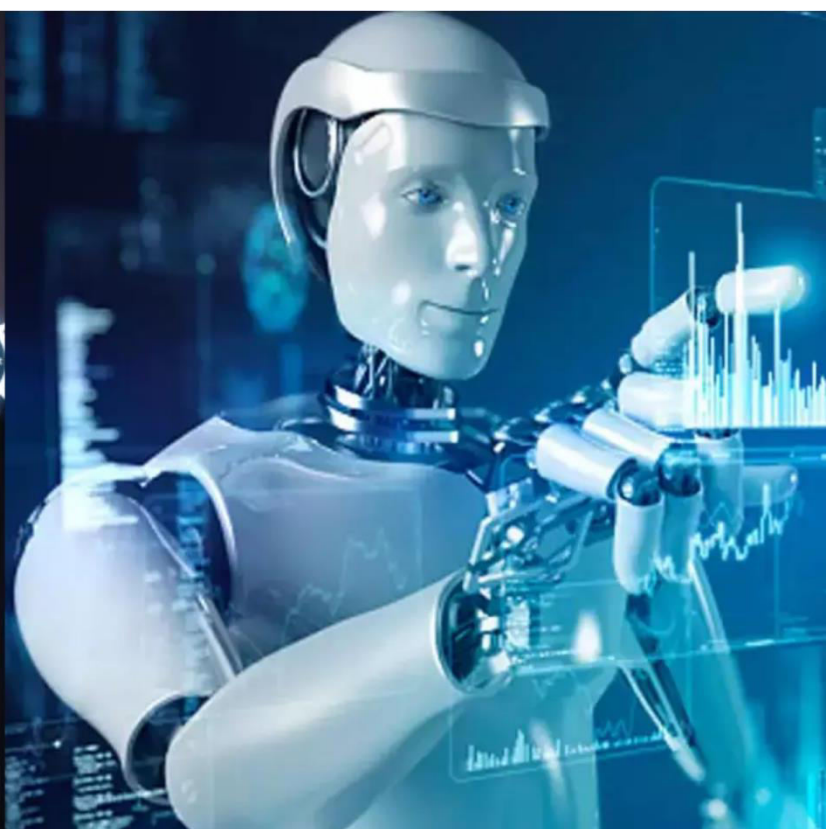




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Automotive Hood Weather-Strip CLD Assessment: CAE–Test Comparison and Lateral-Position Selection

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ABSTRACT: Compression load-deflection (CLD) describes the reaction load of a weather-strip as it is compressed during closure. This study compares the reported numerical results of an automotive hood weather-strip with physical test results and examines the effect of lateral installation position. The section consists of sponge EPDM and solid EPDM. The CAE assessment covers the BASE, +1 mm, +2 mm and –2 mm positions, with loads reported from D–4 to D+2 on a 100 mm evaluation basis. Individual test results are compared directly with CAE at D–1, D0 and D+1. Both the baseline simulation and test show a relatively level response near D0 followed by a pronounced load rise. Positive lateral movement increases the D+1 load, whereas the –2 mm position delays the main rise until D+2. Visual comparison identifies the updated BASE position as the closest overall match to the measured trend among the reported CAE positions. The study demonstrates how CLD graphs and deformed shapes can guide lateral-position selection.

KEYWORDS: Hood weather-strip; compression load-deflection; CAE–test comparison; lateral position; EPDM; contact deformation.

I. INTRODUCTION

Automotive weather-strips deform as the mating surfaces approach each other. The resulting reaction force contributes to closure resistance, while the deformed section establishes contact with the surrounding profiles. Compression load-deflection, commonly referred to as CLD, expresses this relationship between compression travel and reaction load. A CLD graph therefore provides a practical way to assess both the level of closure resistance and how that resistance develops through the working travel [1,2].

The response depends on the elastomeric material and the shape of the section in contact. Earlier weather-strip studies have examined nonlinear contact, variable cross-sections and assembly-related deformation [1–4]. Related work has described sponge and dense EPDM material behaviour and the influence of section geometry on sealing contact [5,6]. These studies provide the background for assessing an installed seal through its load curve together with its deformation sequence.

