Nonlinear Analysis on Refrigerated Display Case Shelf

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ABSTRACT

Nonlinear analysis study is performed to understand the Physical behavior of shelf, which is located in refrigerated display case and to compare the displacement of numerical value with the experimental value. Nonlinear analysis is beneficial in achieving accurate results as compare to linear static analysis. This was done by using HyperMesh to build mathematical model and Optistruct to simulate problem with respect to the Lab conditions.

Hussmann refrigerated display case is specially used for food stores. The shelf has to carry all food weight without failure and it has made with steel sheet metal with optimum thickness. The linear static analysis has given good result with in elastic limit and which are comparable with tested data's. But after certain load, the material has to reach plastic large deformation and the numerical results are not correlating with tested data. Hence nonlinear analysis is performed on the shelf and the test lab results are correlated with FEA results.

Keyword: Shelf, Nonlinear analysis.

Introduction:

Hussmann is more than a world-class manufacturer of quality display cases and refrigeration systems. We create innovative solutions and value-added benefits that improve financial results. Hussmann produces different kind of display cases, which are assembled with shelves. Since in a year thousands of shelves are manufacture in plant in different sizes, depend on loading application. The shelves are carrying different things like daily foods, meat, flowers, vegetables etc. This made with galvanized steel material in order to avoid corrosion and supported by two brackets. The bracket has made with large thickness compare to shelf pan and it is hanged to upright as shown in figure.1. The load has transferred from shelf to upright through bracket.

In order to optimize the thickness of shelves, the experimental test has carried out in Hussmann test lab and study the physical behavior of shelf pan while the loading and predicts the value of displacement and sagging. In this study there are two different sizes of shelves, first shelf has size of 300x1600 mm and second shelf has size of 450x1600 mm. The FEA has performed on each shelf and boundary, load conditions were applied with respect to experimental set up. The nonlinear geometric analysis has performed to correlate the FEA results with test lab result.

Figure.1 Shelf assembly

Experimental setup:

The test was done in Hussmann test lab and setup was same for both sizes of shelves (300x1600 and 450x1600) as shown in below figure.2. Here the load was applying through brick and each brick has mass of 4 kg. Two different shelves has different allowable load. The 6 dial gauges were mounted over the shelf at different location as shown in figure.3, it helps to find out the displacement at different locations over the shelf.

The load was applied at different level and each level has different load distribution pattern over the shelf. The load level and load pattern of 300x 1600 mm shelf was different from 450x 1600 mm shelf. The load level and pattern has given in figure.4 for both shelves. Finally note down the displacement of each dial gauge and calculate the sag of the shelf along width and depth.

