Flexural testing, Ball impact testing and FEA of display lens

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***Abstract*— Domestic appliance products subjected to impact load testing were analyzed by FEA simulations. Hence accuracy of FEA model is one of the important points during design phase. To verify the FEA material model used for design of plastic parts, its validation under impact loading need to be done. Material model validation using three point bending test, dart impact test was commonly performed for impact simulations. The experimental method to measure impact data by using accelerometer was common. We have carried out experimentally three point bending test, ball impact test on product in assembled position and as a single part too. These experimental results have been compared with FEA results by performing these tests in FEA module. The results obtained from FEA gives 10% variation with experimental results which shows that this material model can be used for product level simulations.**

***Index Terms*— Ball impact test, Tri-axial accelerometer, LS-Dyna, Hypermesh**

I. INTRODUCTION

Domestic appliance components were subjected to impact load testing during UL certification tests [4]. Electronic component casing was made of polymer material and such type of products was subjected to drop impact test, Hence Design of such components with better drop protection was preferred [5]. For design of polymer material parts against impact analysis FEA tool was used predominantly. Hence it is necessary to ensure FEA model must replicate accurate behaviour of polymer material in Simulations. Validation of material model used for such parts was first step in impact simulations [1]. The experimental measurement of impact test can be done using accelerometer set up. The accelerometer allows us to measure acceleration, velocity, displacement of particular position at particular time [2].The initial input parameters required for FEA model while using polymer material has been explained by Robert Lobo [3].The material card must have data of strength variation of material with respect to change in strain rate. The parts to be used in Home appliances aesthetics section were subjected to impact resistance test as per UL standards, hence during design of such parts impact simulation has prime importance.

In this work, FEA model which to be used in actual product simulation was validated against standard three point bending test. The same model has been used for simulation of experimental ball impact test of product in assembled position. The bending test specimen was cut from injection moulded product. Experimentally acceleration at particular location was measured using accelerometer for multiple trials. The experimental result obtained was compared with FEA simulation results. The impact simulation was performed using Hypermesh and LS-dyna softwares. Objectives of study as follows:-

- Verify effect of change in strain rate on flexural properties o PVC.
- Verify the material model response under lateral condition and impact loading condition.

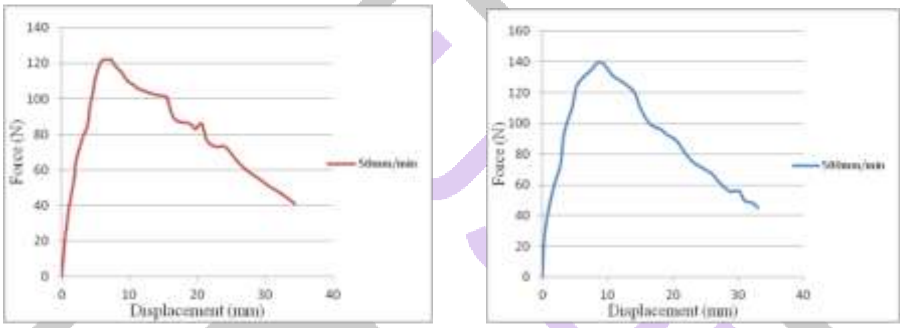
II. SPECIMEN PREPARATION AND EXPERIMENTATION

The product which was used in this work was made of PVC. PVC was available in number of grades out of which PVC with highly transparent characteristics was selected. The specimens used for testing purpose were cut from the prototype of product. The product used in testing was display lens of home appliance product. For assembly level testing the lens in assembled condition was used. The specimen used for flexural testing was as per ASTM standard D790. The flexural testing was carried on two specimens. For each specimen different strain rate was used. The main purpose of testing was to know change in flexural properties of material with change in strain rate. Testing was performed with speed of 50mm/min and 500mm/min. Figure 1 shows the specimen with fixture and test setup before and after the testing.

(a) Flexural Test setup (b) Fixture for Testing

Figure 1. Test set up and Test Fixture

The testing was carried on UTM with Advanced Computerized Electromechanical System Machine. The load cell used for machine has capacity of 10000N with least count of 0.1N force. The material selected was good in flexing as it does not rupture at high speed of testing.



(a) 50mm/min (b) 500mm/min

Figure 2. Force Vs Displacement Graphs

Figure 2 shows experimental plots for two selected strain rates. The results obtained from the testing were in the form of the Force-Displacement plot. From these two graphs it has seen that with increase in strain rate flexural modulus of the material also increases. The material has good flexural characteristics as it does not rupture at high testing speed. The result obtained from testing had effect of noise factors such as specimen preparation, machine least count, manufacturing factor effect etc. After flexural testing ball impact test was performed on lens sample cut from available prototype. The fixture was prepared for ball impact test separately. The fixture was prepared such that the lens during testing can be approximated same as in assembled condition in one of the home appliance product. This testing mathematically can be considered as simply supported plate subjected to impact loading. For experimentation purpose Tri-axial accelerometer was used. Figure 3 shows experimental setup for accelerometer testing. Figure 3 also shows the position of the accelerometer probe. The position of accelerometer probe was important for recording acceleration data during simulations.

