EZSLAMX
Training Program

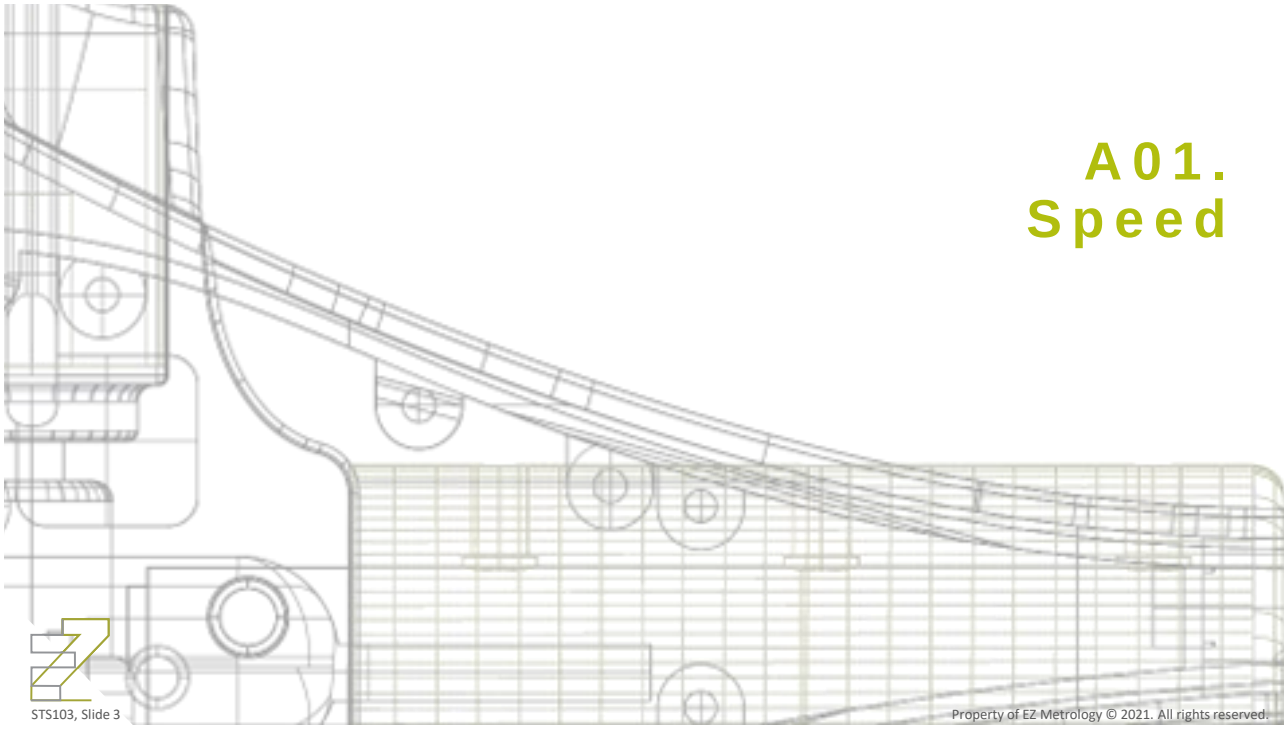
CHAPTER 3
A Graphs and Metrics

1

A Graphs and Metrics

A01. Speed
A02. Overslam
A03. Alignment
A04. Static Force
A05. Open Sweep Force
A06. Close Sweep Force
A07. Door Rise
A08. Pressure (Speed)
A09. Pressure Wave
A10. Plop
A11. Wiggle
B. Metrics

2



A01. Speed

3

A01. Speed
1. Points of Interest

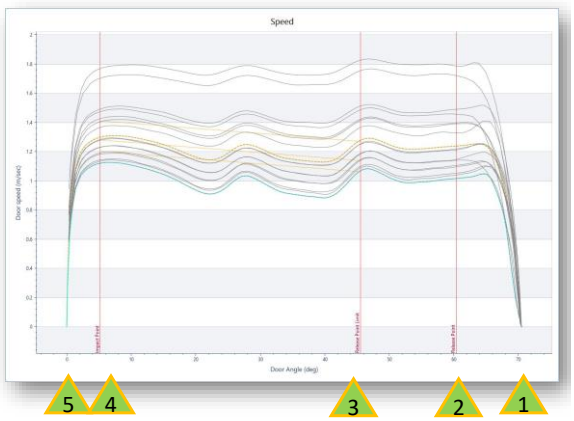
Definition

Represents the speed of the door during the trajectory from open to close.

Only closed slam test will appear in this graph.

Points of Interest

1. **Open**: Door starts on the right side Click to add text
2. **Release Point**: The most extreme point when the operator was still pushing the door
3. **Release Point Limit**: The set acceptable limit for release point
4. **Impact Point**: The point where the door has 90mm of travel left (arbitrary)
5. **Closed**: X or door angle equals '0'



4

A01. Speed
2. Curves of Interest

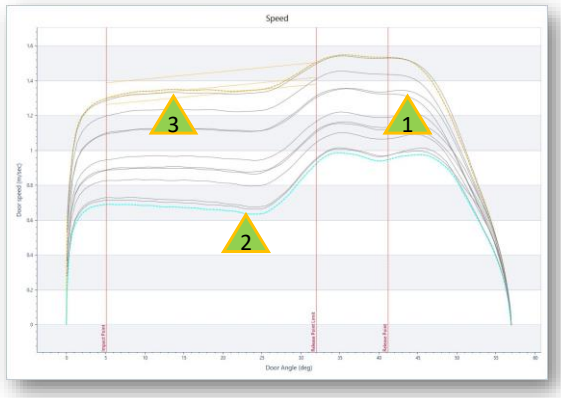
Measurement Curves

1. **Slams**:
   - Each (closed) slam has a matching speed profile.
   - Grey
   - Can be selected to identify the run number.

Established Curves

2. **Minimum Closing Speed**:
   - Speed of the door in minimum closing situation.
   - Often the results of all factors combined (mixed).
   - Light Blue

3. **Typical Speed**
   - Speed of the door when closed at reference speed (convention).
   - Yellow
   - This curves also determines Check Slope and Check Linearity.