For the hood-front weather-strip, lateral installation position is examined as a design variable. Moving the same section sideways changes its alignment with the hood and bumper profiles without directly adding to the closure travel. The objective is to compare CAE with the measured CLD trend, explain the response of the reported lateral positions, and identify the preferred position for reproducing that trend. The discussion is based on the supplied load values, graphs and section images.

II. COMPONENT AND CLD ASSESSMENT

The component is the HOOD STRIP. The section contains a solid EPDM attachment region and a sponge EPDM bulb. Figure 1 shows these material regions, the surrounding profiles and the lateral-position alternatives. The same section is assessed at BASE (0 mm), +1 mm, +2 mm and -2 mm.

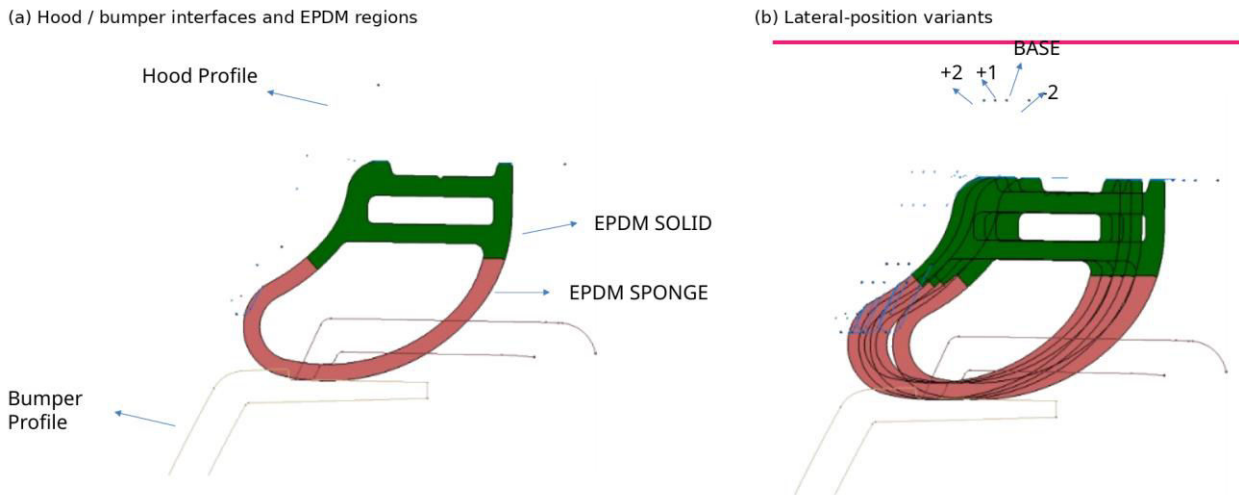


Figure.1. (a) Hood weather-strip, mating profiles and EPDM regions; (b) lateral-position alternatives. Original geometry and position labels from the supplied presentation.

Table.1. Component and evaluation conditions recorded in the supplied CAE and test reports.

Item	Reported condition
Component	Hood-front weather-strip;
Evaluation length / load unit	100 mm / N per 100 mm
Sponge / solid material	EPDM SOLID / EPDM SPONGE
Contact friction coefficient	Sponge: 0.30; solid: 0.55
Lateral positions	BASE (0 mm), +1 mm, +2 mm and -2 mm
CAE sequence	Step 1: flange; Step 2: D-4 to D+2
Comparison states	D-1: 10 mm; D0: 11 mm; D+1: 12 mm
Physical test	50 mm/min; 12.0 mm set travel

A. Compression travel and lateral position

Compression travel is the movement that closes the mating profiles and deforms the bulb. D0 identifies the design-reference compression state; D-1 and D+1 are the adjacent states on either side. The test sheet identifies D0 at 11 mm, and the comparison presentation places D-1 and D+1 at 10 and 12 mm. These states are distinct from the lateral-position labels.

Lateral movement changes the installation alignment shown in Fig. 1(b). The positive direction is described as forward protrusion in the original CAE records. The local +1, +2 and -2 mm labels are retained here, rather than assigning an additional vehicle-axis convention. Each lateral case is compared at the same D states.

B. Common CAE result set

All lateral-position curves in this paper use the complete result set, including its updated BASE case. The BASE shown in the later compilation is not mixed with these updated lateral results. This keeps the position comparison within one reported CAE revision.

