2005 NUMISHEET BENCHMARK 1
─ Springback Prediction of Decklid Inner Panel

The objective of this study is to benchmark springback prediction capability of various software and skills of users on a complex inner body panel.

This benchmark is provided by the Metal Fabrication Division, General Motors Corporation (GM) in Pontiac, Michigan. GM provided the math model, technical support and major funding for this benchmark. The following organizations also contributed to this benchmark. Troy Design and Manufacturing in Redford, Michigan conducted tool construction, tryout, and test panel production for both steel and aluminum. The US Steel Corporation in Troy, Michigan provided steel material and conducted data (strain/thickness) measurement. Alcan provided the aluminum material for the benchmark.

TOOL GEOMETRY

The simulation process of stamping a deck lid inner panel consists of three operations: forming, trimming and springback. Participants should not move the tooling position in the x-y plane.

1. Forming

Lower punch, binder and upper die are illustrated in Figure 1. This tooling geometry has a symmetry plane at x=0. The process is a three-piece air draw. The punch is stationary. The upper die is a solid one-piece tool. The binder is supported by hydraulic cylinders, which provide binder holding force. The tooling model with and without bead geometry is provided. Two blank materials are used for stamping: a 0.9 mm AL 6111-T4P aluminum alloy and a 0.8 mm BH 180 bake-hardenable steel. The die clearance is 0.9 mm for both cases.

Total blank holding force: 1334 kN (150 English Ton) for both materials. Participants need to use half of the specified holding force if only half the tooling geometry is used in the simulation. However, a one metal thickness equalizer, or kiss block, is used to provide a constant binder gap. This means that the binder gap will remain the same unless the metal thickens above the initial thickness in the binder area, or the force required to set and hold the beads exceeds the blank holding force.

Binder Travel: 65 mm (-z direction).

Initial blank setup position: Gauging pins are used to locate the part in proper location during binder closure. The pin locations are provided in the Nastran format mesh model file and are located at $(x, y) = (\pm 420, -496)$ mm, each with a radius of 15 mm. A pre-bent blank is used and the shape of the pre-bent blank is provided in the blank mesh file. The rolling direction of the sheet coil is along the x-axis (see Figure 2).
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Tool moving direction: Lower Punch: stationary
Upper Die: moving down (-z direction)
Binder: moving down (-z direction)

