with its packaging were clamped using articulating clamps and its crashworthiness was evaluated using Ls-Dyna. To perform this first Ls-dyna deck was prepared in HYPERMESH V11. After meshing proper materials and properties such as density (ρ), young's modulus (E) and poisson's ratio (μ), were assigned to all the parts as shown in the Table-1.

Table -1: Materials and properties

Part Name	Material Name	Material Type	ρ (kg/mm³)	E (Mpa)	μ
Articulating clamps	Steel	MAT24	$7.86e^{-6}$	$210e^{3}$	0.3
Panels	Steel	MAT24	$7.86e^{-6}$	$210e^{3}$	0.3
Corner post	Paper board	MAT24	$9.0e^{-7}$	2600	0.1
Bottom EPS	EPS	MAT63	$2.4e^{-8}$	6.47	0.1
Corrugated box	Liner board	MAT24	$5.4e^{-7}$	668	0.1

After assigning the properties proper boundary conditions were applied to the clamps. That is a velocity of 150mm/sec was applied at both the clamp cylinder locations in global x-direction and constrained translation and rotation of clamp guide in y and z directions. Later on proper contacts and control cards were given so that simulation performed is similar to real life scenario.
The contacts used in the simulations are

- *CONTACT_SINGLE_SURFACE
- *CONTACT_SURFACE_TO_SURFACE
- *CONTACT_ NODE_TO_SURFACE
- *CONTACT_NODE_TO_NODE

The control cards used in the simulations are

- *KEYWORD
- *TITLE
- *CONTROL_TERMINATION
- *CONTROL_TIMESTEP
- *CONTROL_SHELL
- *CONTROL_HOURGLASS
- *CONTROL_SOLID
- *CONTROL_ENERGY
- *CONTROL_DATABASE_OPTION

3. TWO PRODUCT CLAMPING SIMULTION

Once the Ls-Dyna deck was prepared in HYPERMESH the FE model was exported in .k format and solved in Ls-Dyna software and results were viewed in Ls-Prepost.

3.1 Simulation Results of Existing Packaging System

After solving the FE model in Ls-Dyna the stress-strain plots and energy plots were obtained from Ls-Prepost. Following Fig-4, 5, 6, 7 shows the stress-strain plots of essential parts of washing machine after clamping while Fig-8 shows energy plot of washing machine.