III. ELASTOMERIC MATERIAL BEHAVIOUR

The hood weather-strip combines two elastomeric regions with different deformation behaviour. The sponge bulb provides the compliant part of the section, while the dense rubber forms the attachment region. The material description follows the supplied weather-strip reference paper, which uses a foam model for sponge rubber and a Mooney–Rivlin-type model for dense rubber [5].

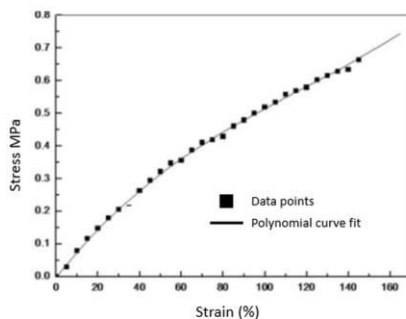
A. Sponge EPDM

The reference describes sponge rubber as nonlinear, elastic, isotropic and highly compressible. Its response is represented using a foam strain-energy description, with material behaviour characterized through tension, compression and volumetric testing. The compression response is particularly relevant to a hood-strip bulb as it folds and changes volume under closure. A single linear stiffness does not describe all stages of this deformation [5].

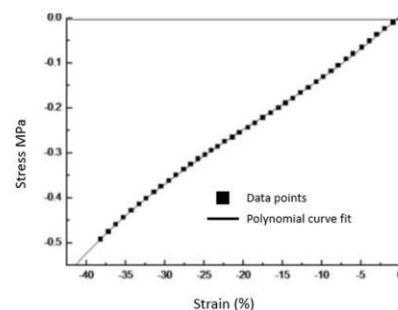
B. Solid EPDM

Dense EPDM is described as nonlinear and approximately incompressible. The supplied reference uses a Mooney–Rivlin-type representation for this material. In the hood-strip section, the dense region supports the attachment geometry while the sponge bulb accommodates most of the visible section change. Both regions remain part of the contact and deformation assessment [5].

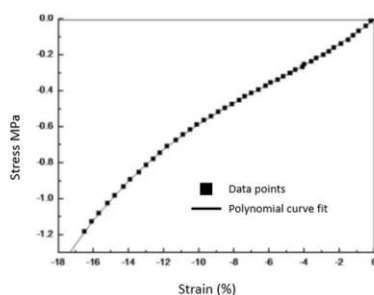
(a) Sponge: uniaxial tension



(b) Sponge: uniaxial compression



(c) Sponge: volumetric response



(d) Dense rubber: tensile response

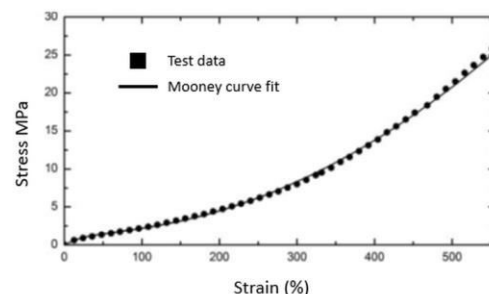


Figure.2. Original elastomeric stress–strain plots retained from the supplied reference manuscript [5]: sponge tension, compression and volumetric response, and dense-rubber response. These are reference material curves, not new measurements of the compounds.

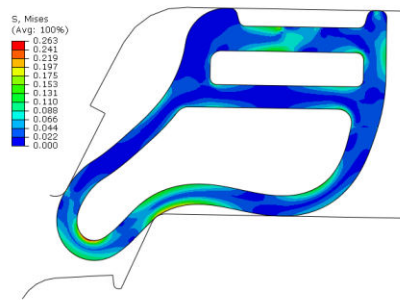
C. Material basis for the position study

The records identify sponge EPDM and solid EPDM. The reference curves in Fig. 2 explain the material-model approach; the reports do not provide a complete material-parameter set. No new compound properties are assigned from the component CLD graph. The lateral study is interpreted through the reported changes in installation alignment and section response, with the same listed compound pair used for the compared cases.