STS103, Slide 5

5

A01. Speed
3. Application

Compare the Typical Curves

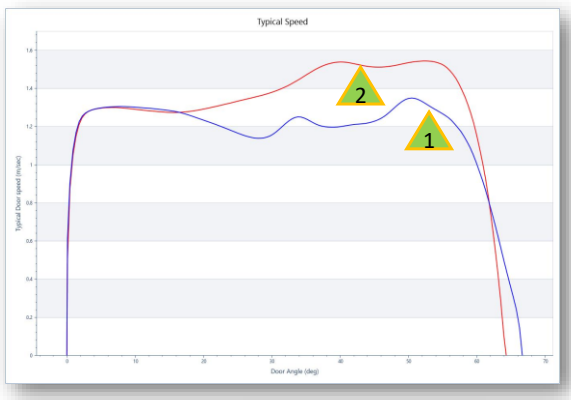
Compare two doors in the situation where they both have the identical ('typical') impact speed.

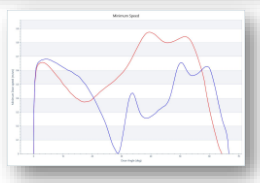
1. **Blue**:
   - Requires significantly less initial speed (approx. 1.3m/s) from full open to achieve the preset speed of 1.3m/s

2. **Red:**
   - Requires much more speed, or kinetic energy, nearly 1.6m/s, to achieve the impact speed of 1.3m/s

The Red door system has more obvious net losses during the course of the travel.

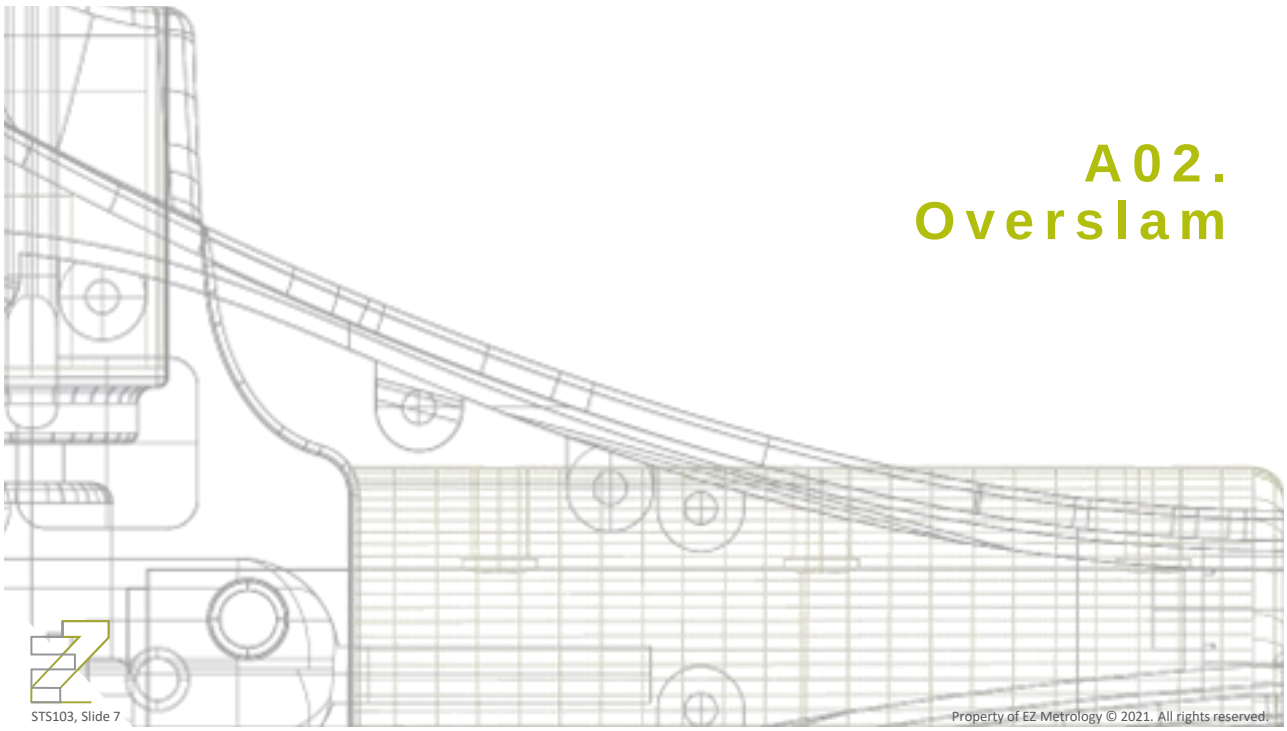
These differences indicate a deviation of the hinge and/or check mechanism.





STS103, Slide 6

6



A02. Overslam

7

A02. Overslam
1. Data Points

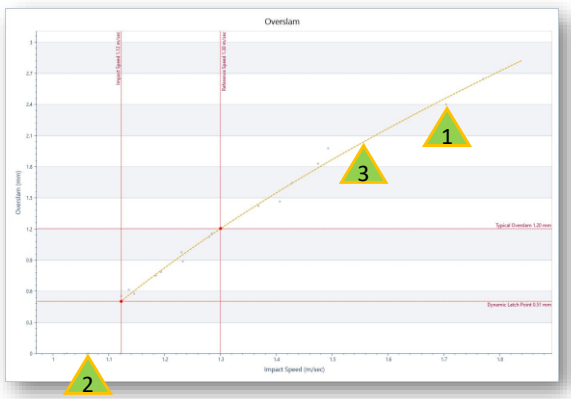
Definition

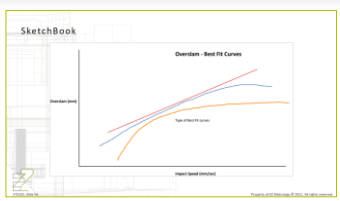
Established the relationship between overslam and impact speed.

Only closed slam test will appear in this graph.

Data of Interest

1. **Closed Slams**: will be represented as a single point at matching [‘Speed’, ‘Overslam’] relation
2. **Not latched Slams**: will be represented at a coordinate of [‘Speed’, ‘0’] indicating a valid measurement where the door did not close.
3. **Best Fit Curve**: A mathematical best fit relationship between all the points. Deviations from the curve are calculated in %, any fit withing 5% is accepted. Any fit uncertainty beyond 5% will be flagged as yellow or red if it is above 10%





8

A02. Overslam
2. Application: Curve Position

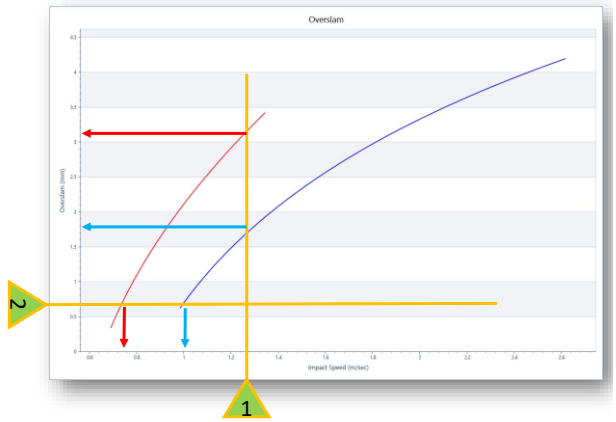
A characteristic that is higher on the chart indicates an easier to close door system.