1) U-shaped cabinet

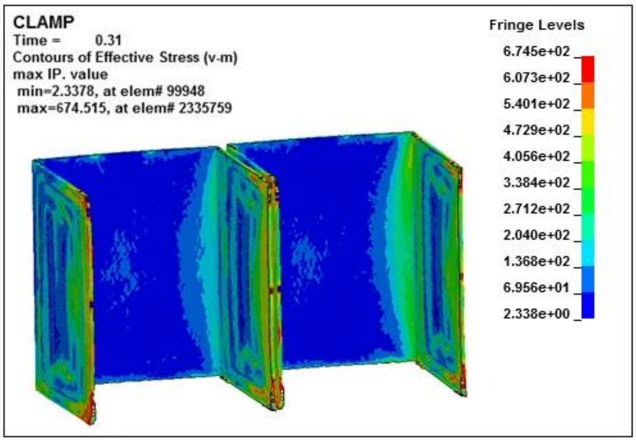

Fig -4: U shaped cabinet: Max Von-mises stress

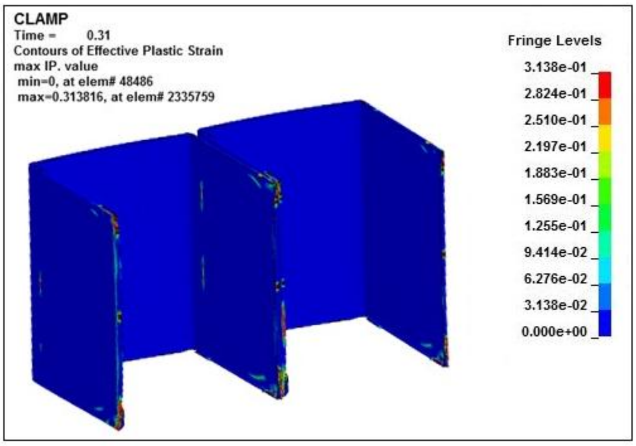

Fig -5: U shaped cabinet: Effective plastic strain

2) Rear panel

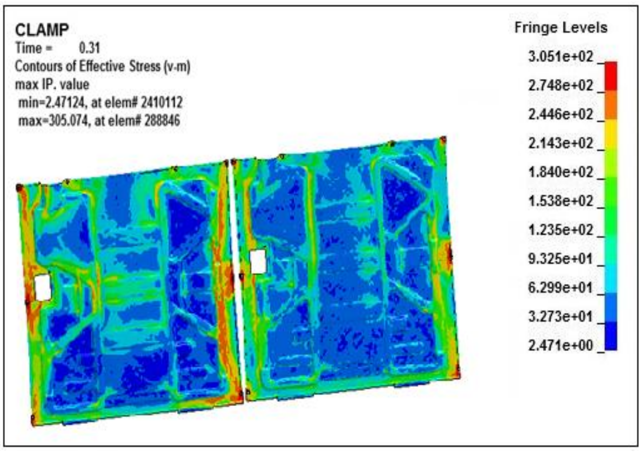

Fig -6: Rear panel: Max Von-mises stress

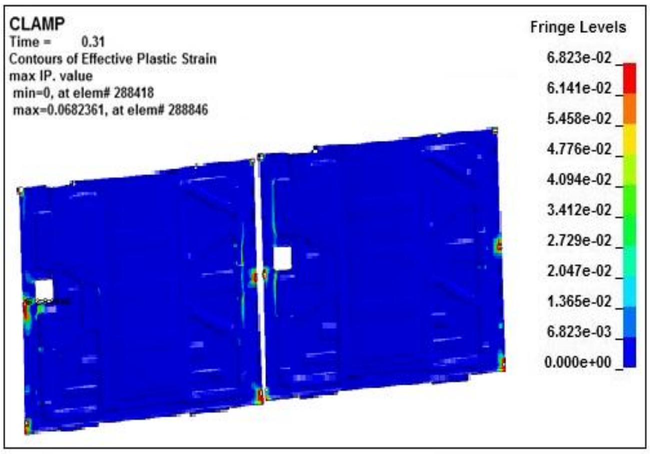

Fig -7: Rear panel: Effective plastic strain

3) Energy plots

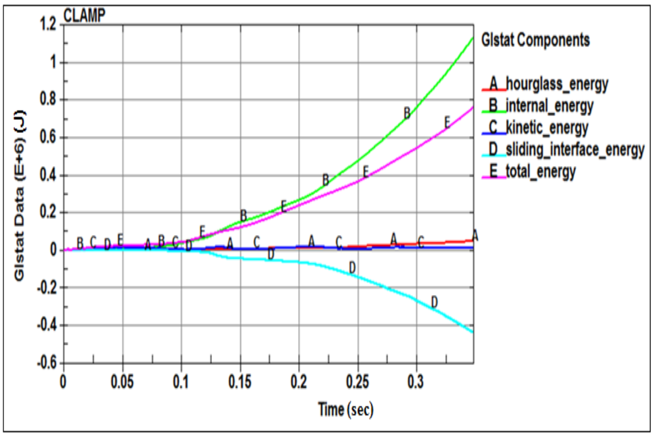

Fig -8: Energy plots

Following Table-2 shows the stress-strain values of the individual components and compared with the yield strength of the material.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 03 | June-2015 www.irjet.net p-ISSN: 2395-0072

Table -2: Stress-strain results

Part Description	Yield Strength (Mpa)	Max Von Mises stress	Effective Plastic strain	Risk Factor
U shaped cabinet	227	674.51	0.31	Major risk
Rear panel	169	305.07	0.06	Major risk

From Table-2 we conclude that U shaped cabinet and rear panel stress values exceeds the yield strength of the material and also the strain value of U shaped cabinet exceeds the effective permissible strain value of 0.25 therefore the damages are observed on the panels of washing machine during clamping. Also from energy plots it is observed that the total energy and internal energy absorbed by the washing machine during clamping are 1100KJ and 800KJ. Hence some necessary changes should be made in the packaging unit to bring the stress and strain values within the permissible limit so that the washing machine is safe during clamping scenarios.

