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IMPACT CORRELATION WITH ACCELEROMETER IN HOME APPLIANCE INDUSTRY

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ABSTRACT

Non destructive testing in Verification and Validation (V&V) are playing a significant role now a days. Since validated simulation model provide more insight of product and gives real time behavior without consuming the physical product for testing. Acceleration data is very valuable input for finding loopholes in the simulation models and optimizing the method of modeling. Once validated simulation model has been set up, multiple iterations can be run for solving material differences, geometrical changes and variations in process tolerances which will ultimately reduce the build-fix-rebuild time.Simulation methodology helps to arrive at appropriate decision for selection of optimized and safer design.

Keywords: Flat Drop,inclined impact,g value,correlation

NOMENCLATURE & TERMS

CAD	Computer Aided Design
FEA	Finite Element Analysis
LDC	Local Distribution center
EPS	Expanded Polystyrene
PVC	Polyvinyl Chloride
PC	Polycarbonate
LS-Dyna	Finite element program
C.G	Center of Gravity
WOOD-001L	Internal Standard

INTRODUCTION

Product development cycles can be tedious and expensive procedures, particularly when physical prototypes are required. When a tangible model is involved, the product must be designed,built,tested,and then fixed accordingly. Physical prototypes must be built and rebuilt after every unsuccessful test, making them a less than optimal choice for a company that values efficiency. With Simulation, however, the development of a product moves straight from design to testing and analysis, and then finally to build. Virtual prototyping or Simulation allow for the digital exploration of a complete simulated product before it is actually built, decreasing the number of rebuilds necessary and minimizing material waste. Organisations now have opportunities to move towards the simulations which allows to test product without destroying the physical product once the validated model has been set.

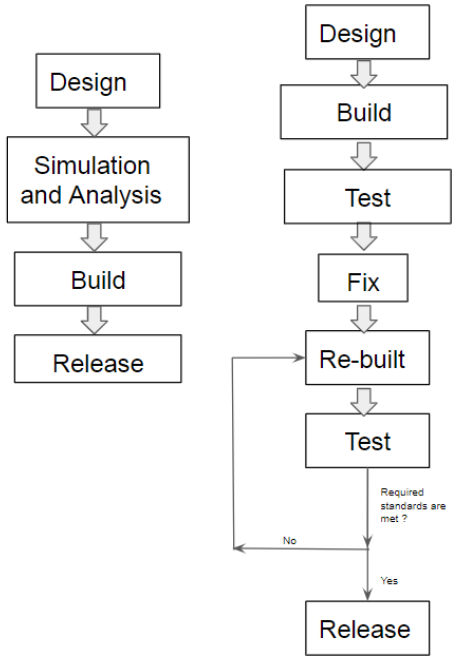

FIGURE 1: SIMULATION AIDED DEVELOPMENT CYCLE Vs CONVENTIONAL DEVELOPMENT CYCLE

Transit Handling of Home appliances during distribution chain involves damages. To verify product sustainability to these damages, internal and external specifications are set in every region of the world.These specification test includes drop

on bottom, Impact on lateral faces, dragging of product, clamping of Product and Foot Impression test on top of product.

Drop test is important because it helps to quantify the strength of package as well as Product. This drop test method is particularly suitable where the products are normally handled manually during some part of the distribution cycle (LDC or Trade Partner)when the product may be dropped from some height.This load case may also relate to low frequency truck vibration such as the product loading when going over a "speed bump"and especially the back of the trailer. The packaging design should be robust enough to withstand this kind of shock loading resulting from a free fall. Typical damage photographs from bottom drop shocks. Shown Fig.2

FIGURE 2: DROP DAMAGE TO SIDE PANEL

FIGURE 3: SIDE INCLINED IMPACT DAMAGE

Impact test represents scenario when the product may be impacted with some velocity. This load case may also relate real world examples include a packaged product sitting in the back of a truck abruptly coming to a quick stop, or a forklift driver picking up a palletized load on-the-fly.The packaging design should de robust enough to withstand this kind of shock loading resulting from a face impact. Typical damage photographs from Inclined Impact shocks. Shown Fig.3