It physically represents the dynamic stiffness of the door system.

Points of Interest

1. "For a given speed, the door travels much deeper."
2. "For a given overslam, the door can travel much slower."

In cases it will be easier to reach the point where the latch will engage (close) the door.



STS103, Slide 9

9

A02. Overslam
3. Application: Curve Slope

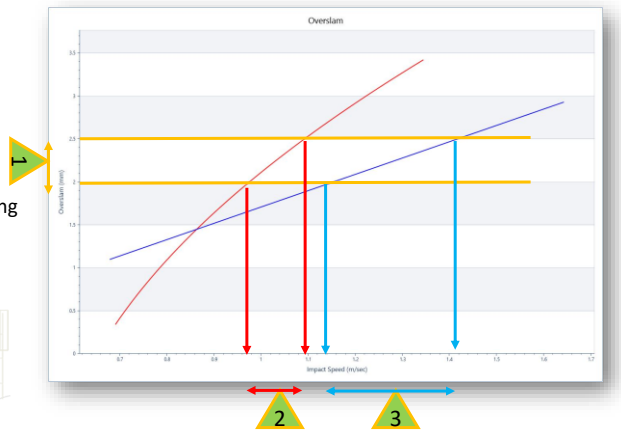
A characteristic that has a steeper slope indicates a more forgiving design.

A given variation of overslam, associated with build variation (Y position of the striker), will result in a matching variation in closing speed.

Points of Interest

1. For a given variation in Y position of '0.5mm'
2. Steep Slope: 0.9 to 1.1 or about '0.1m/s'
3. Soft Slope: 1.13 to 1.42 or about '0.3m/s' change

In cases it will be easier to maintain good closing speed with steeper slope (less stiffness).



STS103, Slide 10

10

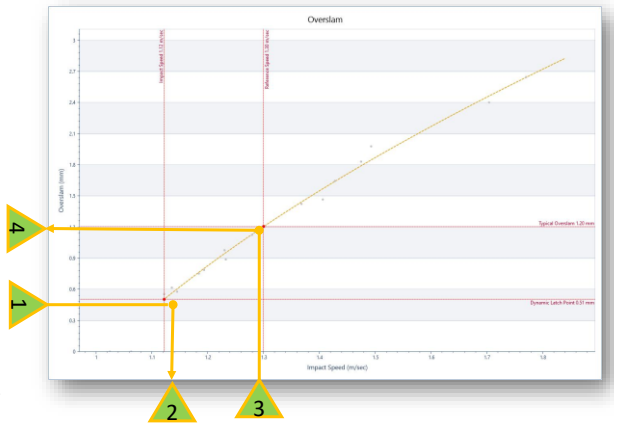
A02. Overslam
4. Points of Interest

Minimum Closing Speed

1. **Latch Point**: For a given overslam (push test).
2. **Minimum Closing Speed**: The door will latch if the door travels the required amount to latch.

Typical Overslam (~slope)

3. **Reference Speed**: At a given reference speed, input from convention.
4. **Typical Overslam**: The door will travel this deep.



11

A03. Alignment

12

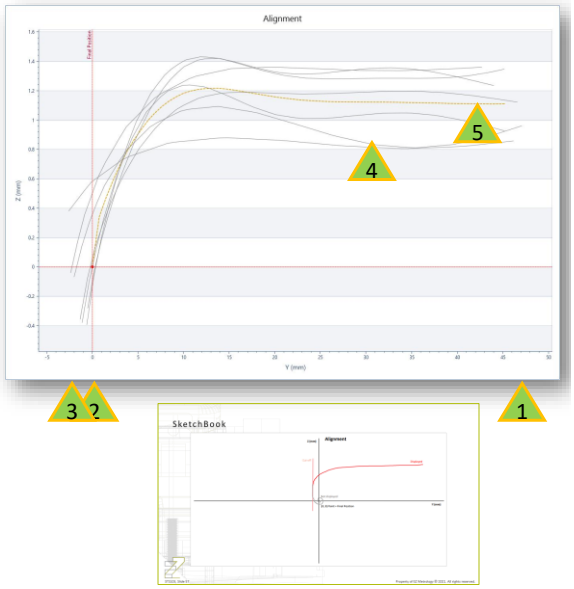
A03. Alignment
1. Data

Definition

Represents the vertical position of the door during the last 75mm of travel. This is the moment of impact.

Points of Interest

1. **Open**: Door comes in from the right side of the graph.
2. **Final Closed Position**: The door comes to a halt at the '0' position.
3. **Overslam**: The curve stops at the maximum overslam travel.
4. **Grey Lines**: All closed slam measurements
5. **Yellow Line**: Average Trajectory



STS103, Slide 13

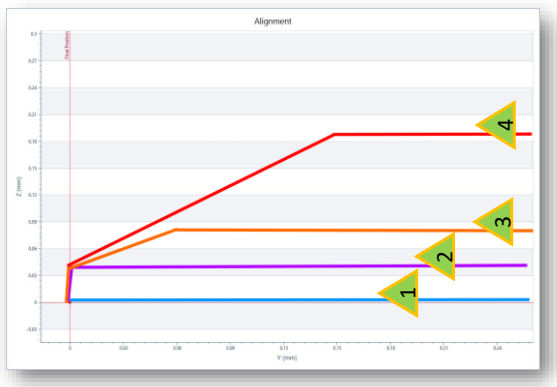
13

A03. Alignment
2. Application: Shape of Alignment

General Shape

1. **Perfect**: No change in Z
2. **Small Step**: A small step at the end indicates the rotating claw of latch, pulls the door up or down.
3. **Slope (starting at 5mm*)**: The striker could be rubbing the fish mouth.
4. **Big Slope (starting at 15mm*)**: The door is being pushed up or down potentially by seal system on rocker or roofline.