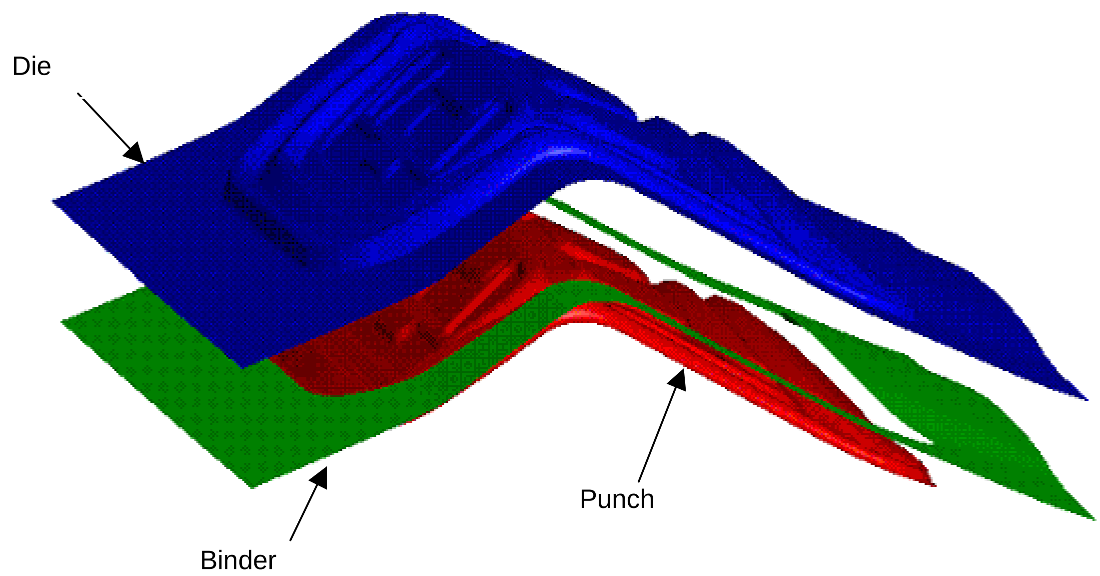

Figure 1. Forming tool

In this benchmark, participants can use either physical beads or line beads in the forming simulation. The information for the physical bead geometry and bead centerlines is provided in the math files. Line Bead forces should be calibrated from the following bead section profiles (see Figures 2, 3 and Tables 1 and 2).

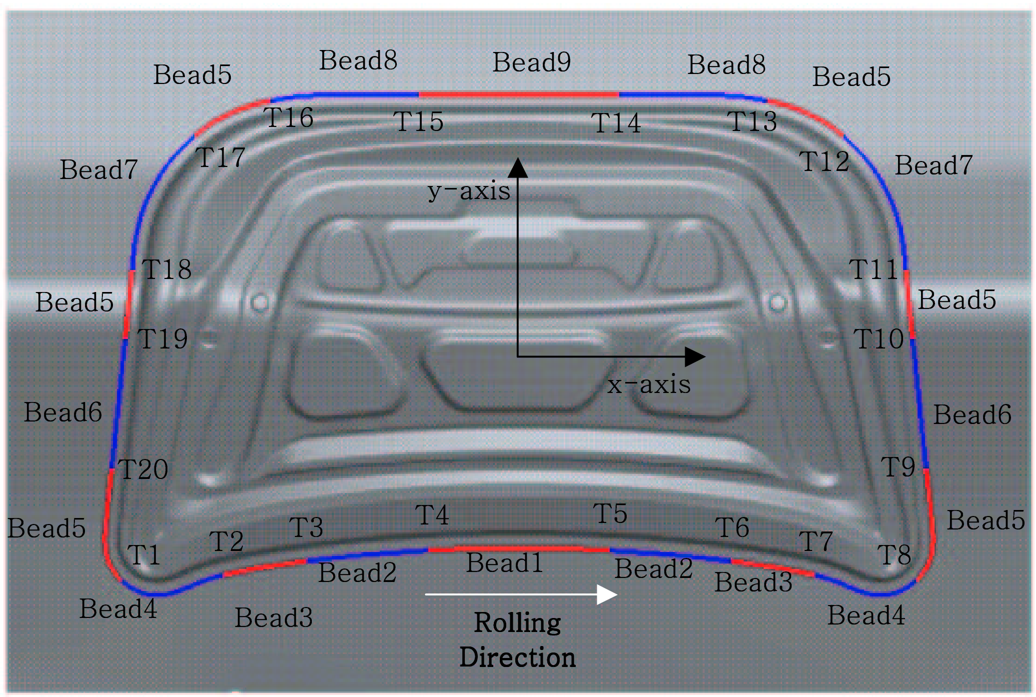

Figure 2. Bead centerlines, transition points, and coordinate system orientation.