The term g-force actually measures the Acceleration. The g-force (with g from gravitational) is a measurement of the type of acceleration that causes a perception of weight. Despite the name, it is incorrect to consider g-force a fundamental force, as g-force is type of acceleration that can be measured with an accelerometer. Since g-force acceleration responsible for weight of the Object, which causes weight reaction when one object hits another object. These forces are transmitted through objects by interior mechanical stresses like waves. The g-force acceleration is the surface contact forces cause stresses and strains on objects, since they must be transmitted from an object surface.Because of these strains, large g-forces may be destructive. Gravitation acting alone does not produce a g-force, even though g-forces are expressed in multiples of the acceleration of a standard gravity. Accelerometers are commonly used in product testing to measure and understand various performance criteria. Acceleration measurements complement product development and testing to enhance reliability, durability, security, quality and noise vibration & harshness. Acceleration is a very valuable resource for finding the mistakes of the simulation and optimizing the method of modeling. Also in Automobile industry to examine and quantify the injury potential during head strikes the glass, accelerations and Head Injury criteria used[1]. To quantify simulation model fidelity with physical prototype, Accelerometers can be mounted on product and analysed the behaviour of various components. This will build confidence on Simulation model once the analysed results shows correlation with Physical prototype. Validated model will have better fidelity in results predictions and Future modifications.

1. METHOD FOR DESIGN VALIDATION

Baseline simulation evaluation carried with physical test and correlation performed. Improvements in FE model based on test correlation done over modeling techniques and contact parameters and Simulation based design modification suggested by carrying out multiple iterations with material differences, geometrical changes and variations in process tolerances which will ultimately reduce the build-fix-rebuild time. Specification Or Standard tests performed to gain confidence on simulation model. Method shown in Fig.4

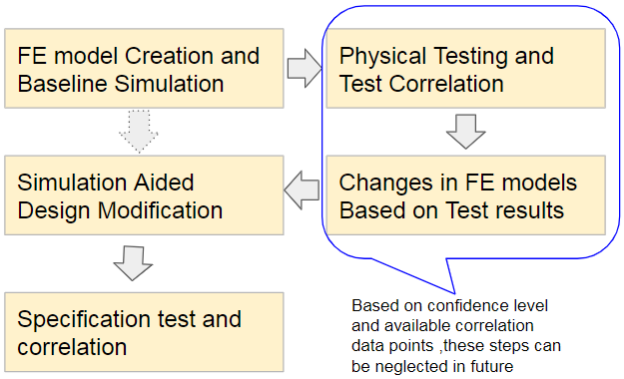

FIGURE 4: METHOD FOR DESIGN VALIDATION

2.1 INSTRUMENTATION AND LAB PROCEDURE

Internal laboratory test performed at appliance lab. Instrumentation done as per lab procedure explained below with flow chart. Refer Fig.4

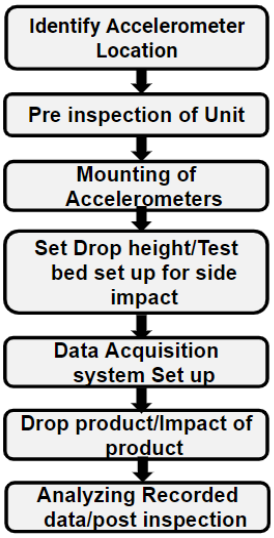

FIGURE 4: LAB PROCEDURE FOR DROP AND IMPACT

Selection of Accelerometer location for quantifying typical subsystem is significant. Since it evaluates the behavior of typical subsystem. Similar locations are attached with modeled accelerometer in simulation mode. Prerequisites to be done for product subsystem for getting acceleration data. Pre-inspection of product done to check if any pre-dents, damages, loose fixation of any part. Mounting of accelerometer done on identified location and allowed wired system to connect to Data Acquisition shown in Fig.5. Drop tester is the machine used for capturing behaviour during free fall from specific height. Impact tester is the setup used for capturing behaviour during impact with specific velocity.

