EVALUATION OF COMMERCIAL LAUNDRY MACHINE IN ROUGH HANDLING LOAD CASE

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Abstract - *Rough handling is a major issue that arises in the industries i.e. in the manufacturing plant as well as the customer's domain. The intension of this project is to evaluate a unpackaged laundry machines ability to withstand specific levels of dynamic stresses it may experience. Due to rough handling damages are seen with severe conditions on the rear consoles. Hence it becomes necessary to carry out the analysis of the machine under this load case. The machine is impacted on the rear end, where it's made to fall on the rear part hitting to the rigid wall. The model was built using SOLID WORKS V14 and meshed using HYPERMESH V11. After meshing the crash analysis was carried out in Ls-Dyna. The results obtained from simulation showed that the parts present at the rear end were not safe and because of which the inner structural parts may get damaged. Since, damage occurs; a small modification was made that is introduction of nylon grommets instead of nut and bolts at the rear end. Again the simulation was and the results obtained after this modification shows that the stress and strain values obtained are satisfactory. Hence it is conclude that the modified model is better that the existing one for rear impact rough handling load case. Experimental analysis is performed according to Consumer Rough Handling standards (T 7 Series). Experiment of the modified model was done and the results obtained from the experiment and simulation are in good co-relation, hence proves the validity of results obtained.*

***Key Words*: Solid Works V14, Hypermesh V11, Ls-Dyna, T-7 Series standard.**

1. INTRODUCTION

A laundry machine is a device used for all types of laundry jobs. In industries hand trucks and dolly are very effectively used for moving the products from one place to other. The use of hand truck and dolly leads to a need for performance testing of unpackaged product. Also rough handling of the machine within the customer's domain leads us to check the performance of the machine under the rough handling load case.. The product must have the ability to withstand sudden impact caused by rough handling by the user. T-7 series standard specifies the current procedure for rough handling simulation. Understanding of the environment in which the unpacked product moves is an essential part of this process. These arise from distribution activities that are manual handling, transportation, and storage and can easily damage a product that is unpacked. Although proper care is taken while transferring the machine but due to rough handling the tipping of the machine takes place. Due to tipping the rear end parts which are fragile gets damaged due to impact. Hence it becomes necessary to carry out the analysis of the machine under this load case.

1.1 Objective and Methodology

The main objective is to protect the laundry machine from rough handling. When the machine hits the ground with a velocity shock waves are produced in the machine and this shock will be transferred to the entire machine. Due to this the structural parts inside the machine gets damage since we cannot avoid this situation we can reduce the amount of shock experienced by the machine with the help of nylon grommets and evaluate the severity of damages in the rear console. Methodology is the flowchart in which the work has be carried out and is as follows in Fig-1,

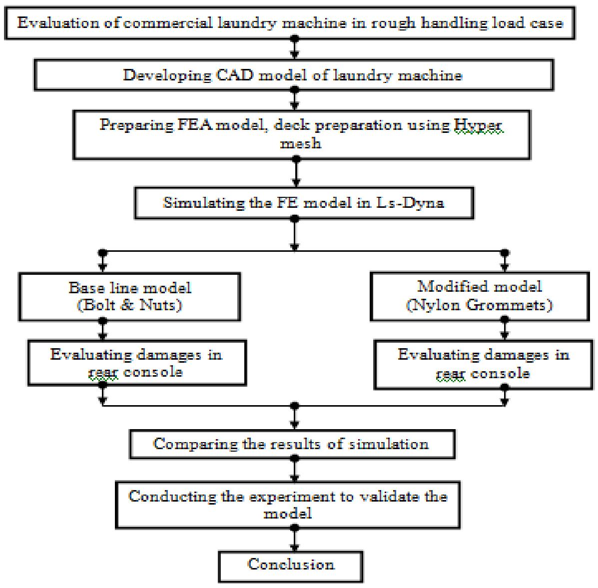

Fig -1: Methodology.

2. GEOMETRIC MODEL AND MESHING

A geometric model of the machine was created using Solid Works V14. Fig-2 shows the geometric model and its capacity is 73.9kgs. The model is saved in .iges format.

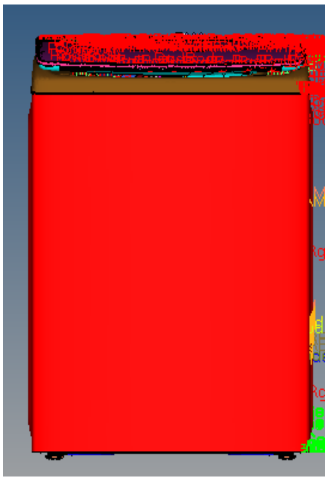

Fig -2: Geometric model.