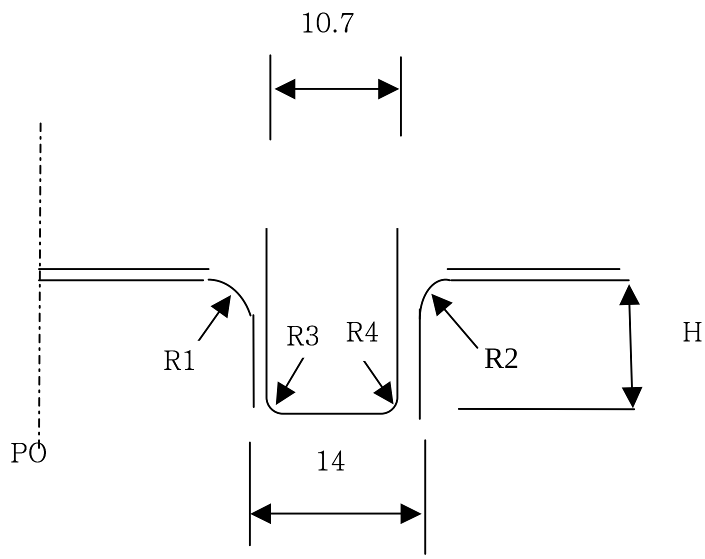

Figure 3. Bead section profile

Bead #	R1 (mm)	R2 (mm)	R3(=R4) (mm)	H (mm)
Bead1	2.50	2.50	3.0	7.0
Bead2	2.50	2.50	3.0	4.5
Bead3	2.50	2.50	2.5	6.0
Bead4	2.50	2.50	2.5	7.0
Bead5	2.75	2.75	3.0	5.0
Bead6	2.50	2.50	3.0	6.5
Bead7	3.50	3.50	3.5	5.0
Bead8	2.50	2.50	3.0	7.5
Bead9	3.00	3.00	3.5	5.5

Table 1. Parameters of draw bead section

Drawbead Transition Point	X (mm)	Y (mm)	Z (mm)
T1	-734.08	-400.28	-57.45
T2	-544.72	-389.44	-41.33
T3	-392.22	-364.10	-8.87
T4	-167.66	-344.64	18.28
T5	167.66	-344.64	18.28
T6	392.22	-364.10	-8.87
T7	544.72	-389.44	-41.33
T8	734.08	-400.28	-57.45
T9	752.26	-192.44	58.93
T10	727.40	45.97	215.75
T11	714.74	174.37	220.39
T12	598.88	422.09	82.90
T13	458.56	486.78	61.74
T14	182.87	498.80	57.81
T15	-182.87	498.80	57.81
T16	-458.56	486.78	61.74
T17	-598.88	422.09	82.90
T18	-714.74	174.34	220.39
T19	-727.39	45.97	215.75
T20	-752.26	-192.44	58.93

Table 2. Transition points between bead section geometries identified in Figures 2 and 3 and Table 1.

2. Trimming

Complete trim lines are defined in an IGES file for trimming operation.

3. Springback

After trimming, the part is rotated around x axis toward y direction (rear ward) 40 degree to be put on checking fixture (car position). The checking fixture constraint points are shown in Figure 4, listed in Table 3, and in the IGES file: ***decklid_spbk_constrain_point.igs.***