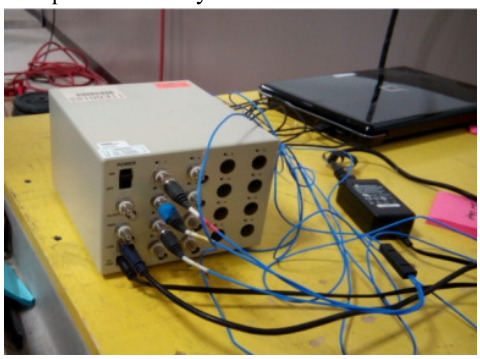

FIGURE 5: DATA ACQUISITION SYSTEM FOR DROP AND IMPACT

The complete test procedure is defined in the testing specification i.e WOOD-001L. Product Manufacturer can either set and follow the internal standards or follow the regional standard of relative authority. Full scale FE model shown in simulation model, physical model and schematic of loading condition for Lab specification shown in Fig.6 and Fig 7.

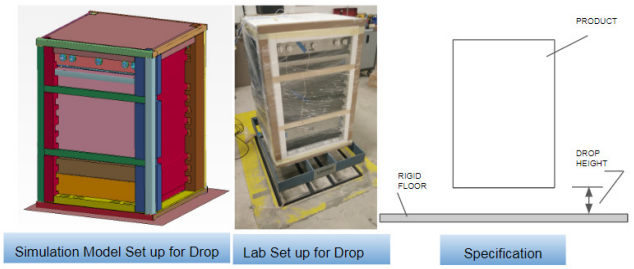

FIGURE 6: DROP SETUP AND SPECIFICATION

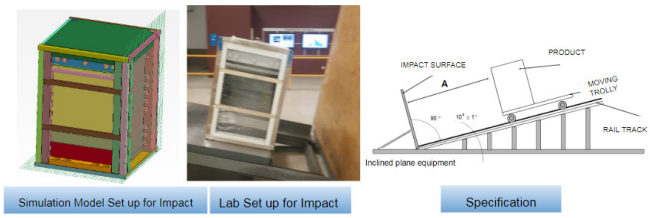

FIGURE 7: IMPACT SETUP AND SPECIFICATION

Test Partner™ 3 is a powerful combination of computer software and hardware specifically tailored to the capture and analysis of transient shock events. It can acquire up to sixteen channels of acceleration data simultaneously from shock, drop, or other kinds of important events. Test Partner 3 utilizes the USB port on your computer for convenient plug-and simplicity. This USB connected to Data Acquisition System to ensure its connectivity. After drop and impact has been performed its necessary to retrieve the data for Analysis. Post inspection done for collecting the damage, dislocation, bending and bowing information.

2.2 SIMULATION ROADMAP

A Free Standing Range has been chosen as the study subject. All the Parts would be modeled with the finite element modeling in the LS-DYNA software. Full product assembly (product & packaging) needs to be considered for the simulation. FEA model should be checked with CAD assembly for verification of mass and center of gravity of the product. Simulation Roadmap given in Fig.9