2.1 Meshing

The geometric model in .iges format is taken in Hypermesh and the meshing was carried out. Shell mesh was done on the 2D components using 2D elements while tetra and hexa mesh was done on 3D components using 3D elements. The meshing was done as per the quality check. After meshing was completed the number of elements and nodes that were found are 2359917 and 1168721. The Fig-3 shows the meshed model from the rear side.

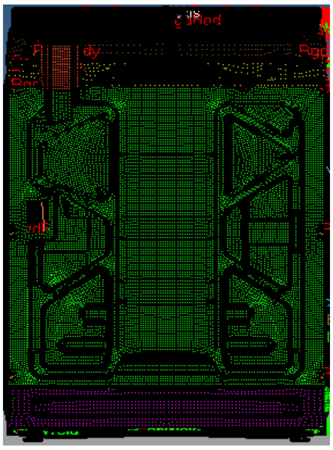

Fig -3: Meshed model.

2.2 Materials and Properties

The deck is prepared in hypermesh where in the meshing is done using Hypermesh and the materials and properties are assigned then boundary and loading condition is applied and finally the simulation is carried out in Ls-Dyna. The materials and properties such as density, young's modulus and poisson's ratio have been applied to the parts as shown in the Table-1.

After the material and properties are assigned the boundary and loading condition are to be applied. An initial velocity of 2.3 radians/sec is given to the full product so that it falls on the rigid wall with its rear face on it and a gravity load of 9810mm/s^2 is applied to it. The simulation is done only for this loading condition and hence stress and deformation are only for the loaded condition. Stresses generated due to stress concentration effects are neglected. High stresses near sharp corners and bolt holes are neglected due to the above assumption.

Table -1: Materials and Properties

Part	Mate-rial	Density ton/mm^3	Modulus MPa	Poisson ratio	Yield strength
Rear panel	Steel	7.86E-09	210000	0.3	169
Top Rear channel	Steel	7.86E-09	210000	0.3	169
Wire shield cover	Steel	7.86E-09	210000	0.3	169
Rear assembly Upper tray	PVC	1.310e-09	1117.67	0.35	40.1
Rear assembly Lower tray	PVC	1.310e-09	1117.67	0.35	40.1
Glass	Glass	2.5e-9	70000	0.23	145

3. CRASH ANALYSIS

Crash test is a form of destructive testing performed in order to check safe design standards in crashworthiness and crash compatibility. Instead of physical models, a finite element model is generated and is used for the analysis. Crashworthiness simulation is less expensive and gives more information than experimental techniques.

When a crash analysis is been done is may so happen that a component may penetrate into the other which gives us wrong results so to avoid this contacts are used. Contacts are evoked using *CONTACT. The contacts that have been used are automatic single surface, automatic surface to surface, and automatic nodes to surface. After the contacts the control cards such as keyword, readme, output energy, hourglass energy, terminate , time step etc., have been used so as to avoid the unwanted time that it might take to execute the simulation.

3.1 Simulation Baseline Model

Simulation is a process by which the product validation can be done on the software. Simulations show how a system will behave in real life when it is subjected to a particular boundary and loading condition. Simulations are used when a mathematical model is complex. In the machine considered in the study there are three nuts and bolts present at the top rear end which are used to provide a rigid joint between components. Since they are rigid connections there will not be any flexibility for the components which are attached with them. The simulation was done in Ls-Dyna and the stresses and strains were found in the individual component. The stress-strain plots of components which have maximum impact of tip over are as follows.

1. **Rear Top Channel.**

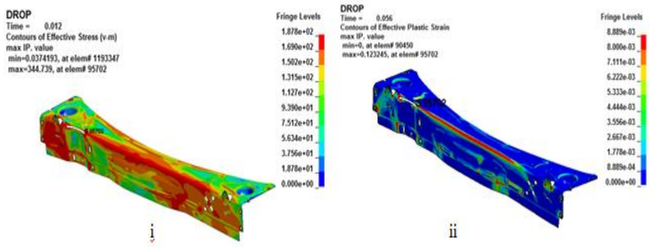

Fig -4: Rear top channel: (i) Max Von Mises stress (ii) Max Principle strain.