3.2. Simulation Results of Modified Packaging System

The packaging system of washing machine is modified by introducing X-braces. The X-brace is a beam like structure made up of paper board material same as that of corner posts. Two X-braces are placed on the top of two units of washing machine inside the corrugated box in a crossed position therefore they are also called as cross braces. The dimensions of X-braces are 2.76mm thick and 764mm long. The Fig-9 shows the modified packaging system of washing machine.

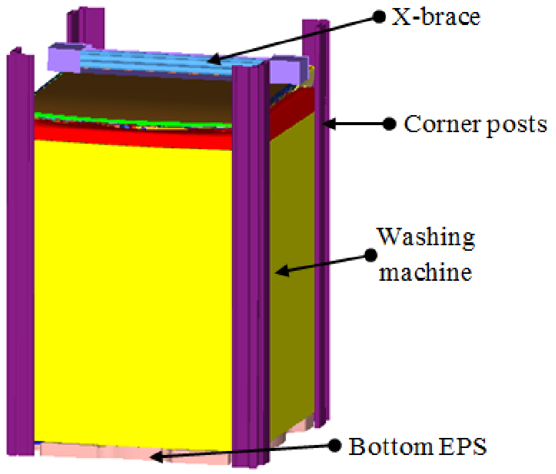

Fig -9: Modified packaging system of washing machine

The modified model is again meshed and solved in Ls-Dyna with the same material properties, boundary conditions, contacts and control cards and results are observed in Ls-Prepost. Following Fig-10, 11, 12, 13 shows the stress-strain plots of essential parts of washing machine after clamping while Fig-14 shows energy plot of washing machine.