(a) Test set up (b) Accelerometer Position

Figure 3. Ball impact test set up and accelerometer position

The testing was carried on two specimens cut from prototype. Impact testing was carried out with 3 impact energy levels. The impact energy has been decided by height of fall of steel ball from the pipe. Experiment has been done repeated number of times to ensure the repeatability of the results obtained. The path followed by ball through the pipe was not same in each trial due to which exact repeated results were difficult to obtain. The average of the obtained results was calculated and that result was used for comparing results with simulation results.

Table.1 Results of Product level Ball impact test

	Acceleration					
	0.5Joule		1Joule		1.5 Joule	
Trials	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
1	148.281	142.18	193.652	186.27	240.05	259.95
2	149.065	136.56	169.363	189.24	238.24	260.39
3	140.025	154.23	184.237	181.12	223.37	251.05
Mean	145.79	144.3233	182.417	185.543	233.887	257.13

(a) Lens assembly

(b) Accelerometer position

Figure 4 Assembly impact test set up

Table 2 Results of Assembly level Ball impact test

	1.5Joule		
Trials	1	2	3
Acceleration	107.869	96.8018	123.363
Mean	109.344		

III. SIMULATION

The simulation test has been performed with help of Hypermesh and LS-Dyna tools. Preprocessing of all models has been performed in Hypermesh and LS-Dyna used as solver. Flexural test has been simulated with same loading and boundary conditions as per experimentation.

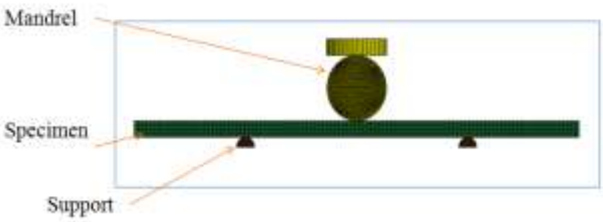


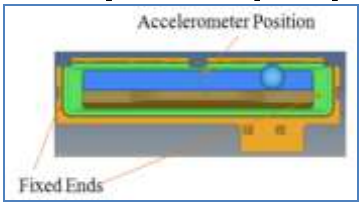
Figure 5 Flexural test simulation boundary conditions

Figure 5 shows loading and boundary conditions of flexural test simulation. The specimen was simply supported at its ends and mandrel has been displaced with required velocity. The maximum load obtained from simulation has been compared with experimental results.

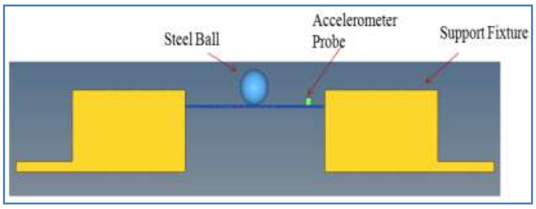
Table 3 Maximum load Results Comparison

	Max. Load (N)	
	50mm/min	500mm/min
Experimental	123	140
Simulation	132	153
% Error	7.317	9.2857

Table 3 shows comparison in experimental and simulation results of flexural test. The simulation results were close to experimental results. Simulation shows slight over-prediction in maximum force estimation. The flexural test simulation was followed by ball impact simulation. Figure 5 shows loading and boundary conditions of ball impact test simulation. The accelerometer probe has been modeled in Hypermesh and material has been assigned to it. In simulation acceleration level was measured from accelerometer probe and that value was compared with the experimental results. Figure.6 shows loading and boundary conditions of ball impact test with pocket panel simulation.



(a) Lens assembly



(b) Lens impact test set up

Figure 5 Boundary condition of lens impact simulations

The selection of type of meshing and element forms used in simulation was as per guidelines for impact simulations. For Tetra mesh elements Type (13) element form was used. For Hex Meshing Type (1) element form was used. The ball impact simulation on pocket panel assembly has been performed same as of previous simulation. The accelerometer probe was positioned at some distance from impact position as per measurement in experiment. The acceleration value was measured for impact simulation and compared with experimental results. The results obtained from impact simulations were tabulated in Table 4 and compared with experimental results.

Table 4 Comparison of Results

	Acceleration			
	0.5Joule	1Joule	1.5 Joule	Assembly level
Experimental	145.79	185.84	257.13	109.344
Simulation	127	196	241	97
% Error	12.8	5.183	6.2731	11.28

The results obtained from the impact simulation shows good resemblance with experimental results.

IV. CONCLUSIONS

1. Experimental results of flexural test show increase in flexure strength with change in strain rate. The material has ability to flex without rupture at high strain rate.
2. The simulation results of flexural testing shows slightly over predicted force prediction with percentage error of approximately 10%.
3. The results obtained from impact testing shows good repeatability and simulation predictions gives good validation with percentage error of approximately 9%.

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