2. **Wire shield cover.**

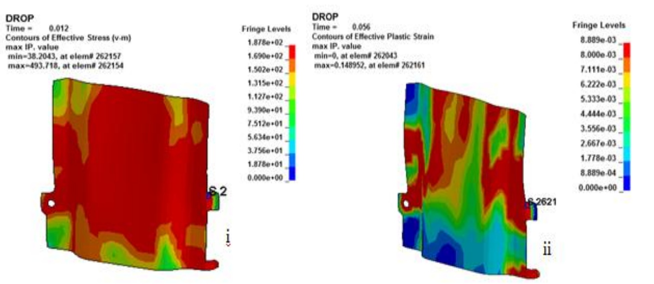

Fig -5: Wire shield cover: (i) Max Von Mises stress (ii) Max Principle strain.

As the plots of stress and strain are obtained for the above components similarly they are obtained for the remaining components and their values of stress and strain are tabulated below in Table-2.

We can see from the table that except for glass all the remaining parts are crossing their yield value which means that a modification is required in order to protect these components from rough handling.

Table -2: Baseline Model Results

Part Description	Yield strength (Mpa)	Baseline model	
		Max Von Mises Stress/Max principle stress	Max principle strain (%)
Upper tray	40.1	91.73	46%
Lower tray	40.1	126	51%
Rear top channel	169	344.73	12.3%
Wire shield cover	169	493.71	14.8%
Glass	145	87.81	3.3 mm
Rear panel	169	198.9	2.9%

3.2 Section force in bolt for baseline model

The force that is induced at the time of impact is known as the section force in the bolt. Totally there are three bolts at the rear end of the machine and the section force is found for the one bolt. The section force in bolt 1 is found to be 326.88 N and is shown in Fig-6.

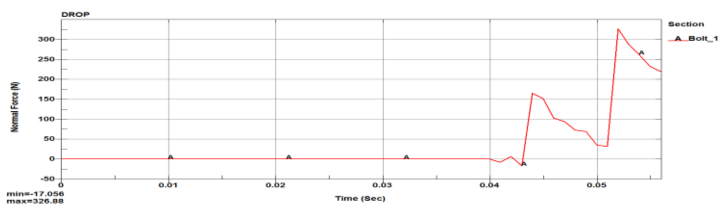

Fig -6: Section force in bolt 1 of baseline model.

3.3 Simulation Modified Model

Since the components in the baseline model exceed their yield values which causes permanent deformations and damage in them. Hence the nut and bolt has been replaced by the nylon grommets Fig -7 so as to reduce the damage caused by the impact.

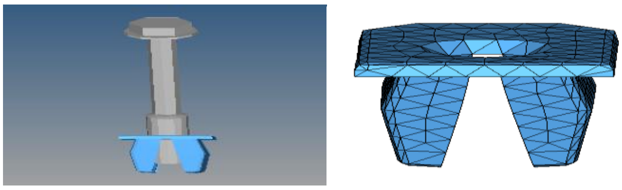

Fig -7: Nylon grommets in the modified model.

Nylon grommets are a one -piece self-retaining blind screw receptacles which are non-corrosive in nature that spread the load over a wide area, because of the flex to give strength and high load bearing capacity. They provide flexibility upon impact and distribute the impact force uniformly by reducing the stress values. The simulation was done once again with the modification by keeping the boundary and loading conditions same. The stress strain plots that were obtained are as follows.

1. **Rear Top Channel.**

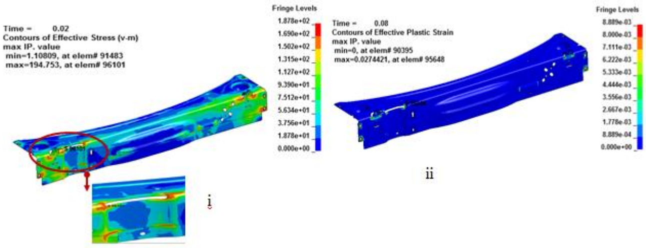

Fig -8: Rear top channel: (i) Max Von Mises stress (ii) Max Principle strain.

2. **Wire Shield Cover.**

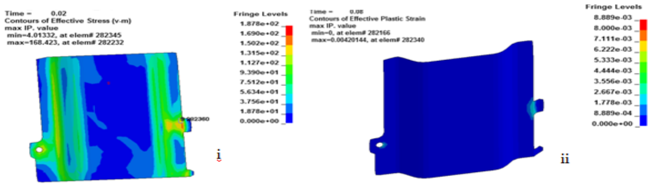

Fig -9: Wire shield cover: (i) Max Von Mises stress (ii) Max Principle strain.