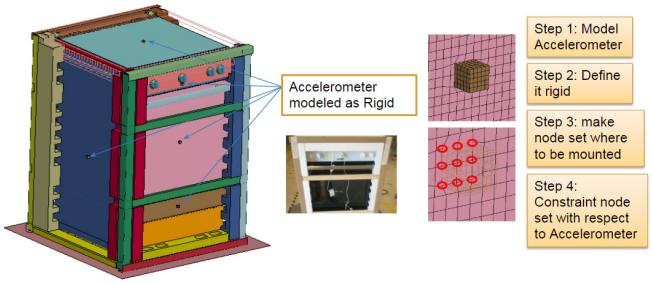

FIGURE 8: FE FULL SCALE MODEL WITH ACCELEROMETER

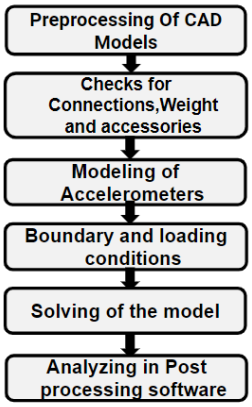

FIGURE 9: SIMULATION ROADMAP

Moving Parts inside products needs to be modeled as it is looks in physical model since that has proven to be effective for real life modeling. Constrained nodal rigid bodies used to represents connections. Plastic parts modeled as tetrahedral and hexahedral. Outer carton modeled using mid mesh with shell element type. Mass elements for un important parts are kept at their CG locations to adjust for weight Distributions. Then, the parts will be connected with each other by welding, rigid body, joint, etc. Some unimportant parts are changed to rigid body for releasing computing time. After that, the weight distribution will be adjusted. Fig. 8 shows the initiatory completed free standing model with Accelerometers. The accelerometer are modeled as Hexahedral rigid. Critical components from assembly chosen for mounting of accelerometer and similar are modeled on Product.

To protect the product against drop and Impact, EPS (Expanded Polystyrene) base pad and corner posts often used along with Braces. Packaging parts are mostly consists of Expanded polystyrene(EPS), Carton, plastics and recycled papers. Thickness, density and surface area of EPS base pad are critical factors used to design the optimum EPS base pad. Structural parts are often made of steel and there are often plastic components in the door assemblies that are made of rigid PVC, PC. The glass components should be made of tempered glass for both strength and safety reasons. For drop, product is placed at a specific height and input to simulation given in form of velocity. Refer Fig.6. For Inclined impact, trolley is moving at a velocity for a sufficient period of time since trolly positioned in such a way that it can achieve specific speed. Refer Fig.7.

The parameters of the model are provided by the specification. Rigid floor set for drop loadcase at a very minute distance from product surface. Unlike drop, Impact have two rigid walls perpendicular to each other standing 10°to ground. Impact surface are modeled nearer to impacting surfaces. After that, the product is tilted 10° to base rigidwall, with product base absolutely close to the rigid surface but doesn't interfere with it. Finally for drop the initiatory equivalent velocity equal to drop height along the Vertical axis of the product is added before starting to solve. For Inclined Impact horizontal and vertical component of Velocity applied to assembly as loading condition.

2. RESULTS AND DISCUSSION

3.1 ENERGY CONVERSION AND VALIDITY OF MODEL

For explicit numerical solutions convergence is checked through convergence of energy. Binary output can be retrieved from ASCII files. Where one can get output parameters like Boundary condition forces and Energy(BNDOUT), Element History data(ELOUT), Material Energie (MATSUM), Sliding interface energy(SLEOUT), Resultant Interface Forces (RCFORC), Global data (GLSTAT) gives energies, velocities and percentage mass increase. Energies needs to be checked once the preliminary run is completed. Typical graph of energy given in Fig.10. Sliding and Hourglass are the energies which affects the solution drastically. Sliding energies are induced due to friction value included in contact parameters.Total energy is contributed by Kinetic energy, Internal energy, Sliding Energy, Hourglass Energy[2]. For Ideal Energy conversion,Total energy has to contributed by Internal and Kinetic Energy. Hourglass and sliding Energy are acceptable upto 5-10% of peak internal energy.