Figure.2 Experimental setup

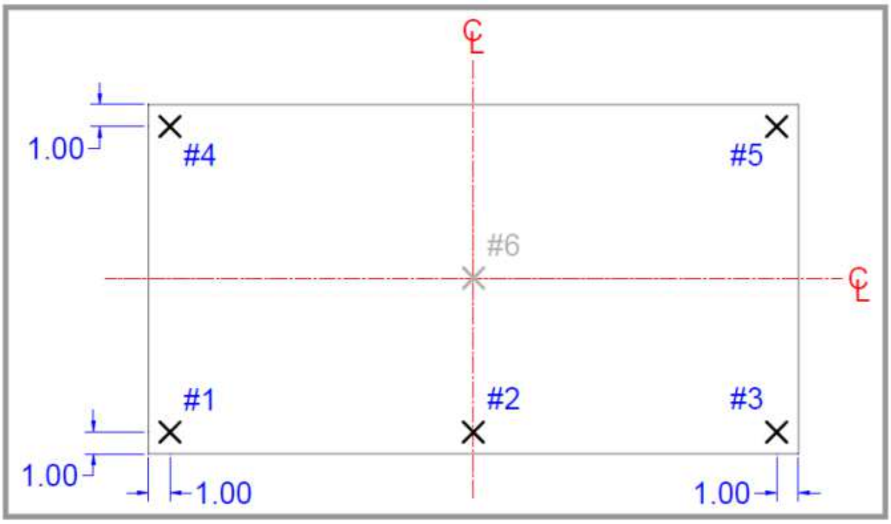


Figure.3 (a) Dial gauges locations – Top View

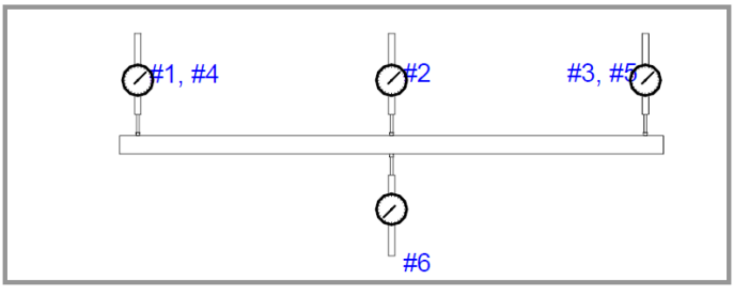
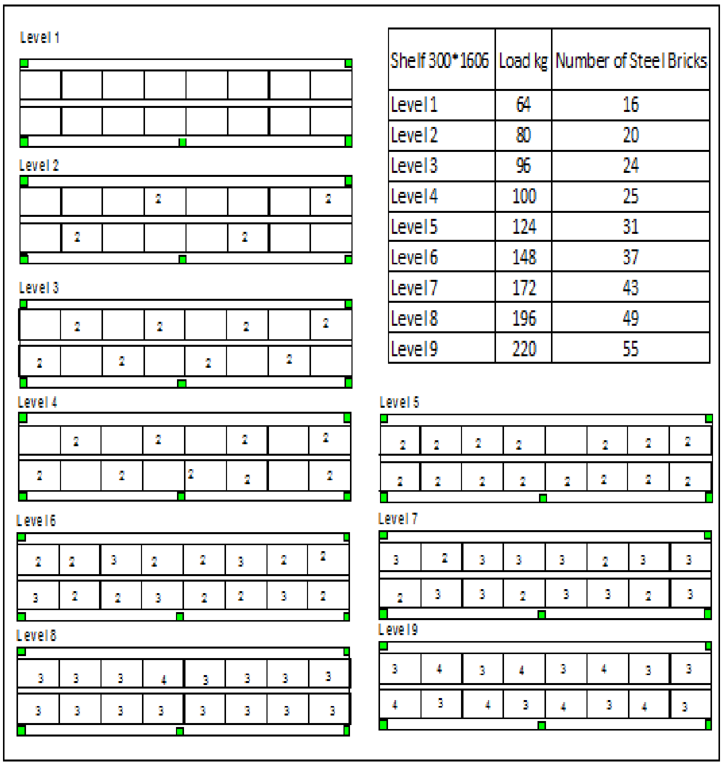
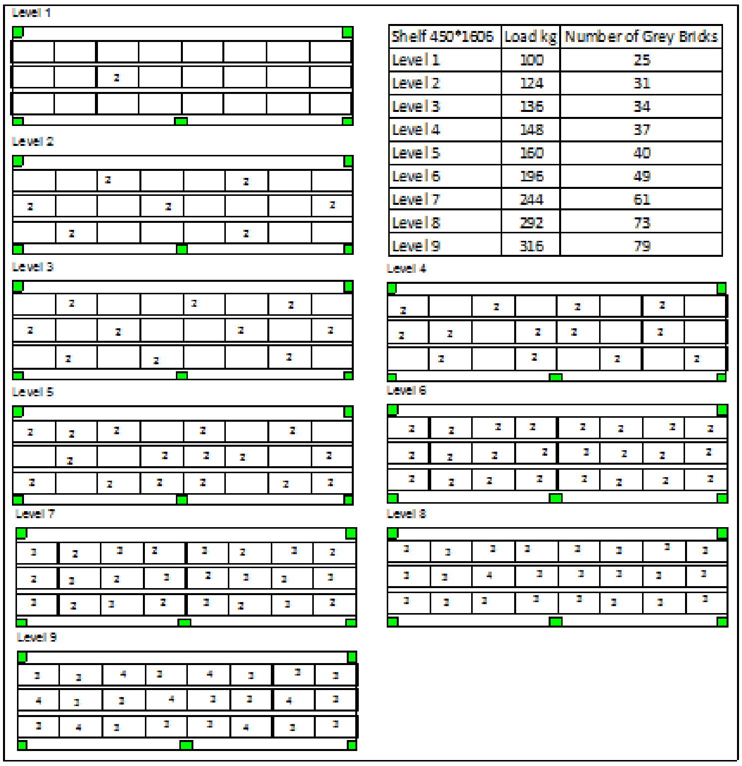