Table -3: Modified Model Results

Part Description	Yield strength (Mpa)	Modified Model	
		Max Von Mises Stress/Max principle stress	Max principle strain
Upper tray	40.1	41.15	8.4%
Lower tray	40.1	89.35	68%
Rear top channel	169	194.75	2.74%
Wire shield cover	169	168.42	0.42%
Glass	145	85.27	2.2 mm
Rear panel	169	209	5.1%

From the above Table -3 we can see that the stress and strain values have been considerably reduced as compared to baseline model results seen in Table -2. The components upper tray, wire shied cover and glass are found to be completely safe. While the components like lower tray, rear top channel and real panel cross the yield values yet they are safe because the maximum stresses are found on the bolt locations, corners and locaters which can be neglected.

3.4 Section force in bolt for modified model

The section force in bolt 1 is found to be 92.66 N and is shown in Fig-10. Which is less than that of baseline model.

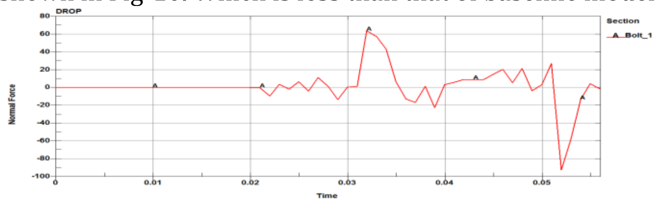

Fig -10: Section force in bolt 1 of modified model.

4. EXPERIMENTAL PROCEDURE

The experiment on the machine for impact is carried out on the basis of the standard T-7 series. The rough handling tip testing procedure is as follows.

- Purpose define the procedure used to determine the performance of an unpackaged product during mishandling – tipping.
- Install feet per the installation instructions.
- Slowly tip the unit forward until unit begins to fall forward independently.
- Stop tipping and allow the unit to fall backwards onto feet.
- Repeat on all 4 sides.

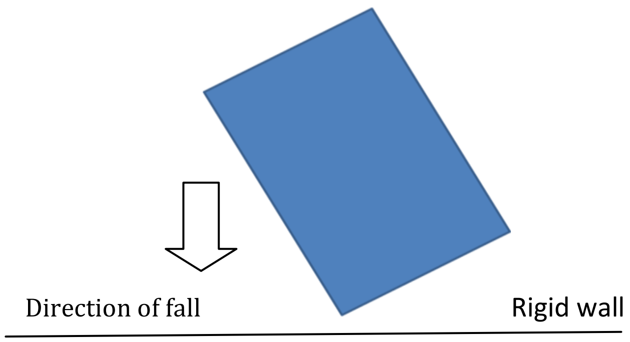

Fig -11: Model Setup.

4.1 Accelerometer Test Result Data

Accelerometer is an instrument used for measuring the acceleration of a moving or vibrating body. The accelerometer is placed on the valve body as shown in fig -12 to record acceleration with respect to time when the impact occurs.

Fig -12: Mounting of accelerometer on Valve body

The graph in fig -13 is generated from the accelerometer which is on the valve body. Acceleration v/s time graph gives us the magnitude of acceleration i.e. 'g' value that has been induced in the machine due to impact and can be directly noted from the graph. The highest value irrespective of the sign must be considered as the value of 'g'.

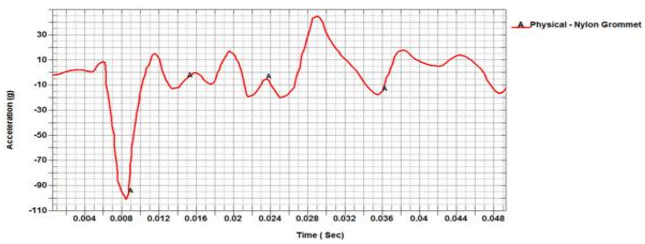

Fig -13: Acceleration v/s time of experimental modified model.

Now the acceleration v/s time graph is obtained for the simulation with the help of LS PrePost. In the simulation, the graph of acceleration v/s time is obtained on the valve body. Similar to the graph that has been obtained for the modified model the graph for the baseline model is also obtained in Ls prepost. The graph below fig -14 in which all the three acceleration v/s time graphs are merged. The red color line in the graph represents the physical model variation, green line represents the simulation modified variation and the blue line represents the simulation baseline model variation.