*: example numbers



STS103, Slide 14

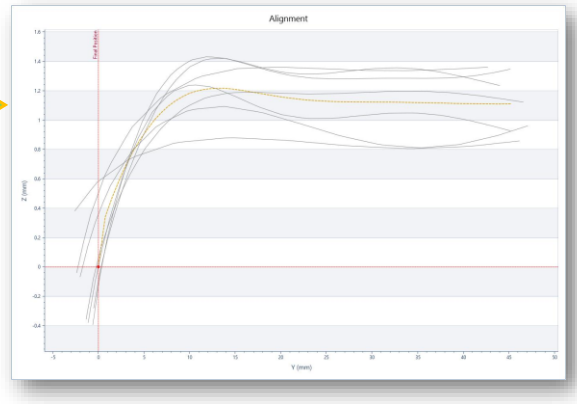
14

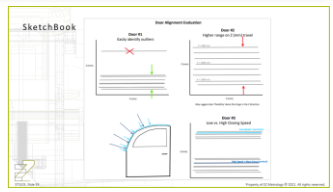
A03. Alignment
3. Points of Interest

Striker Alignment

1. **Striker Alignment**: Z value of the door when it comes near the impact point.

The hinge angle has little influence on these last 2-3 degrees of rotation.





STS103, Slide 15

15

A04. Static Force

STS103, Slide 16

16

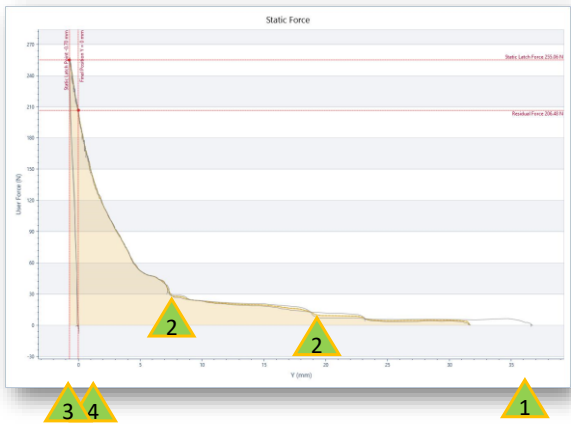
A04. Static Force
1. Data Interest

Definition

Represents the force in function of the last millimeters of travel. The recording needs to end as close as possible to minimum latch point.

Points of Interest

1. **Open**: Door starts on the right side, at rest with '0' force.
2. **Break Points**: The curve has a bump or changes slope, meaning the door is coming in contact with another seal or obstruction.
3. **Latch Point**: The peak force at which the latch engages.
4. **End Point**: The door relaxes and comes out at the final '0' reference point.



STS103, Slide 17

17

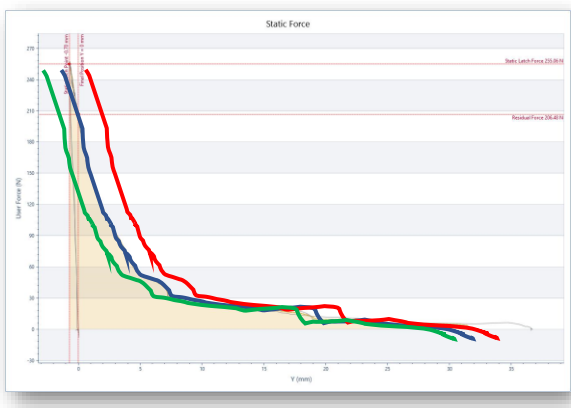
A04. Static Force
2. Application: Seal Gap

The seal gap can be identified as a horizontal shift of the curve.

Curve Observations

1. **Increased Gap**: Curves move from Blue to Green, corresponding to later compression and less peak force.
2. **Decreased Gap**: Curve moves from Blue to Red, corresponding to earlier contact and higher loads.

The gap change can be deducted from the amount of shift in Y.



STS103, Slide 18

18

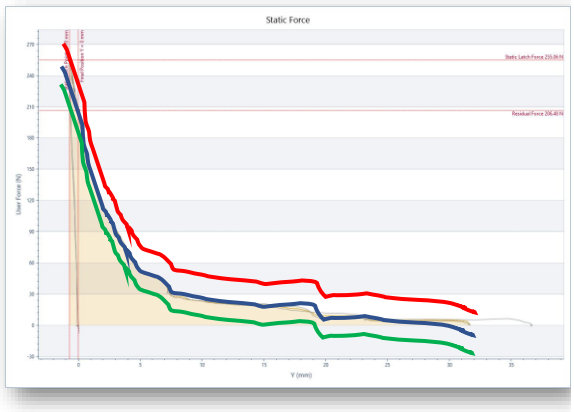
A04. Static Force
3. Application: Seal Stiffness

The seal stiffness can be identified as a vertical shift of the curve.

The Y location of the breakpoints do not shift.

Curve Observations

1. **Increased Stiffness**: Curve moves from Blue to Red,. At the same Y-position (on X axis) the door experiences a higher resistance force.
2. **Decreased Stiffness**: Curve moves from Blue to Green. At the same Y-position (on the X-axis) the door experiences less force.



STS103, Slide 19

19

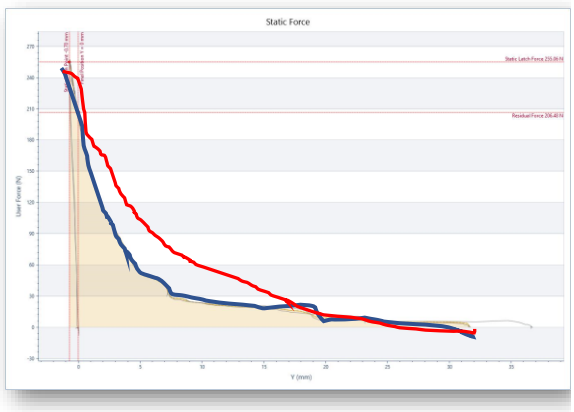
A04. Static Force
4. Application: Door Fit

Depending on design, a constant seal gap should result in noticeable breakpoints.

The seal on the B-pillar (for front door) compresses at once.

Curve Observations

1. **Sharp Breakpoints**: Door is aligned, and the seal is equally compressed.
2. **Soft Breakpoints**: Seal is compressed little by little as the door comes closer to its final position.



STS103, Slide 20

20

A04. Static Force
5. Application: Forces

The compression curve is identified by two force points near the impact.

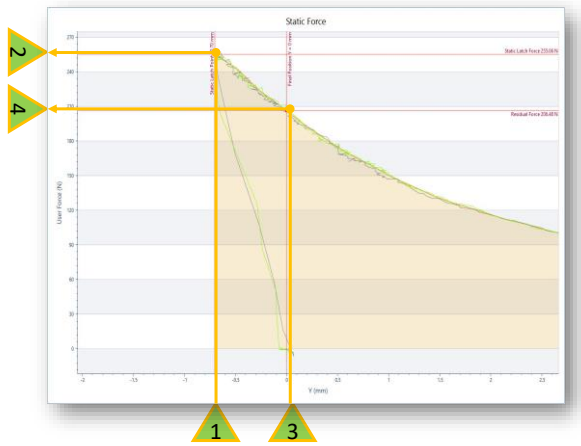
Latch Point - Force

1. **Latch Point**: Minimum overslam the door has to make for the latch to engage.
2. **Latch Force**: The force experienced from the seal and latch to reach the latch point.