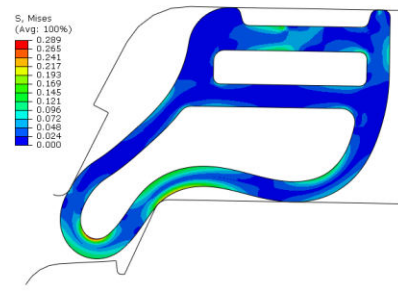
IV. CAE COMPRESSION RESPONSE

The reported CAE sequence first establishes the flange condition and then evaluates compression from D-4 to D+2. Figure 3 shows the baseline section at successive closure states. The bulb bends and folds as the profiles approach, and the internal space available for deformation becomes smaller. The reported loads are listed in Table 2 on the 100 mm evaluation basis.

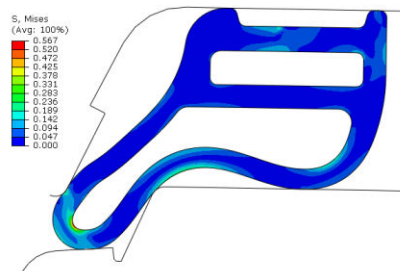
(a) D-1



(b) D0



(c) D+1



(d) D+2

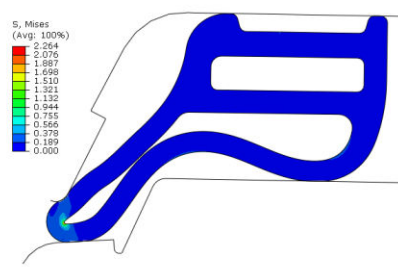


Figure.3. Baseline section deformation at D-1, D0, D+1 and D+2, arranged from the original CAE screenshots. Panels retain their source contours and scales and are used here to discuss shape change.

Table.2. Reported CAE compression loads for the updated lateral-position series (N/100 mm).

Position	D-4	D-3	D-2	D-1	D0	D+1	D+2
BASE	3.6	4.7	5.6	5.3	4.5	13.0	29.4
+1 mm	3.3	4.3	5.1	4.9	4.6	15.6	29.2
+2 mm	3.2	4.1	4.5	4.4	6.1	16.5	24.5
-2 mm	4.8	6.4	7.2	6.6	6.3	7.1	26.1

A. Baseline load trend

At BASE, the load increases in the earlier states, becomes lower between D-2 and D0, and then rises rapidly at D+1 and D+2. The change in curve shape is consistent with the visible folding and later compression of the bulb. This interpretation relates the reported force sequence to the section images; it does not identify a new material or contact parameter.

B. Reading the deformed shape together with CLD

The load curve shows when the section becomes more resistant to closure, while the images show how the bulb is positioned between the mating profiles. Both are needed for a useful design comparison. A position with a higher load at one state is not necessarily higher throughout the remaining travel, as the lateral results demonstrate.

V. CAE-TEST CLD COMPARISON

The physical W/S test report contains three specimen results. The recorded test speed is 50 mm/min and the set travel is 12.0 mm. Figure 4 compares each specimen directly with the updated BASE simulation at D-1, D0 and D+1. The reported readings are reproduced in Table 3; no combined test curve is substituted for the individual specimens.

Table.3. Individual test readings and updated BASE CAE loads (N/100 mm)

Result	D-1 / 10 mm	D0 / 11 mm	D+1 / 12 mm
Test 1	4.810	4.546	10.111
Test 2	5.339	5.735	10.432
Test 3	5.339	5.339	11.300
CAE: BASE	5.3	4.5	13.0