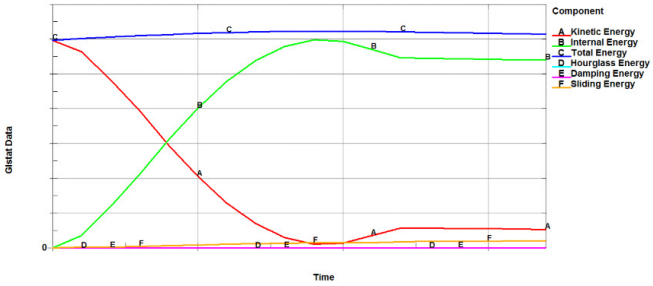

FIGURE 10: SIMULATION OUTPUT ENERGY CURVES

3.2 ACCELEROMETER OUTPUT

Acceleration output from accelerometer retrieved with the help of TP 3 software. Since Data Acquisition output being connected to software. Typical drop test output for 6 channels are shown in Fig.11.

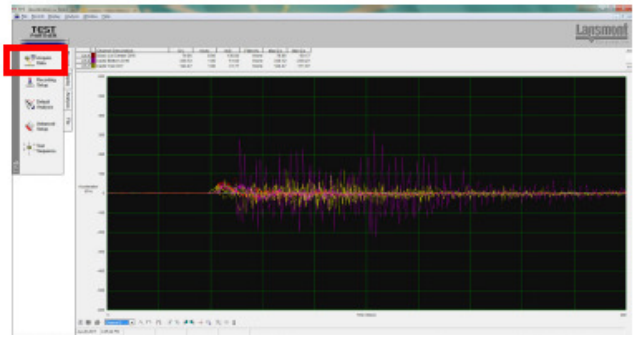

FIGURE 11: DROP ACCELEROMETER OUTPUT DATA

3.3 ANALYSIS OF DATA

After completing the first simulation, a vertical acceleration from drop is compared with test data for channel 1.

Refer Fig.11. Measuring these accelerations mounted on specific locations done by different channels attached to Data Acquisition System. Vertical acceleration is very valuable data for finding the mistakes of the simulation and optimizing the method of modeling. As the comparison shows, the vertical acceleration of simulation obtains three obvious peaks of wave, while the vertical acceleration of test obtains two positive and two negative peaks and seems damping behaviour. In the curve of simulation, the vertical acceleration, which has first peak profile in accord with the actual situation from lab data. This minor variations are due to the Noise of being Handled differently Or minor changes in Testing Lab Loadings. Importantly, the highest peak values and profile shall match that correspond to test data[3]. It could be concluded accelerations of channel 1 is been matched with 15% variation. It is also the reason why a particular method with all necessary parts being modeled, is proposed. As the picture suggests, simulation acceleration profiles are matched. As a result, every wave crest could be coincided. Similar coincidence of Accelerometer data compared for drop and Impact. Refer Fig.12 and 13

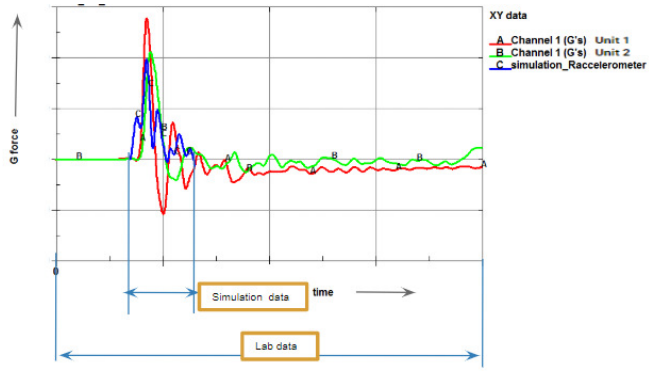

FIGURE 12: LAB DATA VS SIMULATION DATA FILTERED TO BUTTERWORTH_F150

The simulation acceleration is compared with the accelerometer measurements from the dop and impact test. All accelerometer locations are approximately at Parts C.G. Location in Assembly.