Residual - Force

3. **Final Point**: The door will sit at rest at '0'mm.
4. **Residual Force**: The force experienced from the seal and latch to reach the final point.

Residual Force is good, representing the sealing force to avoid wind noise, water leaks. Latch Force is not useful, should be as close as possible to residual Force.



STS103, Slide 21

21

A04. Static Force
6. Compression Energy

Compression Energy

Compression energy corresponds to the energy definition:

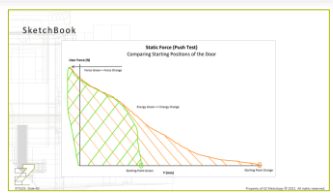
Force × travel.

Energy vs Force

Two doors can have identical Closing Force.

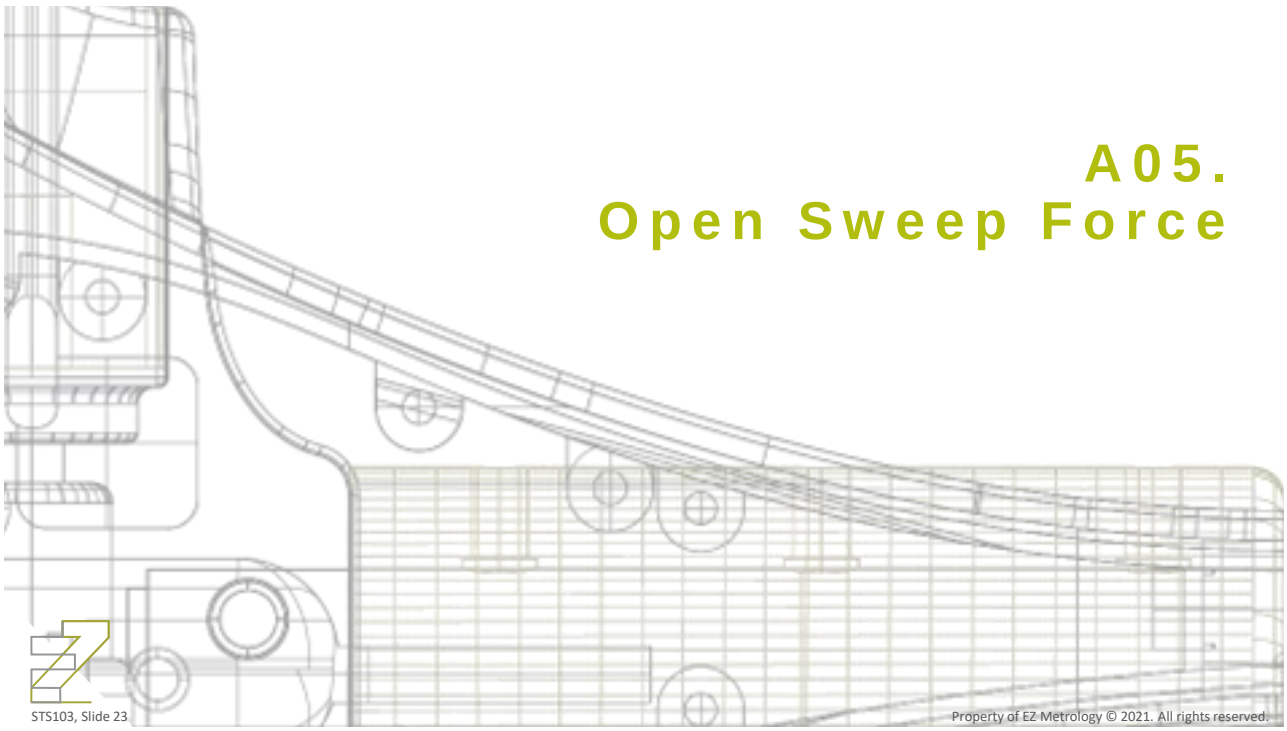
1. **Blue**: Force rises suddenly towards the end of the travel, resulting in a small compression energy.

2. **Red**: Force increases slowly during the motion and could start earlier. This will result in a much higher closing Energy.



STS103, Slide 22

22



A05.
Open Sweep Force

23

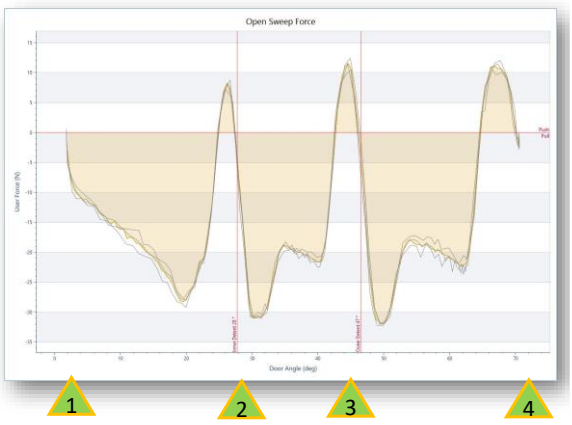
A05. Open Sweep Force
1. Points of Interest

Definition

Force experienced by the user (including gravity) when moving the door slowly from closed to open.

Points of Interest

1. **Start Point**: The door at rest against the seals.
2. **Inner Detent**: First position where the force changes direction (around '0N').
3. **Outer Detent**: Second position where the force changes direction (around '0N').
4. **End Position**: The door is at rest in fully open position.



24

A05. Open Sweep Force

2. Application: Energy

Definition

A check system will absorb (store) energy and deliver (return) energy.

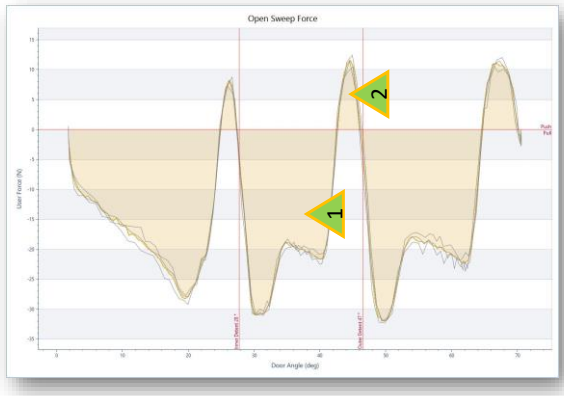
The colored areas represent this energy.