Figure.3 (b) Dial gauges locations – Front View



Shelf 300*1606	Load kg	Number of Steel Bricks
Level 1	64	16
Level 2	80	20
Level 3	96	24
Level 4	100	25
Level 5	124	31
Level 6	148	37
Level 7	172	43
Level 8	196	49
Level 9	220	55

Figure.4 (a) Load pattern – Steel Bricks



Shelf 450*1606	Load kg	Number of Grey Bricks
Level 1	100	25
Level 2	124	31
Level 3	136	34
Level 4	148	37
Level 5	160	40
Level 6	196	49
Level 7	244	61
Level 8	292	73
Level 9	316	79

Figure.4 (b) Load pattern – Grey Bricks

Table.1 Test results for 300x1600 shelf

Level	load Kg/m2	Gauge 1	Gauge 2	Gauge 3	Gauge 4	Gauge 5	Gauge 6	$\sigma_2-\sigma_1$	$\sigma_2-\sigma_3$	$\sigma_6-\sigma_2$	Max σ
Initial	0	35.31	29.53	44.31	23.86	43.67	10.16				
1	134	34.84	23.74	43.69	23.53	43.25	22.26	5.32	5.17	6.31	11.77
2	166	34.75	22.75	43.55	23.45	43.17	23.88	6.22	6.02	6.94	13.31
3	200	34.64	21.25	43.43	23.37	43.07	26.28	7.61	7.4	7.84	15.63
4	208	34.63	20.75	43.4	23.36	43.05	27.65	8.1	7.87	8.71	16.99
5	258	34.48	18.52	43.18	23.22	42.89	30.25	10.18	9.88	9.08	19.45
6	308	34.35	16.78	42.98	23.09	42.77	32.65	11.79	11.42	9.74	21.72
7	358	34.21	14.8	42.79	22.97	42.63	35.2	13.63	13.21	10.31	24.15
8	408	34.09	12.89	42.59	22.85	42.49	37.59	15.42	14.92	10.79	26.42
9	458	33.93	10.61	42.39	22.66	42.32	40.67	17.54	17	11.59	29.31
End	0	35.07	28.76	43.77	23.6	43.5	11.38	0.53	0.23	0.45	1.05

Table.2 Test results for 450x1600 shelf

Level	load Kg/m2	Gauge 1	Gauge 2	Gauge 3	Gauge 4	Gauge 5	Gauge 6	$\sigma_2-\sigma_1$	$\sigma_2-\sigma_3$	$\sigma_6-\sigma_2$	Max σ
Initial	0	35.8	28.86	44.02	23.72	43.52	13.73				
1	138	34.82	19.23	42.55	23.05	42.65	33.1	8.65	8.16	9.74	18.7
2	172	34.6	17.75	42.26	22.91	42.49	35.18	9.91	9.35	10.34	20.64
3	188	34.48	16.51	42.1	22.82	42.4	36.58	11.03	10.43	10.5	21.95
4	205	34.37	15.82	41.95	22.75	42.32	37.6	11.61	10.97	10.83	22.9
5	221	34.25	14.67	41.77	22.67	42.23	39.1	12.64	11.94	11.18	24.32
6	234	33.86	11.86	41.22	22.41	41.89	42.12	15.06	14.2	11.39	27.08
7	338	33.69	10.96	41.05	22.3	41.81	43.23	15.79	14.93	11.6	28.08
8	404	31.83	6	40.79	21.85	41.4	48.43	18.89	19.63	11.84	32.83
9	437	The shelf supporter deform seriously during this level test ,so we terminate the test									
End											

Above table.1 and table.2 shows the sag calculation and maximum displacement values of two shelves for different load levels.

FEM model:

The FEM model was prepared by using Altair Hypermesh-13 version software. The model was discretized by both quad and tria elements. The number of elements and nodes were listed in table.3.