1) U shaped cabinet

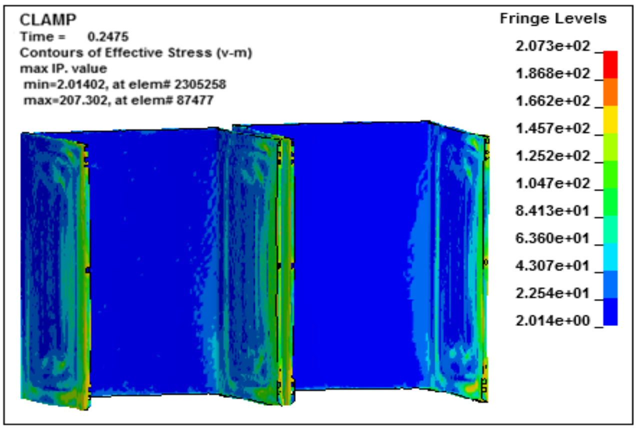

Fig -10: U shaped cabinet: Max Von-mises stress

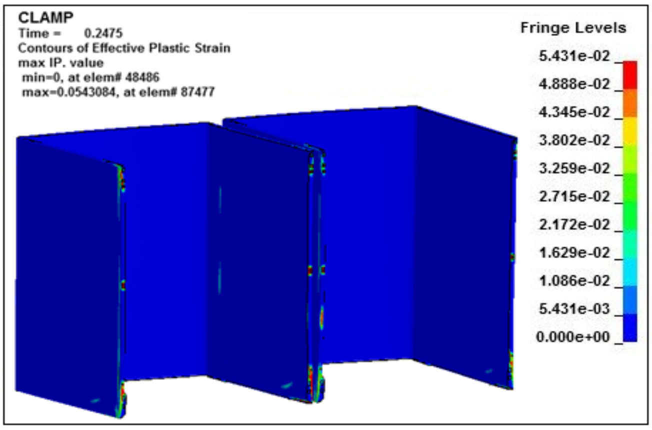

Fig -11: U shaped cabinet: Effective plastic strain

2) Rear panel

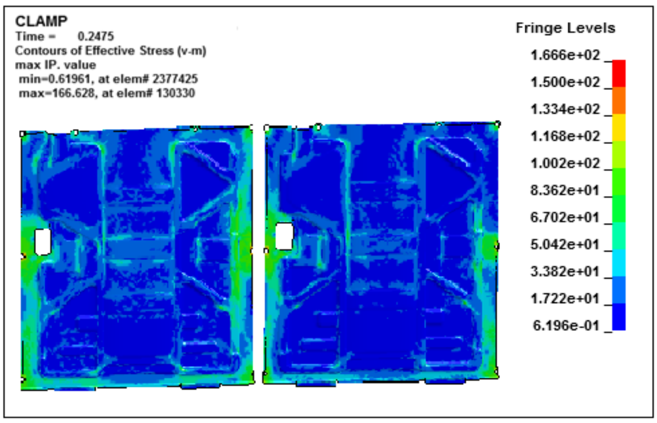

Fig -12: Rear panel: Max Von-mises stress

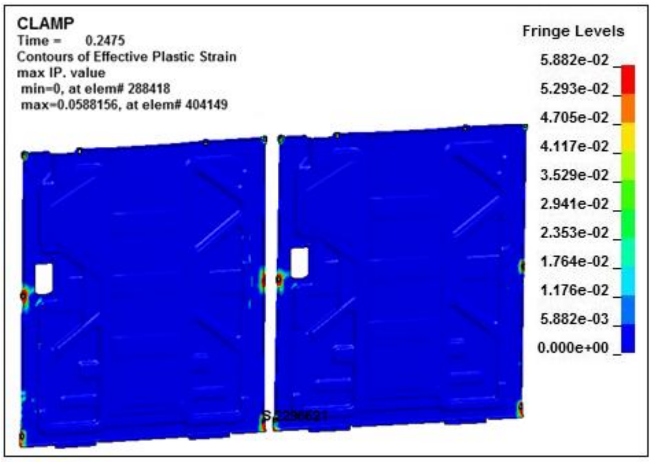

Fig -13: Rear panel: Effective plastic strain

3) Energy plots

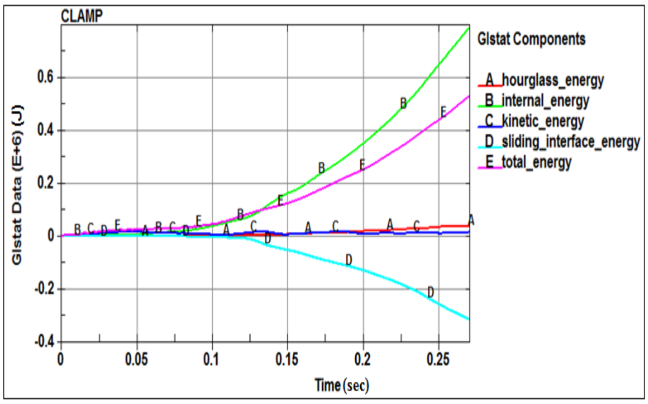

Fig -14: Energy plots

Following Table-3 shows the stress-strain values of the individual components of washing machine with modified packaging unit and compared with the yield strength of the material.

Table -3: Modified stress-strain results

Part Description	Yield Strength (Mpa)	Max Von Mises stress	Effective Plastic strain	Risk Factor
U-shaped cabinet	227	207.30	0.054	No Major risk
Rear panel	169	166.62	0.058	No Major risk

From Table-3 we see that both the components stress and strain values are below the yield strength of the material and the effective permissible strain value. Also from energy plots it is observed that the total energy and internal energy absorbed by the washing machine during clamping are 700KJ and 500KJ which is lesser then existing model. Hence the modified design of packaging system of washing machine is better than the existing packaging system and hence the washing machine is safe during clamping scenario and no damages are observed on the panels of washing machine.