Points of Interest

1. **Check Absorbs Energy**: the door check will slow down the door, or the user has to pull the door open.

2. **Check Provides Energy**: the door will accelerate during these angles in the open direction.

The net result of the door check is the sum of all positive and negative areas. Opening the door often requires a net energy effort from the user.



STS103, Slide 25

25

A06. Close Sweep Force

STS103, Slide 26

26

A06. Close Sweep Force
1. Points of Interest

Definition

Force experienced by the user (including gravity) when moving the door slowly from open to closed.

Points of Interest

1. **Start Point**: The door sits in the resting open position.
2. **Outer Detent**: First position where the force changes direction (around ‘0N’).
3. **Inner Detent**: Second position where the force changes direction (around ’0N’).
4. **End Position**: The door is at rest against the seals.

A06. Close Sweep Force
2. Application: Energy

Definition

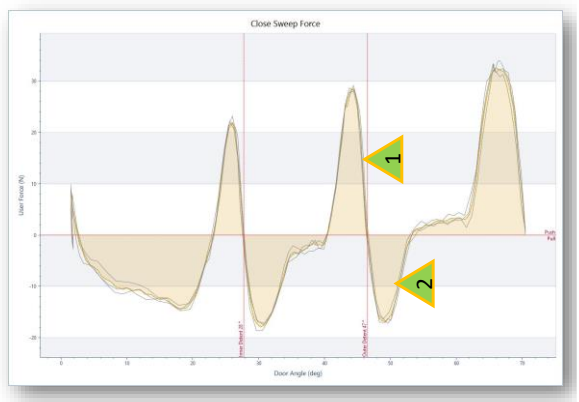
A check system will absorb (store) energy and deliver (return) energy.

The colored areas represent this energy.

Points of Interest

1. **Check Absorbs Energy**: the door check will slow down the door, or the user has to push.
2. **Check Provides Energy**: the door will accelerate during these angles.

The net result of the door check is the sum of all positive and negative areas. Closing the door often results in a small net energy effort from the user (both positive and negative areas are similar).



A06. Close Sweep Force
3. Application: Boost

Definition

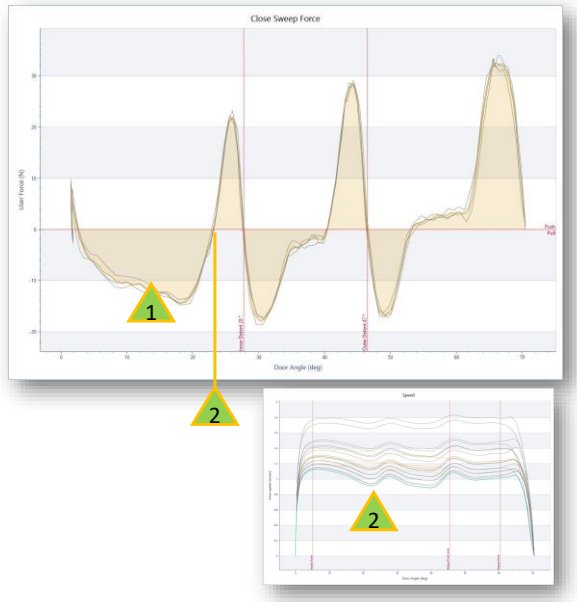
In the closing direction, a check can be designed to accelerate the door during the final degrees of travel.

Points of Interest

1. **Boost Energy**: the last negative area represents how much energy the check will put into the door. This results in an increase in speed.

2. **Boost Angle**: At what angle the energy delivery starts accelerating the door.

The net result of the door check is the sum of all positive and negative areas. Closing the door often results in a small net energy effort from the user (both positive and negative areas are similar).



STS103, Slide 29

29

A07. Door Rise

STS103, Slide 30

30

A07. Door Rise
1. Points of Interest

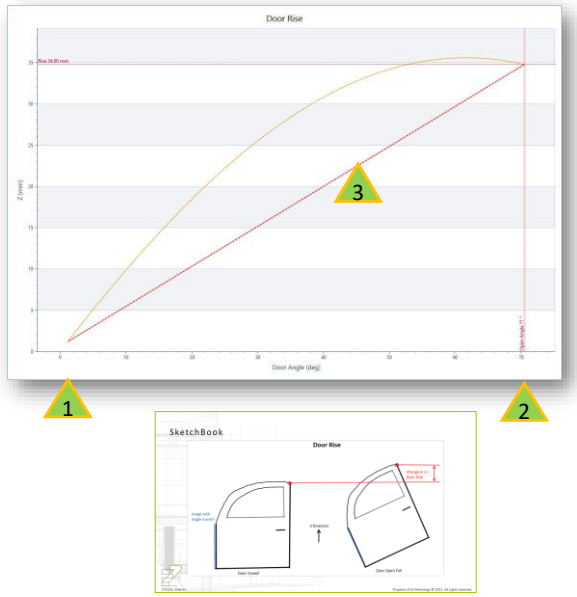
Definition

Represents the vertical position of the hem edge of the door.

The upward, downward or combined motion is a result of the hinge tip.

Points of Interest

1. **Closed**: Door is at height '0' in closed position.
2. **Open**: Due to the hinge tip the door will sit at a different height.
3. **Linear Reference**: A line is drawn to highlight the real vertical motion represented by the yellow line.



STS103, Slide 31

31

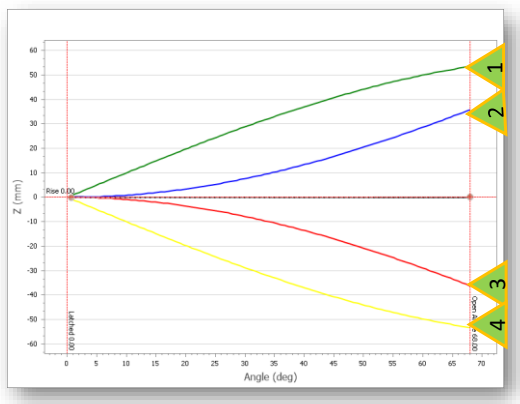
A07. Door Rise
2. Application: Shape

The shape of the door rise can be controlled with the two angles and can result in any combination of both.