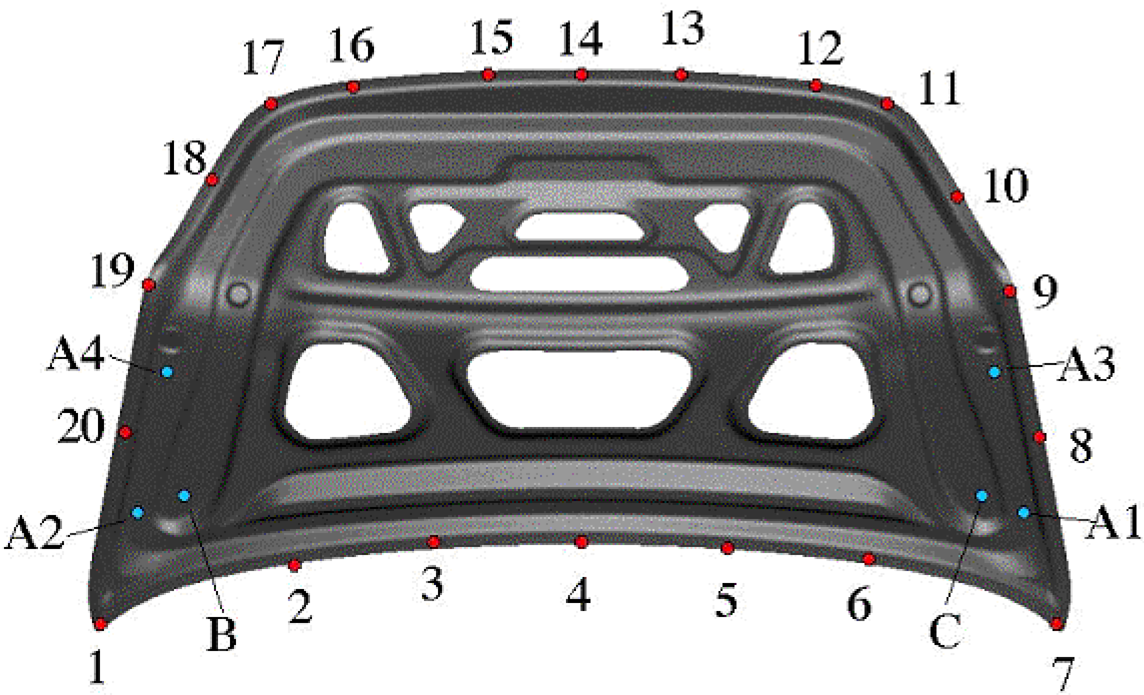

Figure 4. Checking fixture constraints for springback measurements.

Constraint Point	X (mm)	Y (mm)	Z (mm)
A1	618.00	-214.75	53.70
A2	-618.00	-214.75	53.70
A3	584.01	6.22	201.08
A4	-584.01	6.22	201.08
B	-565.00	-182.24	69.39
C	565.00	-182.24	69.39

Table 3. Fixture Constraints for Springback measurements

Locations A1-A4 are 10x10 mm square-shaped clamping in the z direction (up and down).

Location B is a 20 mm diameter hole and pin, also called 4 way constraint (x and y constraint).

Location C is a 20x24 mm slot and a 20mm diameter pin, also called 2 way constraint (fore/after constraint in car position or y-direction constraint on checking fixture).

The participant should apply boundary conditions based on the checking fixture information. The springback should be reported at the specified points 1 through 20 shown in Figure 4, listed in Table 4, and found in the IGES file: ***decklid_springback_measure_location.igs***. The springback amount is measured in the direction perpendicular to the part.

Springback Point	X (mm)	Y (mm)	Z (mm)
1	-674.12	-345.23	-13.15
2	-523.16	-282.28	58.29
3	-222.14	-238.63	118.73
4	0.00	-231.81	131.54
5	222.14	-238.64	118.75
6	523.25	-282.50	58.79
7	674.33	-345.43	-12.67
8	661.97	-162.93	97.69
9	621.09	45.76	231.84
10	532.00	255.73	206.74
11	423.90	385.73	122.57
12	333.82	405.34	119.36
13	158.96	421.62	126.56
14	0.00	424.43	130.23
15	-158.96	421.62	126.56
16	-333.92	405.91	119.92
17	-423.91	385.77	122.60
18	-532.00	255.73	206.75
19	-621.09	45.76	231.84
20	-662.00	-162.96	97.75

Table 4. Points for Springback measurements.

Files for simulation

Geometry data are represented by Nastran mesh format & IGES.

Nastran File:

The blank mesh is defined in its original flat form and after pre-bending in the following two files:

decklid_flat_blank.nas ***decklid_prebend_blank.nas***

The tools are defined in mesh form without bead geometry on the binder in the following file:

decklid_model_without_bead.nas

Triangular and quad elements are used.

IGES File:

The tools are also defined in surface form respectively with and without bead geometry on the binder in the following three files:

decklid_model_w_bead_lower.igs ***decklid_model_w_bead_upper.igs***
decklid_model_without_bead.igs

The upper and lower surfaces with bead geometry included are offset with 0.9 mm clearance. Only the lower surface is provided for the tool without drawbeads. Participants should offset upward by 0.9 mm to create the upper die surface. In an analysis without bead geometry, the bead force can be determined by the bead sectional geometries shown in Figures 2 and 3. The bead centerlines and the trim lines are described by line geometry in the following files, respectively,

decklid_bead_centerline.igs ***decklid_trimline.igs***

The locations of strain and springback measuring points and springback constraint locations (die position) are provided in the following files:

decklid_spbk_constrain_point.igs ***decklid_springback_measure_location.igs***
decklid_strain_meas_sec.igs

Material Property Files

Standard properties are listed on the first worksheet and additional material information is provided on secondary worksheets in the following Excel spreadsheets in case participants want to use more sophisticated material models.