Table.3 FEM model details

Shelf	Nodes	Elements
300x1600	192326	190662
450x1600	260955	259218

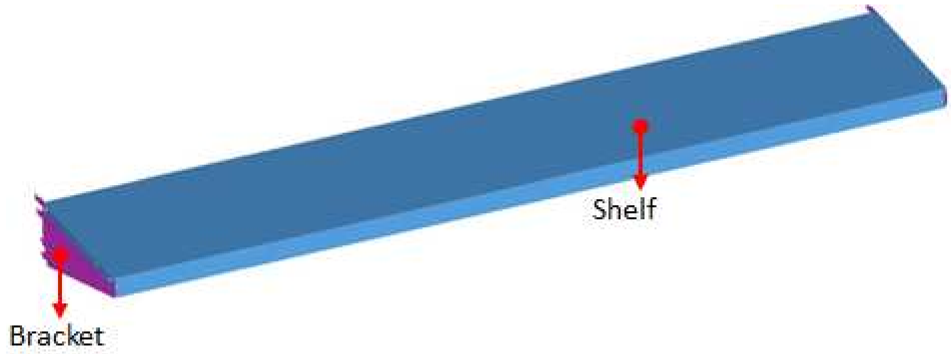


Figure.5 Shelf FE model

Boundary and loading conditions:

All three translation and three rotation of degree of freedom (DOF) was fixed at bracket, where bracket and shelf has contact as shown in figure.6. The boundary condition was same for both shelves. The load was distributed over the shelf as same as load applied in test lab. The analysis was repeated to each load level.

Figure.6 Load and Boundary condition

Material data:

Type of material = Steel

Modulus of elasticity = 2.0e^{5} MPa

Poisson ratio =0.3

Yield stress = 248 MPa

Tensile strength = 460 MPa

Plastic hardening coefficient = 821 MPa

Plastic hardening exponent = 0.23

Results and discussions:

Initially we performed linear static analysis and calculated sag along width and depth as following below and try to correlate with test lab results.

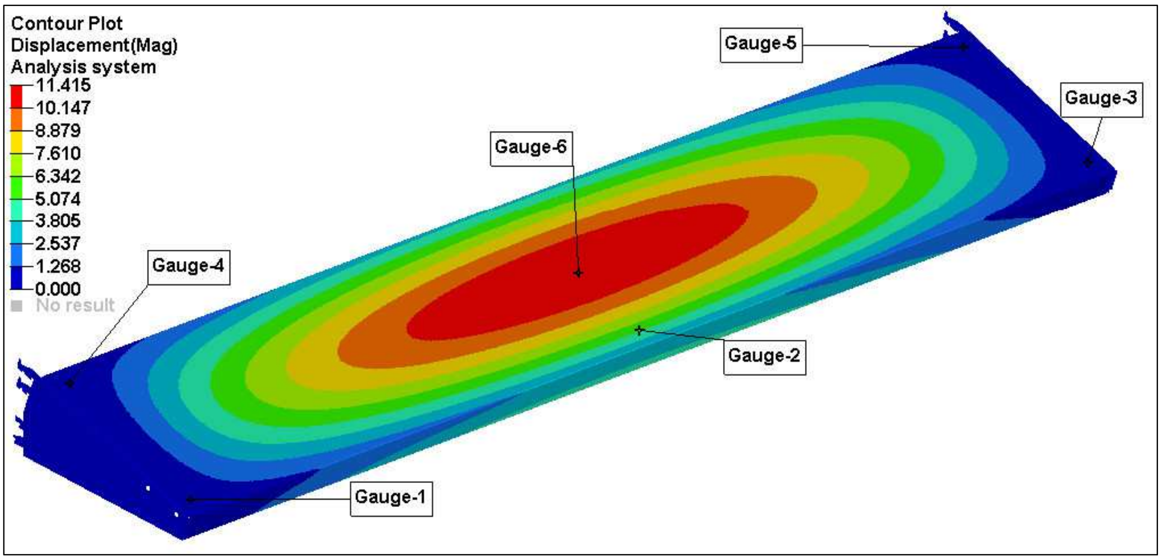


Figure.7 Displacement plot

Table.4 Gauges displacement

Gauges	Displacement in mm
Gauge-1	0.297
Gauge-2	5.228
Gauge-3	0.297
Gauge-4	0.236
Gauge-5	0.236
Gauge-6	11.413

Sag along width = gauge-2 – gauge-1

= 5.228-0.297

= 4.931 mm

Sag along depth = gauge-6 – gauge-2

= 11.413-5.228

= 6.185 mm

Maximum displacement = 11.415 mm

Above calculation was repeated to each level of load on shelf 300x1600 mm. Final results were plotted in graph, as shown in figure.8.