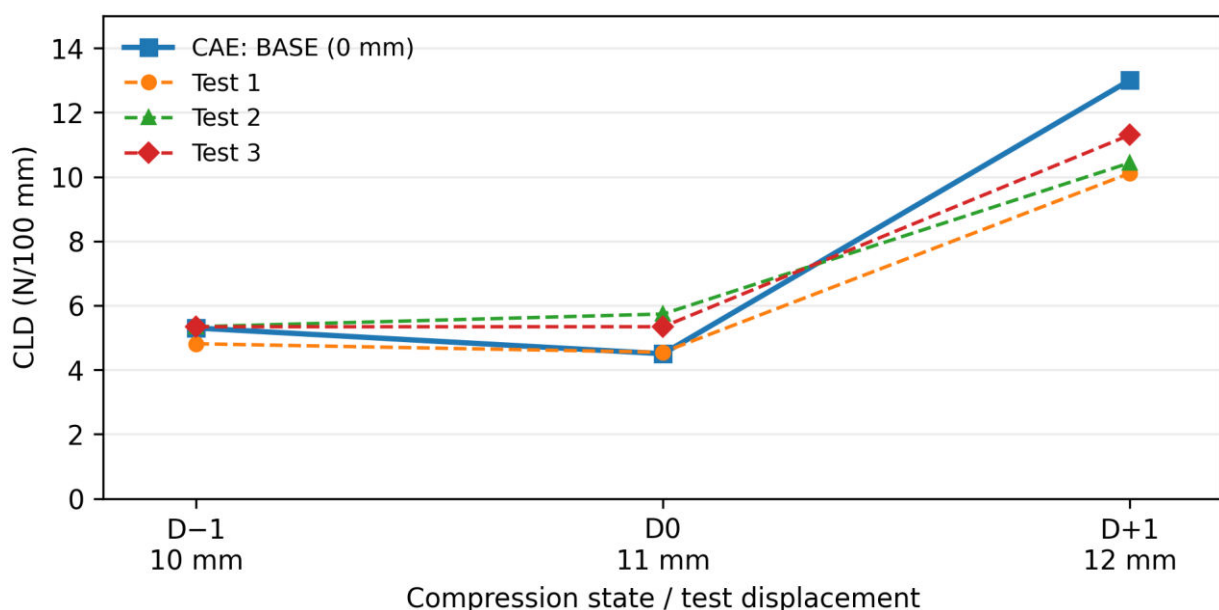


Figure 4. Direct comparison of updated BASE CAE with Test 1, Test 2 and Test 3. Markers show the reported loads; lines connect only the three comparison states and do not reproduce the complete recorded curves.

A. Response around D0

The physical results remain at a similar load level from D-1 to D0. Test 1 decreases slightly, Test 2 increases slightly and Test 3 remains level. The BASE CAE result also stays in this low-load region, changing from 5.3 N/100 mm at D-1 to 4.5 N/100 mm at D0. The simulation therefore represents the relatively level portion of the measured response, although the individual loads are not identical.

B. Load rise after D0

All three specimens show a clear increase at D+1. The simulation also rises after D0, reaching 13.0 N/100 mm, but lies above the three measured D+1 readings. The shared feature is the transition from the near-D0 plateau to the rising closure-load region. This trend agreement supports using the BASE case as a reference for examining the lateral alternatives, without treating the curves as an exact force match.

The direct comparison ends at D+1 because the test record provides no tabulated D+2 reading. The numerical D+2 results are therefore used to compare the lateral cases with each other, not as additional physically verified test points.

VI. EFFECT OF LATERAL MOVEMENT ON CLD

Figure 5 compares the updated BASE, +1 mm, +2 mm and -2 mm CAE results over the reported compression states. The positions change both the load level and the stage at which the main rise occurs. The curves do not remain in the same order across the complete travel, showing why the lateral decision should consider the shape of the CLD response rather than one load value.