BM1_AL6111-T4P.xls ***BM1_BH180.xls***

BENCHMARK REPORT

The due date for benchmark submission is listed on the website. All results are to be reported using the benchmark report template that is included in the download (***BM1_Report_TMP.xls***). Instructions for participating in the benchmark is provided in the file Report_Filing_Instructions.pdf. The following information is requested for each material on the appropriate Excel worksheet prepared for the two metals:

1. Total upper die force (kN) vs. binder travel for full model during forming. Distributions: 1. (max 100 points)
2. Blank draw-in (mm) after forming at **Sections DN1 through DN7** (see Figure 5). The draw-in measurement starts from binder closure and bead set and is defined as the three dimensional distance between the blank edge at the binder closure and the blank edge when forming is complete. Data values: 7.
3. True major strain on top surface, true minor strain on top surface, and thickness (not strain) at elements closest to the specified points on Sections AA through DD (Figure 6). Strains must be dimensionless, not in units of percent. The exact locations of these points are specified in the file: ***decklid_strain_meas_sec.igs*** and listed in Tables 5 through 8. Data values: Section AA: 42, Section BB: 36, Section CC: 36, Section DD: 36, Total 150.
4. Springback measurement at points 1-20 shown in Figure 4 and found in the IGES file: ***decklid_springback_measure_location.igs***. The springback amount is measured in the direction perpendicular to the part. Data values: 20.

It is critical to update the number of points used in the two force vs binder travel distributions in ROW 10 Column A of the two worksheets "BH180" and "AL 6111-T4P".