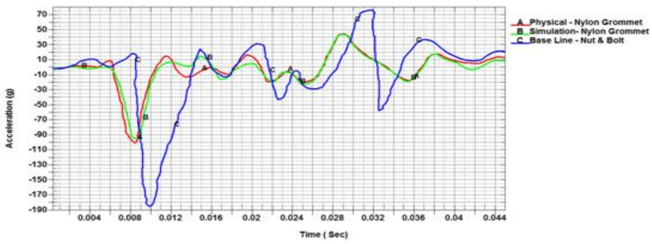

Fig -14: Combined Acceleration v/s time graph.

Now, the comparison of the g values obtained from both experimental and simulation has been done for the modified model in the Table -4.

Table -4: Comparison of 'g' value

Component	Experimental data (mm/s²)	Simulation data (mm/s²)	Error (%)
Valve body	101	95	5.94

4.2 Calculation of Specific Energy Absorbed

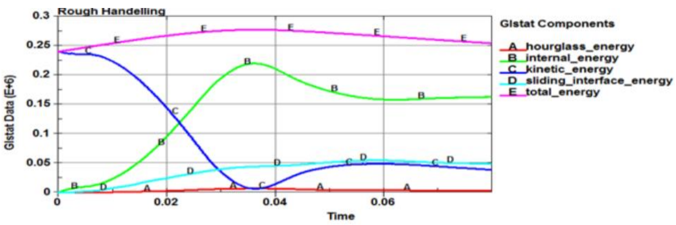

Fig -15: GLSTAT v/s TIME of baseline model

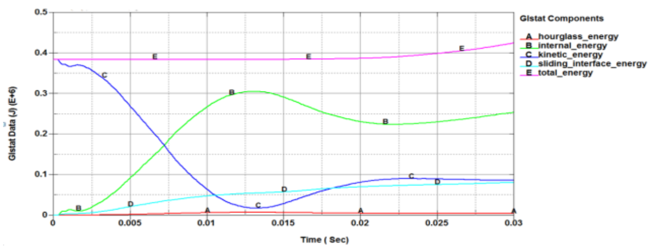

Fig -16: GLSTAT v/s TIME of modified model

Fig -15 and Fig -16 represent the energy plot of baseline model and modified model obtained from simulation, which has different energies and their behavior.

Specific Energy Absorbed (SEA) is the energy absorbed after the impact happens. It is defined as ratio of the maximum internal energy to the total mass of the body.

$$SEA = \frac{Maximum\ Internal\ Energy}{Mass\ of\ the\ body}$$

The internal energy can be obtained from the standard energy graph of each simulation i.e. Fig -15 and Fig -16

For the baseline model maximum internal energy value is $0.225 * 10^6$ as in Fig -15.

$$SEA = \frac{225}{73.9} \frac{kJ}{kg}$$

$$SEA = 3.044 \frac{kJ}{kg}$$

For the modified model maximum internal energy value is $0.31 * 10^6$ as in Fig -16.

$$SEA = \frac{310}{73.9} \frac{kJ}{kg}$$

$$SEA = 4.194 \frac{kJ}{kg}$$

Hence percentage increase in energy absorption is,

$$\text{Percentage increase in energy absorption} = \frac{4.194 - 3.044}{3.044} * 100$$

$$\text{Therefore, Percentage increase in energy absorption} = 37.78\%$$

5. CONCLUSIONS

Analysis have been done on the model with nut and bolt initially and then by replacing the nut bolt with the nylon grommets using LS Dyna software and the following conclusions can be made by comparing the results obtained from the simulation.

- In the baseline model, high stress and strain are observed at several locations which cause plastic deformations and permanent damage to the components. The damages have been avoided in the modified model by replacing the three nut and bolt at the rear end with nylon grommets.
- The simulation results of stress & strain obtained for the various components are found to be lower in modified model than that the baseline model.
- The simulations that have been carried out shows that by replacing the nut bolts with the nylon grommets reduces the 'g' value considerably which can be seen from the acceleration v/s time graph.
- The g value for the baseline model obtained from the simulation is 189 g and the g value for the modified model is 95 g which means that the energy that has been inducted into the system due to impact have been uniformly distributed within the system this is due to the flexibility that the nylon grommet provides.
- The g values from simulation of the modified model and that of the experimental model closely match with each other i.e. 95 g for simulation and 101 g for experimental model and the error in percentage is 5.94% which is acceptable.
- The percentage increase in energy absorption in the modified model over the baseline model is found to be 37.78%.

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