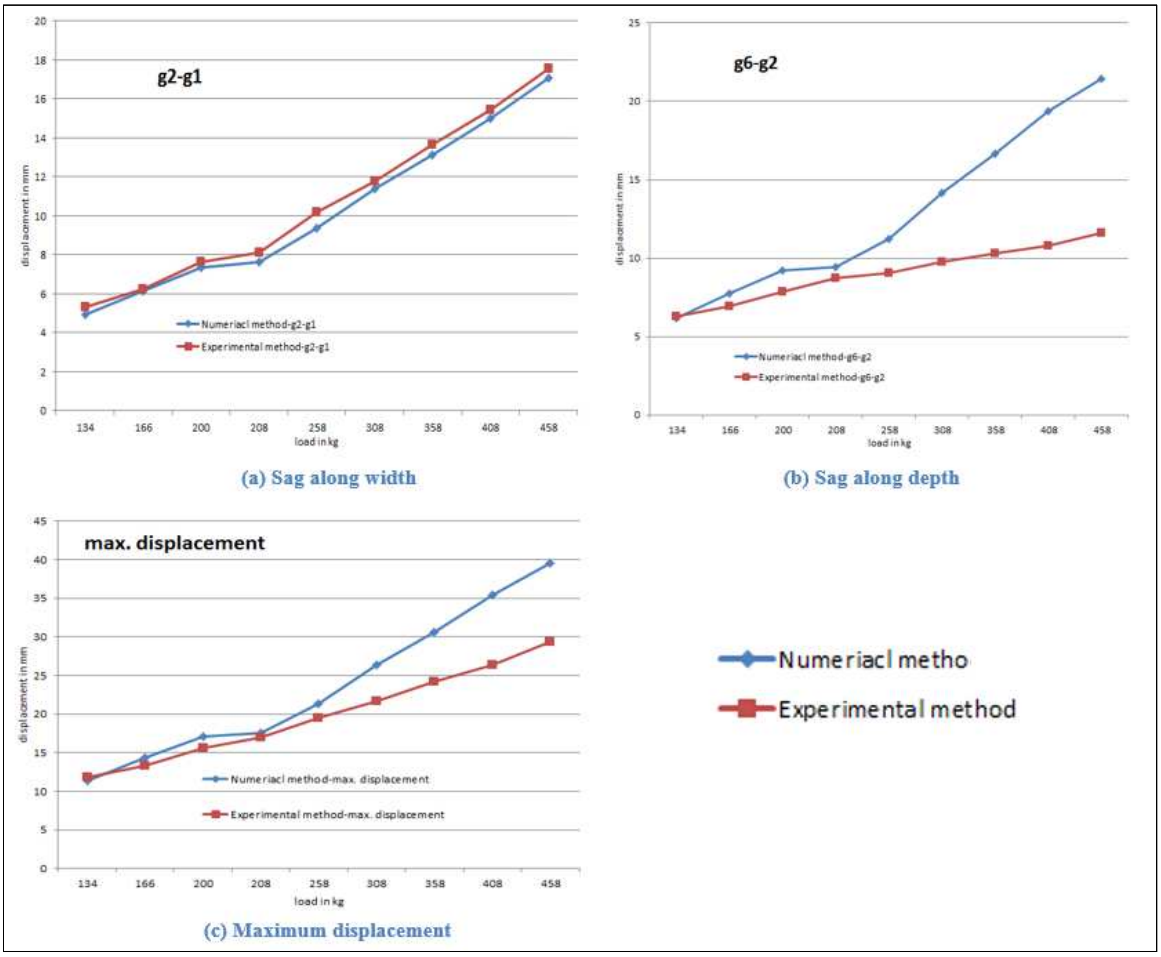


Figure.8 Test lab results Vs linear static FEA results of 300X1600 shelf comparison

If we observe sag along depth and maximum displacement has been correlated up to load 258 kg, as shown in figure.8 (b) and (c), beyond 258 kg the model has reached plastic region and deformation was very large, the numerical results doesn't correlated with test lab results. Hence nonlinear analysis is performed on the shelf and the test lab results are correlated with FEA results.