4. EXPERIMENTAL RESULTS

Experimental test was conducted in a laboratory and an attempt was made to validate the results obtained from simulation by comparing the results of experimental. In this test displacement was measured at four points of U shaped cabinet of two washing machine units using displacement transducer as shown in the Fig-15. CDP-D dual port transducer is used to measure the displacement having the specifications like capacity 50mm, rated output 5mV/V ($10000x10^{-6}$ strain)±0.1%, temperature -10˚ to 60˚ (no condensation). Plot of displacement v/s time graph was obtained at four points of U shaped cabinet.
Similarly in the simulation displacement was measured at four nodal points of U shaped cabinet of two washing machine units using history option in Ls-Prepost as shown in the Fig-16.

Fig -15: Displacement transducer on U shaped cabinet

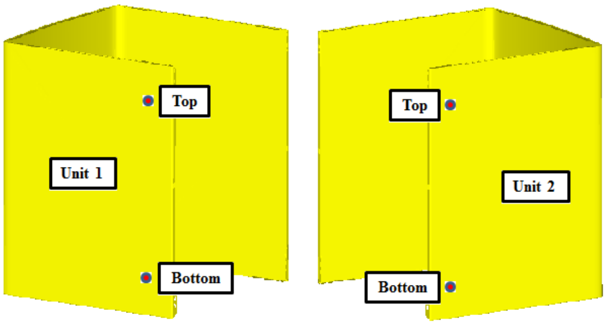

Fig -16: Displacement at four nodal points of U-shaped cabinet

The results of experiment and simulation obtained are clubbed into one graph. Fig-17, 18, 19 and 20 shows the displacement v/s time graph of U shaped cabinet at top and bottom position of unit1 and unit2 of washing machine.