Extremes

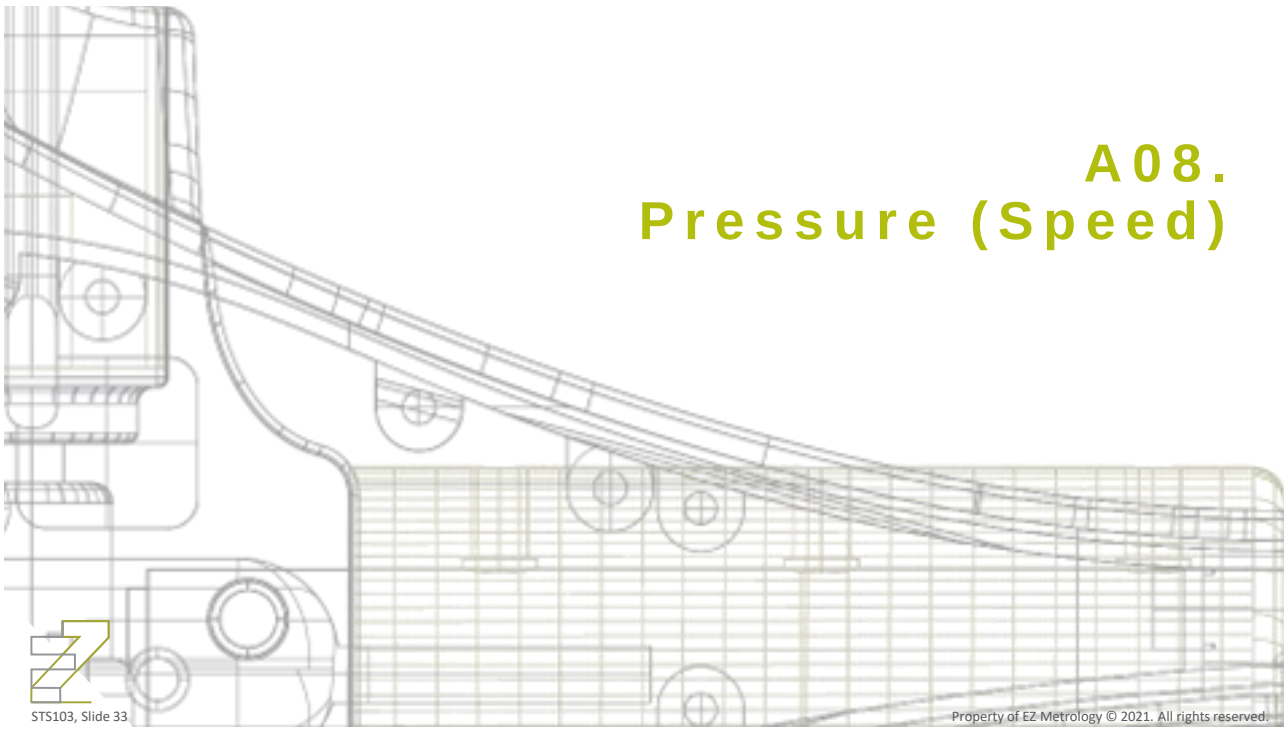
1. **Inboard:** Begin: Up >> End: Flat
2. **Rearward:** Begin: Flat >> End: Up
3. **Forward**: Begin: Flat >> End: Down
4. **Outboard:** Begin: Down >> End: Flat

The shape of the curve will determine how the potential energy from gravity is released during the travel.



STS103, Slide 32

32



A08. Pressure (Speed)

33

A08. Pressure (Speed)
1. Points of Interest

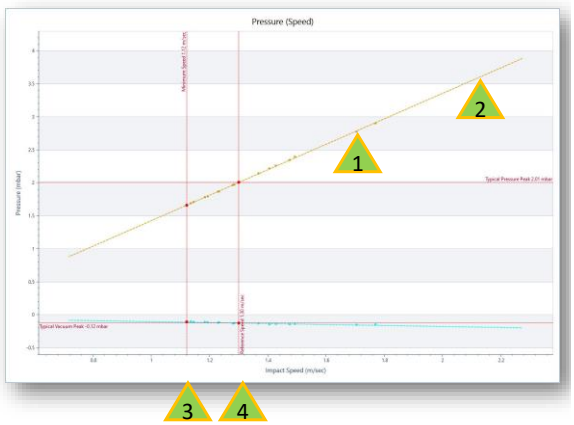
Definition

For each closed slam, the graph will display the matching pressure peak and vacuum peak.

Only closed slam test will appear in this graph.

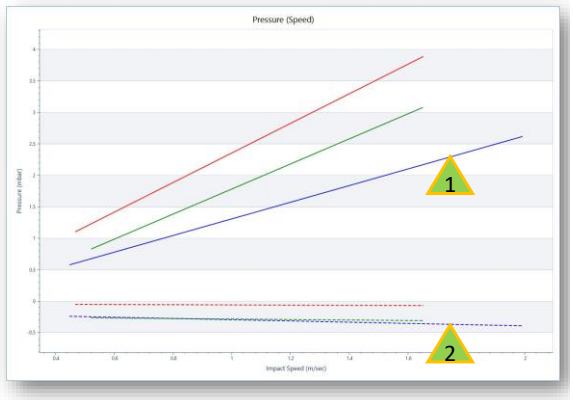
Points of Interest

1. **Samples**: Each slam has a data point.
2. **Curve Fit**: A characteristic curve is fitted through the points.
3. **Minimum Closing Speed**: Pressure at minimum closing speed.
4. **Typical Pressure**: The pressure at a given speed.



34

A08. Pressure (Speed)
2. Application: Peak vs Vacuum



Pressure Peak (1)

A positive value

A combined effect of

- Door area vs cabin volume
- Average Closing Speed
- Seal engagement

Different vehicles can have significantly different peaks.

Vacuum Peak (2)