We repeated same procedure as mentioned above with geometric nonlinear analysis. The results were plotted in graph as shown in figure.9 to both shelves.

- **Shelf 300X1600**

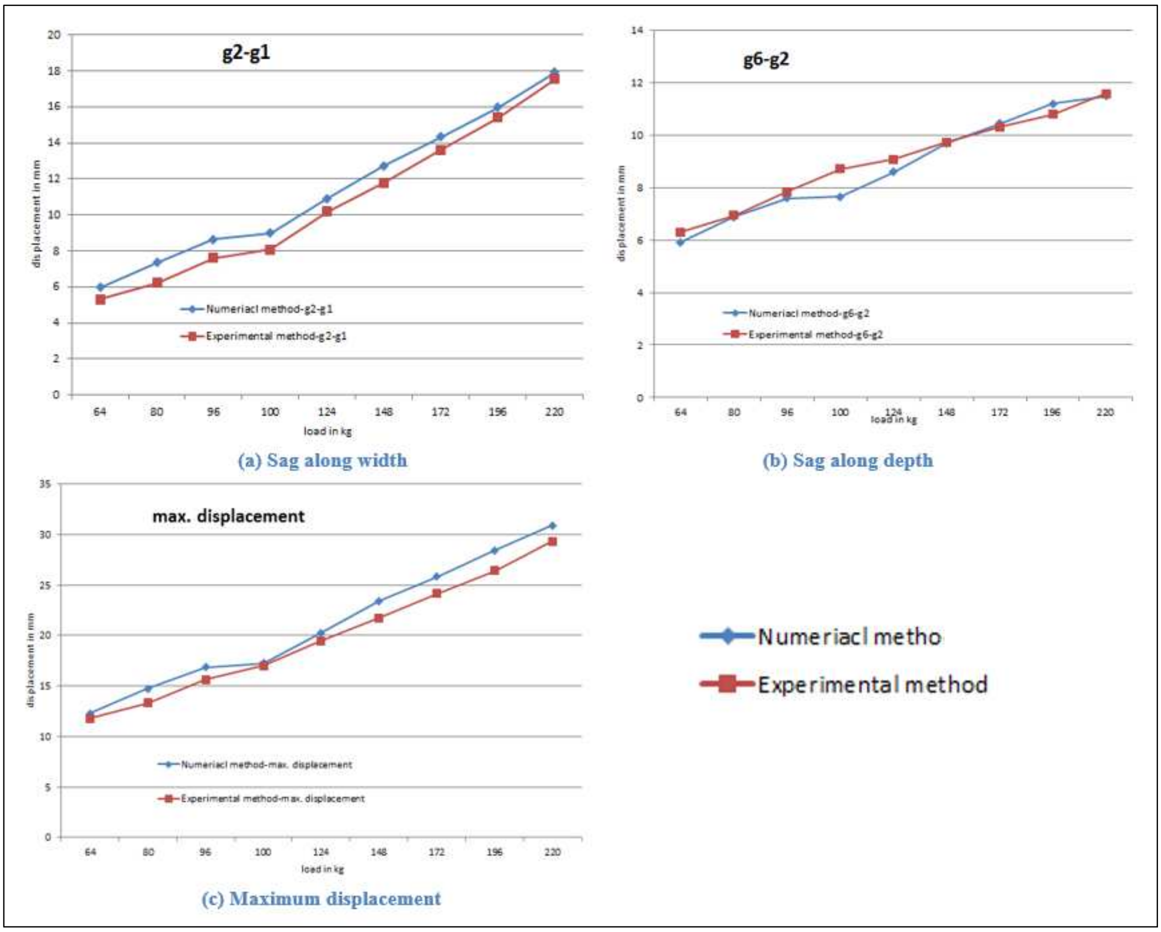


Figure.9 Test lab results Vs nonlinear static FEA results of 300X1600 shelf comparison