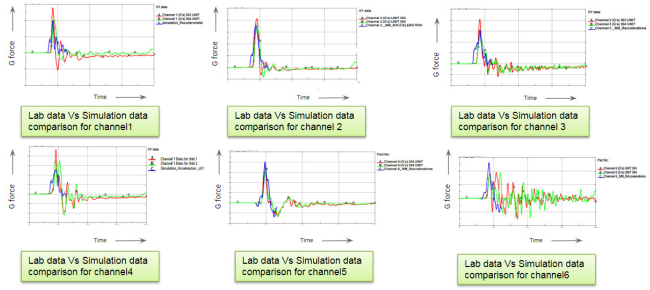

FIGURE 13: DROP TEST ACCELEROMETER DATA COMPARISON

Compared data analyzed for Peak and profile for all channels. Peak values can be considered as a measure for comparison. Simulation Correlation with lab for each channel performed.

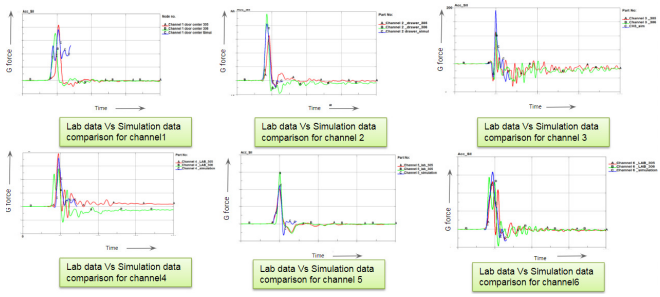

FIGURE 13: IMPACT TEST ACCELEROMETER DATA COMPARISON

Here two different units are considered Unit 1 and Unit 2.Comparison of maximum g value done considering Lab vs. Simulation. Outlier found with Unit 1 channel 3 since peak was quite high and noise included in it. This channel was neglected for correlation purposes. After analyzing, it is observed that correlation with accelerometer data ranging between 81-85% considering both units.Refer Fig.14.

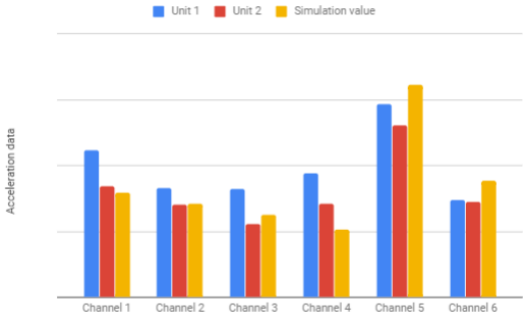

FIGURE 14: DROP TEST ACCELEROMETER DATA COMPARISON

For impact scenario, Channel 3 is subjected to high vibration while inclined impact. Simulation shows high acceleration on side panel, because of the reason that Insulation over cavity not modeled in simulation. So end up with high acceleration values. Considering channel 3, is the outlier so correlations are revised to 83-85%. Refer Fig.15.

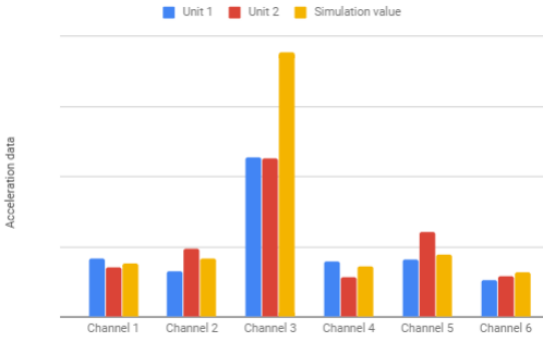

FIGURE 15: IMPACT TEST ACCELEROMETER DATA COMPARISON

Visible damages with quantifiable data observed for structure. Some of the deformation on side panel observed such as bowing Cavity Damage was seen due to impact of Grate box. Refer Fig.16. Measurement was taken on Product foot resting location on EPS. Results found to be correlating greater than 80%. Refer Fig.17.