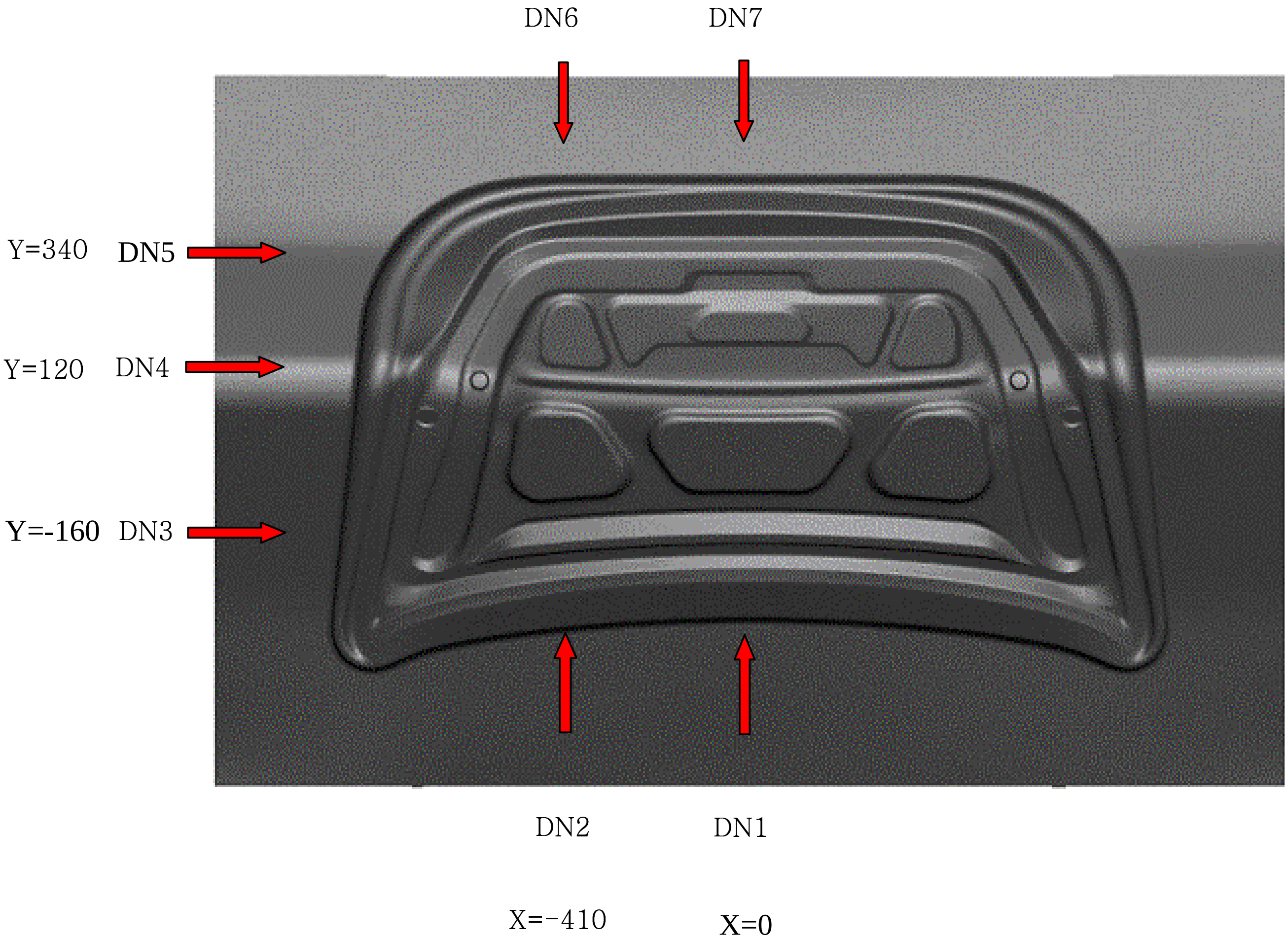

Figure 5. Draw-in measurement locations

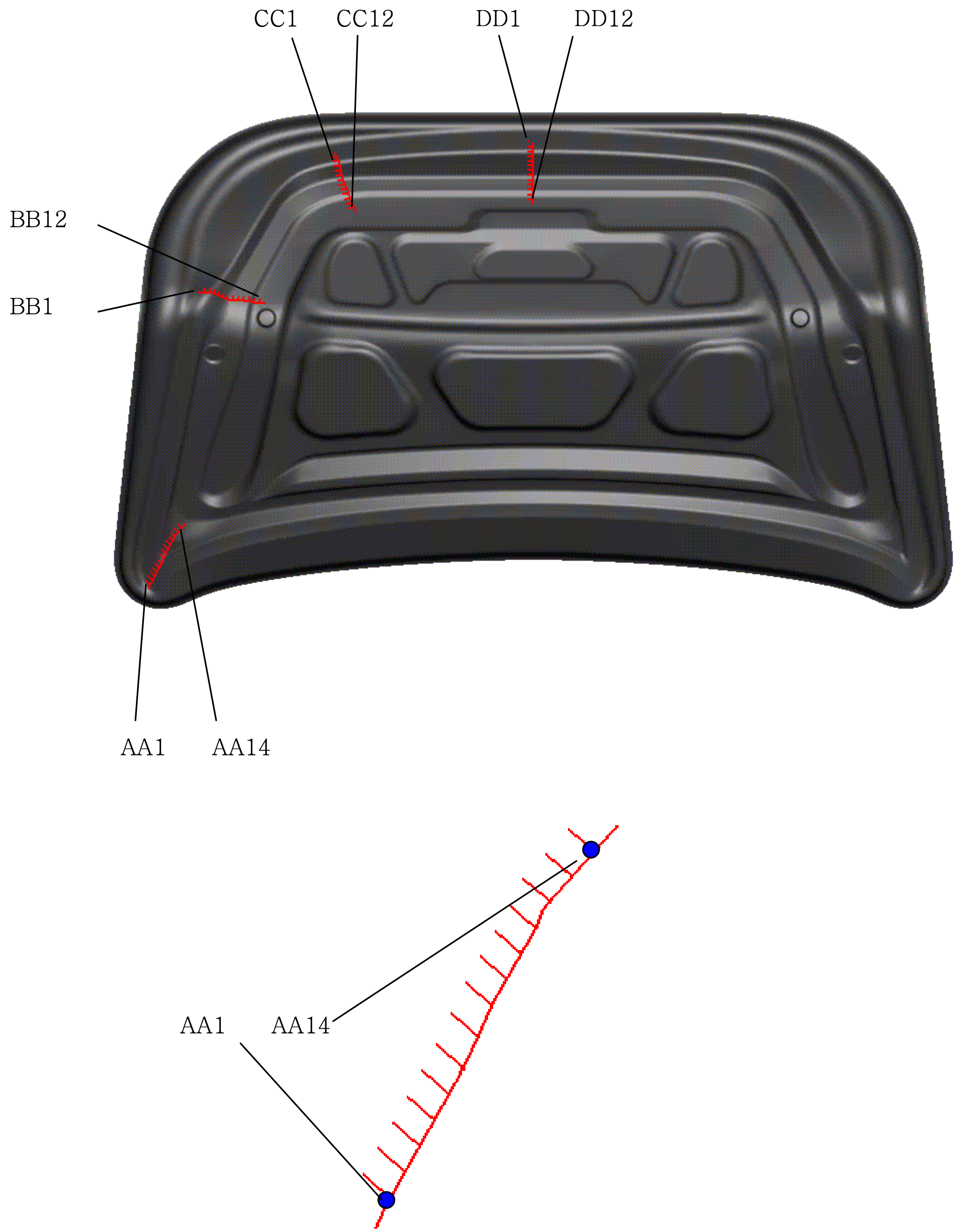

Figure 6. Measurement locations for thickness, and major and minor strains on top surface.

Strain Measurement Point	X (mm)	Y (mm)	Z (mm)
AA1	-686.70	-364.62	-27.25
AA2	-682.63	-356.92	-22.36
AA3	-678.55	-349.34	-17.26
AA4	-674.48	-341.75	-12.19
AA5	-670.41	-334.15	-7.12
AA6	-666.34	-326.61	-1.96
AA7	-662.37	-317.33	-0.29
AA8	-658.50	-308.26	1.35
AA9	-654.44	-300.53	6.12
AA10	-650.38	-293.12	11.48
AA11	-646.32	-285.75	16.88
AA12	-642.39	-277.76	21.08
AA13	-636.22	-270.48	24.08
AA14	-629.98	-263.14	26.77

Table 5. Point Locations for Strain and Thickness measurements Along Section AA.

Strain Measurement Point	X (mm)	Y (mm)	Z (mm)
BB1	-590.01	159.47	268.21
BB2	-580.08	159.39	268.08
BB3	-571.26	157.03	264.16
BB4	-563.91	153.55	258.37
BB5	-556.84	149.91	252.30
BB6	-548.81	146.86	247.23
BB7	-539.31	145.41	244.81
BB8	-529.34	145.02	244.16
BB9	-519.37	144.61	243.49