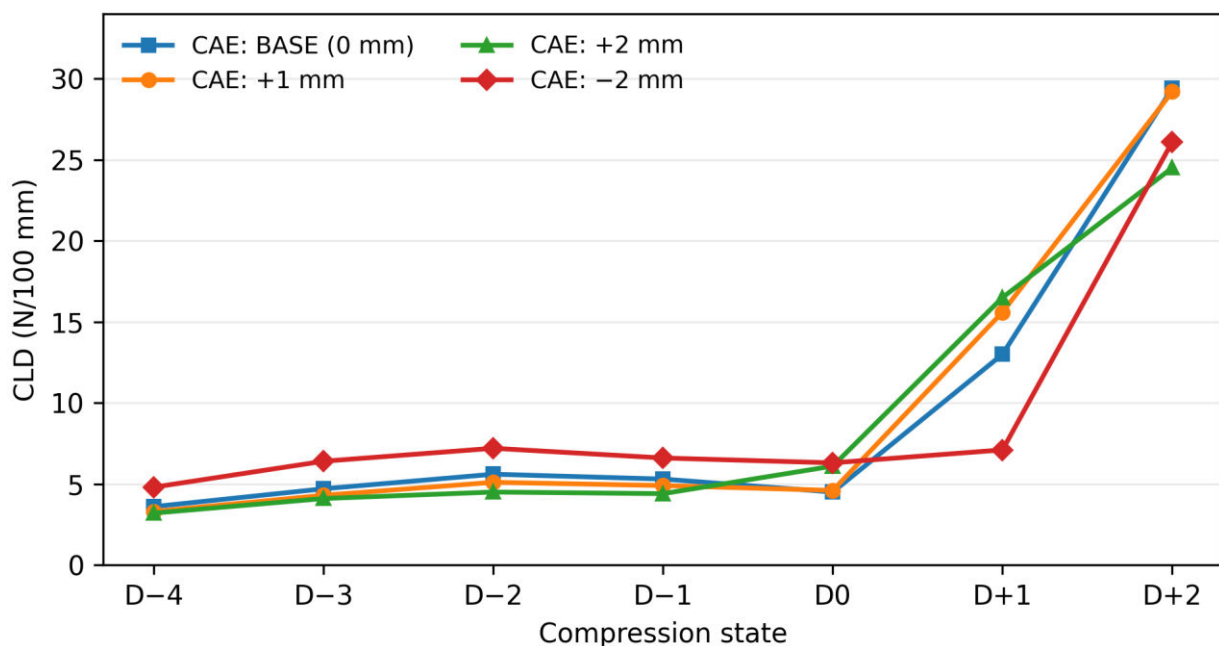


Figure.5. CLD response for the four lateral installation positions from the CAE series. Each marker is a reported compression-state load; the connecting lines are visual guides.

A. Positive movement: +1 mm

The +1 mm curve follows the BASE response closely through the earlier states and near D0. Its load is 4.6 N/100 mm at D0, followed by a stronger increase to 15.6 N/100 mm at D+1. At D+2 it reaches 29.2 N/100 mm, close to the BASE endpoint of 29.4 N/100 mm. This position retains the broad BASE curve shape but makes the first post-D0 rise stronger.

B. Positive movement: +2 mm

The +2 mm case is lower in the earlier states but begins to rise between D-1 and D0. Its loads are 4.4, 6.1 and 16.5 N/100 mm at D-1, D0 and D+1. At D+2, however, its load is 24.5 N/100 mm, below the BASE and +1 mm cases. The position therefore changes the progression of the response rather than simply making the seal uniformly stiffer.

C. Negative movement: -2 mm

The -2 mm position has higher loads during the earlier compression states and remains relatively level through D+1. It reaches 6.3 N/100 mm at D0 and 7.1 N/100 mm at D+1, before rising to 26.1 N/100 mm at D+2. Compared with BASE, the main rise occurs later in the reported sequence. This behaviour is consistent with a different alignment of the bulb against the surrounding profiles.

D. Engineering implication

Positive movement strengthens or advances the rise close to D0, whereas the -2 mm movement postpones it. The useful design information is therefore not only whether a load is larger or smaller, but whether the transition occurs in the required part of the closure travel. The direct comparison with the physical results is shown in Fig. 6.

VII. PREFERRED LATERAL POSITION FROM THE CLD TREND

Figure 6 places the lateral CAE results and the three individual test results on the same compression-state axis. The measured trend is relatively level from D-1 to D0 and rises clearly at D+1. The preferred lateral position is identified by how well it follows both parts of this response, rather than by matching a single state.