- **Shelf 450X1600**

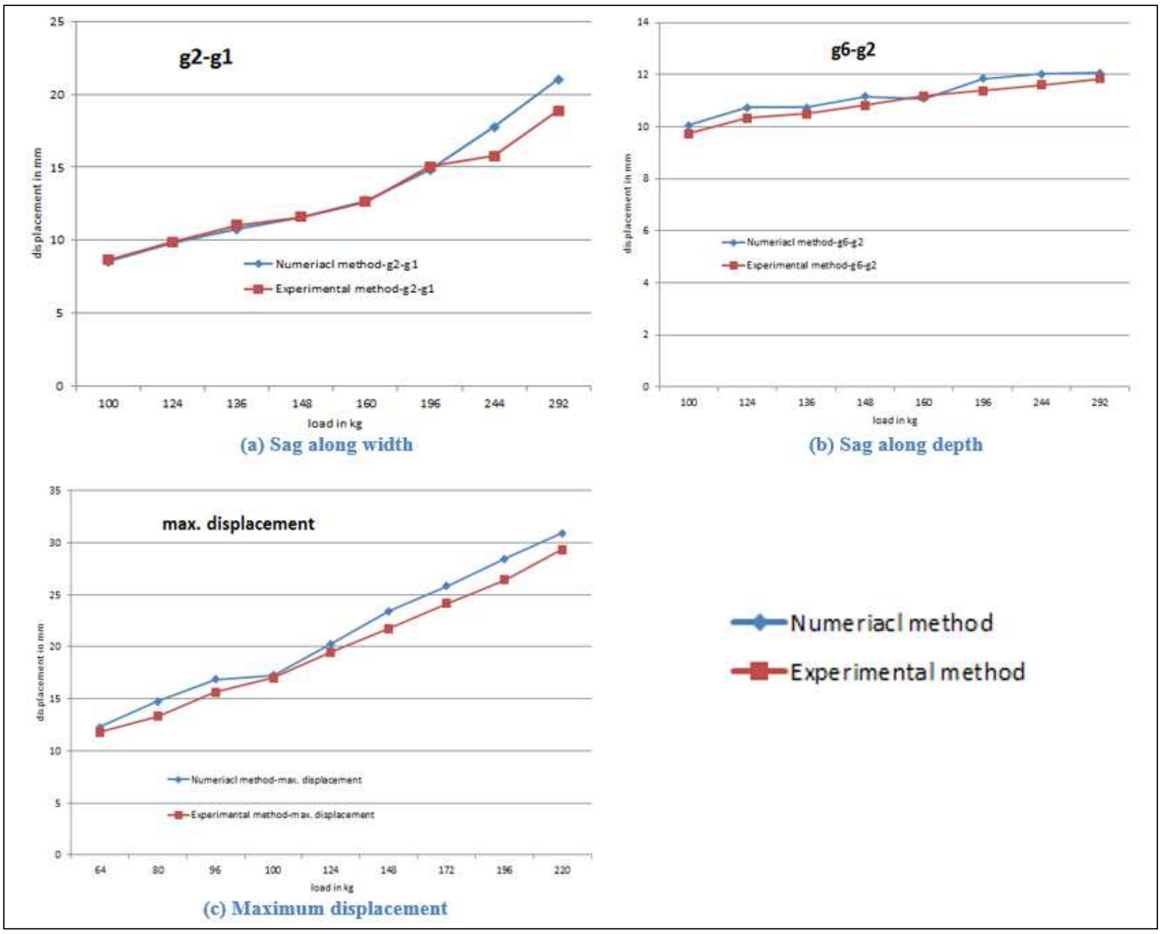


Figure.10 Test lab results Vs nonlinear static FEA results of 450X1600 shelf comparison

Conclusions:

- ➢ In linear analysis test lab results doesn't correlate with test lab results because after certain load model has reached to plastic deformation.
- ➢ Shelf 300X1600 and 450X1600 test lab results and FEA results are correlating very well when we perform nonlinear analysis.

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