BB10	-509.48	143.96	242.41
BB11	-501.25	141.09	237.62
BB12	-491.54	140.16	236.09

Table 6. Point Locations for Strain and Thickness measurements Along Section BB.

Strain Measurement Point	X (mm)	Y (mm)	Z (mm)
CC1	-352.98	402.67	120.75
CC2	-349.68	396.14	127.54
CC3	-346.73	387.03	128.16
CC4	-345.19	378.80	122.70
CC5	-343.69	370.63	117.13
CC6	-341.42	361.64	114.26
CC7	-338.04	353.39	118.62
CC8	-334.63	345.47	123.69
CC9	-331.22	337.38	128.43
CC10	-328.09	328.01	129.60
CC11	-324.69	319.95	134.36
CC12	-321.28	312.19	139.66

Table 7. Point Locations for Strain and Thickness measurements Along Section CC.

Strain Measurement Point	X (mm)	Y (mm)	Z (mm)
DD1	0.00	420.73	134.80
DD2	0.00	412.65	140.36
DD3	0.00	403.41	137.53
DD4	0.00	395.24	131.75
DD5	0.00	387.08	125.98
DD6	0.00	378.92	120.20
DD7	0.00	370.68	114.55
DD8	0.00	361.10	115.07
DD9	0.00	352.73	120.55
DD10	0.00	344.37	126.03
DD11	0.00	334.80	128.16
DD12	0.00	325.69	131.96

Table 8. Point Locations for Strain and Thickness measurements Along Section DD.