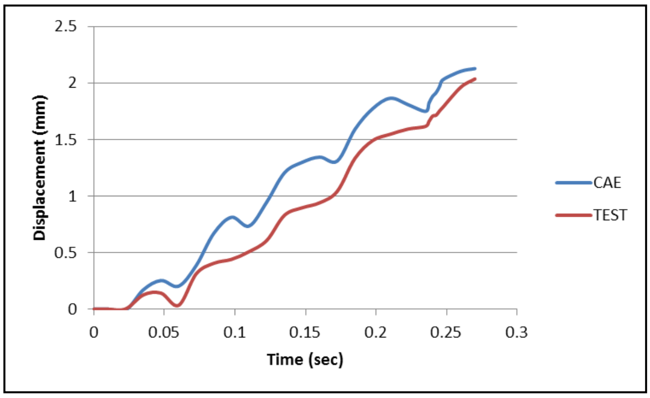

Fig -17: Displacement of unit1 top

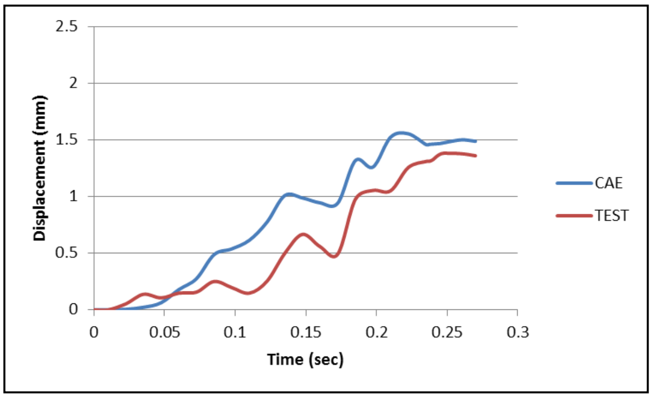

Fig -18: Displacement of unit1 bottom

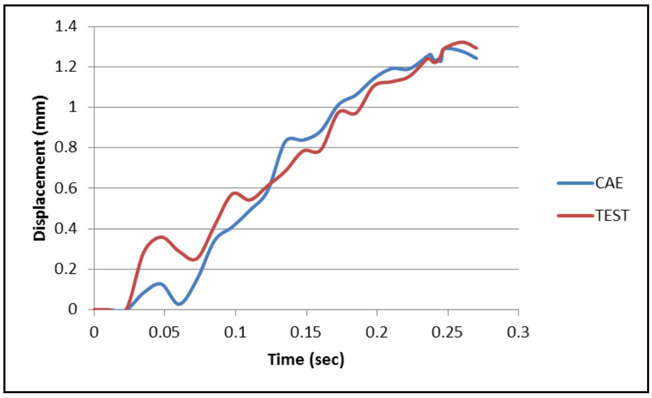

Fig -19: Displacement of unit2 top

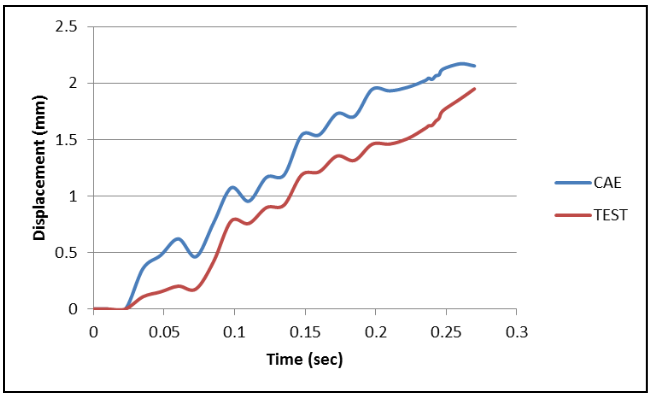

Fig -20: Displacement of unit2 bottom

From graphs we can see that simulation results are higher than the experimental results this is because displacements obtained from simulation were measured at single nodal points. Following Table-4 shows the comparison of displacement results obtained from experiment and simulation.

Table -4: Comparison of displacement results

Component	Displacement of U shaped cabinet (mm)		
	Experimental	Simulation	Error (%)
Unit1 top	2.12	2.03	4.24
Unit1 bottom	1.48	1.35	8.78
Unit2 top	1.29	1.24	3.87
Unit2 bottom	2.15	1.94	9.76

From table it can be observed that simulation results are closer to experimental and error observed is also less than 10%. Therefore the simulation performed is correct and valid.

5. CONCLUSION

The following conclusions are drawn from the present work

1. The stress-strain results obtained with existing packaging system are higher than the yield strength and permissible plastic strain due to which damages are observed on side and rear panels of washing machine.
2. The stress-strain results obtained with modified packaging system are considerably reduced and are well below the yield strength and permissible plastic strain.
3. The total energy and internal energy absorbed by modified packaging system are considerably reduced than that absorbed by existing packaging system.
4. The modified packaging system of washing machine using X-braces is better than the existing one. Also the washing machine is safer and no damages are observed on it in modified packaging unit during clamping scenarios.
5. The displacement results of experiment and simulation are in correlation with each other and hence simulations performed were correct and valid.

REFERENCES

[1]. James Stewart, “Clamp Truck Simulation in the Laboratory Environment”, Thesis, Clemson University, 2005.

[2]. Jing Qian, Heping Cai, Weiwei Ma, and Zhiwei Hao, “Shock Analysis on a Packaged Washing Machine from Damage Boundary: Shock Response Spectrum to

Component Failure", Shock and Vibration, Volume 21, Article ID 462492, 2014.
[3]. Hong Yeol Lee and Yongin-si, "Corner Protection Pad of Washing Machine and Washing Machine Packaging Structure Using the Same", Samsung Electronics Co, assignee, Patent US0132799 A1, 9 Jun, 2011.
[4]. Jay Singh, Tyler Blumer, Soma Roy and Koushik Saha, "Carton Clamp Test Methodologies and the Effect on Load Containment and Retention", Packaging Technology and Science, Volume 28, 2015.
[5]. Sunil Patil and S. A. Kulkarni, "Optimization of Crosspiece of Washing Machine", International Journal of Research in Engineering and Technology, Volume 2, 2013.