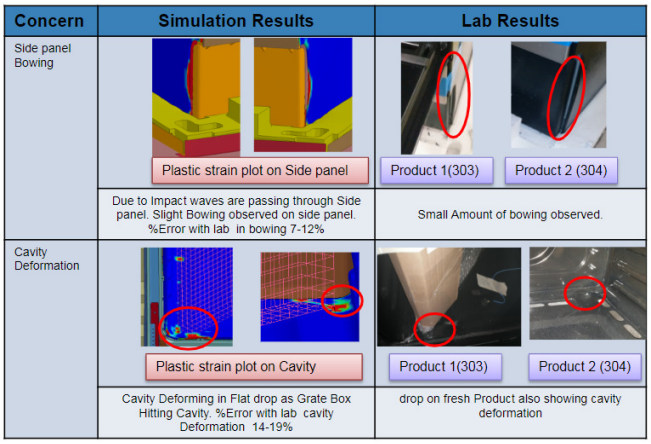

FIGURE 16: DROP TEST STRUCTURAL DEFORMATIONS

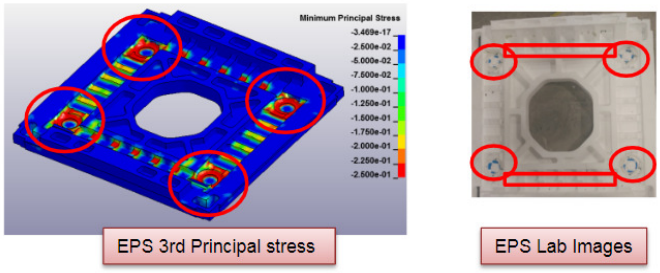

FIGURE 17: DROP TEST EPS COMPRESSION CORRELATION

In inclined impact, Handle Interacting with EPS observed since it was penetrating in physical model. Impact made it worsen with Handle impression. Glass edge impression were also predicted in side inclined impact. Refer Fig. 18.

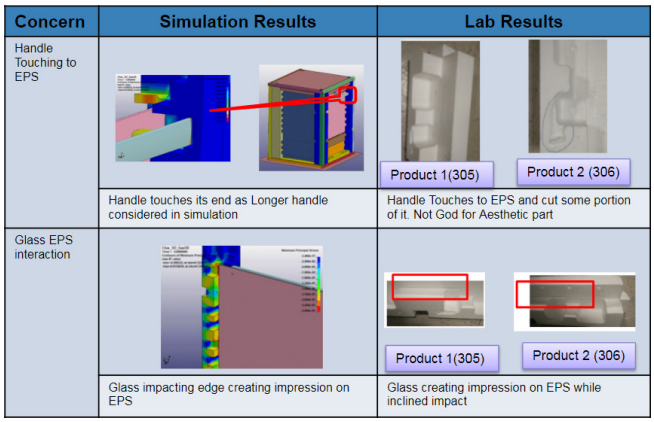

FIGURE 18: IMPACT TEST STRUCTURAL DEFORMATIONS

4. CONCLUSION

A FE model of the Free Standing Range has been developed to simulate WOOD-001L drop and Impact test by the LS-DYNA software. This product test, is used by the Whirlpool for testing the impact performance of various Home appliances at low range speeds. Firstly, a WOOD-001L drop and Impact test has been conducted to observe the acceleration behaviour and areas with deformation of the product structure. Finally, the FE model results compared, analyzed, and modified. This optimization should be carried through multiple times, until the main parameters which have a great influence on the result are found.

The results shown above validate the model, can indeed provide reliable results and be used for the evaluation of impact performance of the other home appliances products. This model can be used by the Engineers that are currently focusing on modelling the products. This LS Dyna tool results in significant cost reduction by reducing the number of impact tests required for a comprehensive evaluation of many home appliances. This is an integrated study of the FE method for simulation of product drop and impact, as well as the solution for the typical problems.

Therefore, future work may focus on using the presented modelling method for solving structural deformations. Additional validation with test data for impact at different speeds and angles of different classes of products will also be very beneficial to replicate warehouse and distribution handling damages.

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