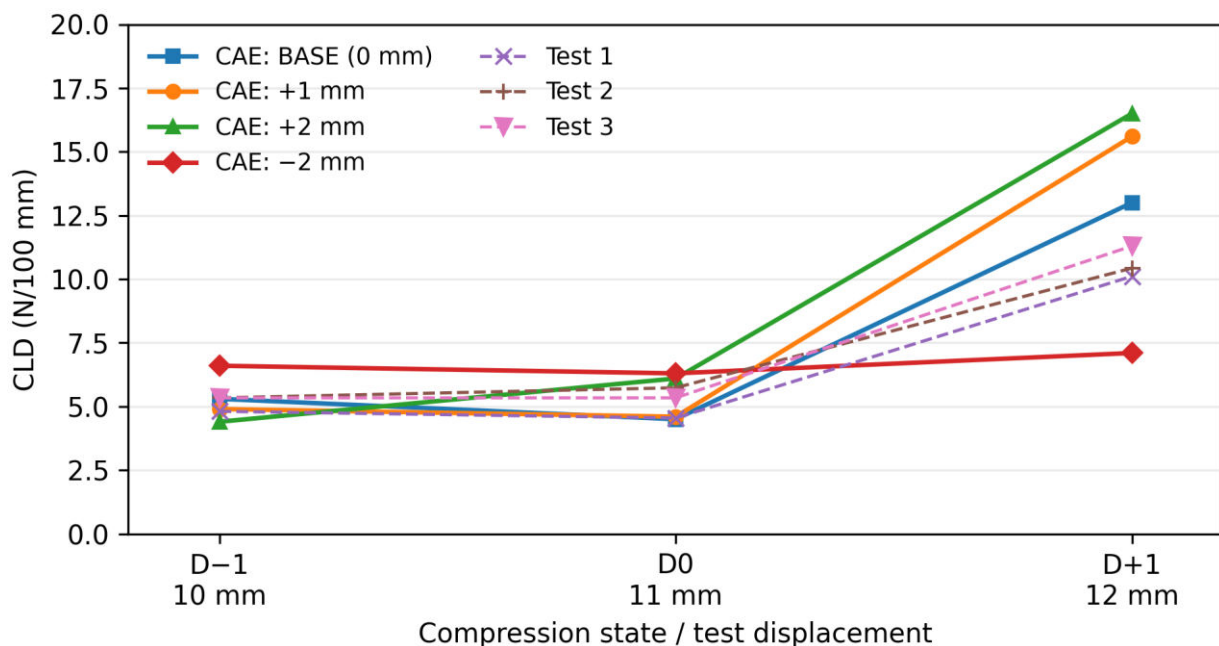


Figure.6. Direct CAE-test comparison of the lateral alternatives near D0. Test 1-3 are the original installation results, shown as the measured reference; they are not separate tests of the shifted positions.

Table.4. Lateral-position selection based on the directly plotted CLD trends.

Position	Observed trend relative to the test	Design interpretation
BASE (0 mm)	Near-D0 plateau followed by a D+1 rise.	Preferred overall trend match.
+1 mm	Similar near-D0 response; higher D+1 rise.	No clearer improvement over BASE.
+2 mm	Rise starts before D0; high D+1 load.	Less similar near-D0 shape.
−2 mm	Remains relatively level through D+1.	Main rise occurs later than the test.

A. Preferred position

The updated BASE (0 mm) is the preferred position among the evaluated cases for reproducing the measured CLD trend. It retains the near-D0 plateau and the post-D0 rise. The +1 mm position does not provide a clearer overall match because its D+1 load is higher. The +2 mm case rises earlier near D0, while the −2 mm case does not reproduce the measured rise at D+1. The plotted comparison therefore supports retaining BASE rather than adopting any reported shift.

B. Application of the selection

This is a selection for agreement with the existing test curve. The shifted positions have not been separately verified by physical CLD tests in the supplied record. The test sheet also lists a requirement of 1.88 ± 0.56 N/100 mm, but does not clearly assign it to a displacement and loading branch. Final specification acceptance must use that confirmed condition; trend agreement alone is not a release decision.

VIII. CONCLUSION

The reported hood-strip results show that the CLD graph is useful for relating closure resistance to section deformation. Direct comparison of the updated BASE simulation with the three test specimens shows the same main response pattern: a relatively level load near D0 followed by a pronounced increase at D+1. The CAE D+1 load remains above the measured readings, so the agreement is in the response trend rather than an exact match at every state.

Lateral movement changes the progression of bulb compression. The +1 mm and +2 mm positions increase the D+1 load, while the −2 mm position delays the main load rise until D+2. Among the reported alternatives, BASE (0 mm) is preferred for matching the measured near-D0 and post-D0 behaviour. None of the shifted cases gives a clearer match across both regions.

The practical outcome is to retain BASE as the preferred installation reference for the present CLD comparison and use the lateral curves to understand the effect of any subsequent position change. A final installation change should be checked against a physical test at that same position and the confirmed specification condition. The original elastomeric material descriptions and figures are retained as the background to the nonlinear section response.

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