A negative value

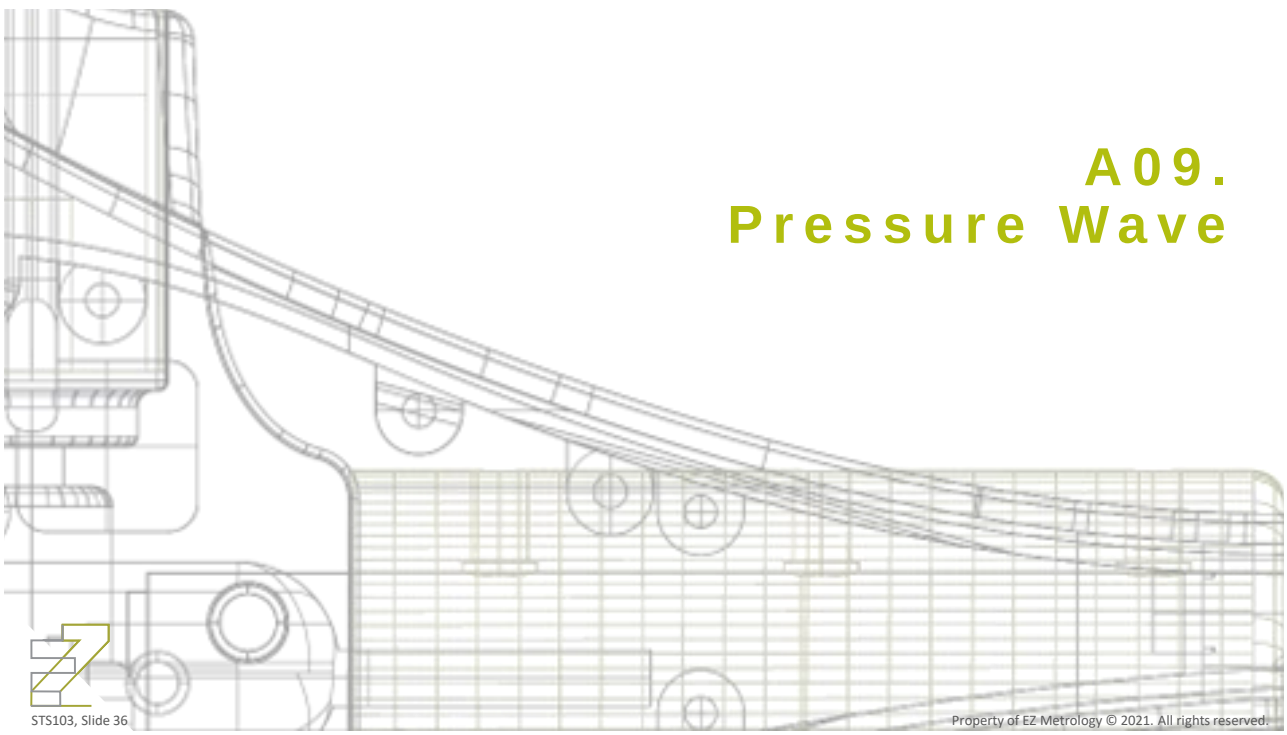
Defined by

- Air evacuation efficiency

Air evacuation is the combined effort of controlled evacuation and leaks. Therefore, an upper and lower tolerance are recommended.

STS103, Slide 35

35



A09. Pressure Wave

STS103, Slide 36

36

A09. Pressure Wave
1. Data

Definition

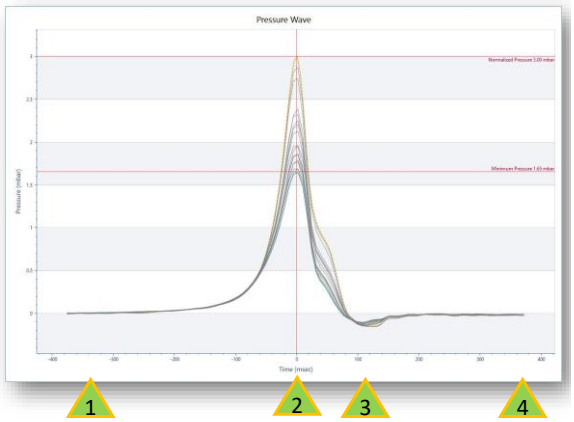
The pressure value during the closing event.

Only closed slam test will appear in this graph.

Points of Interest

1. **Closing**: Door is closing but no pressure peak detected, or '0'.
2. **Pressure Peak**: Peak pressure detected and set time to '0'.
3. **Vacuum Peak**: only if a vacuum is detected.
4. **Closed**: The door is closed and pressure returns to normal.

Note that the pressure measurement is relative with respect to the current ambient pressure.



STS103, Slide 37

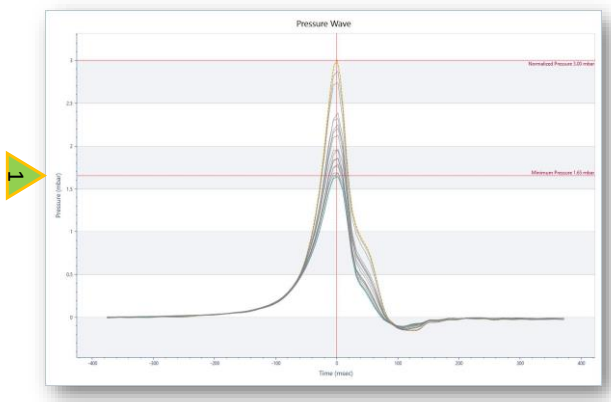
37

A09. Pressure Wave
2. Pressure at Minimum Speed

Definition (1)

The blue curve represents the pressure wave form when the door is closed at minimum closing speed.

As the minimum speed can be influenced by many parameters it can not be used as an absolute value itself. The graph does not indicate or help the user determine cause or consequence.



STS103, Slide 38

38

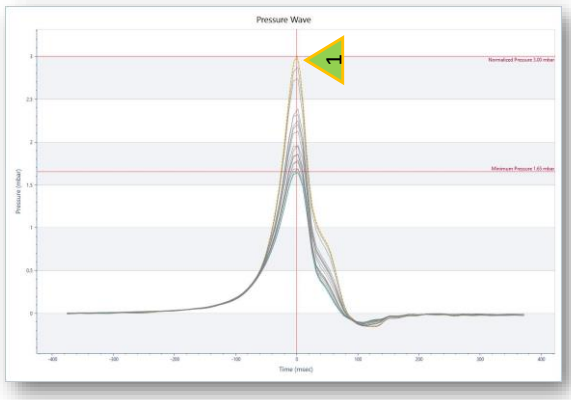
A09. Pressure Wave
3. Typical Pressure Wave

Definition (1)

The yellow curve represents the typical pressure wave. The shape of the pressure wave in case the amplitude is normalized to the typical pressure value.

The value is set in the conventions.

Key metric: Pressure wave size – area under the normalized curve.

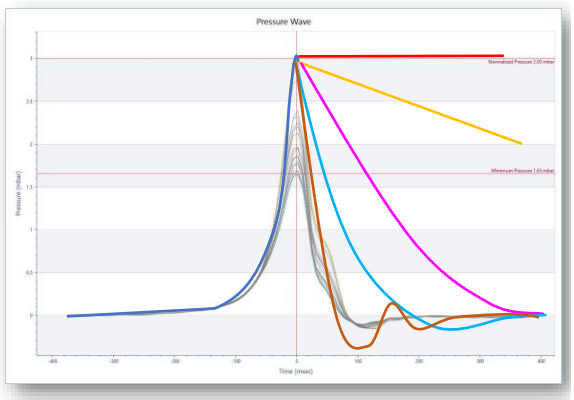


A09. Pressure Wave
4. Typical Pressure Wave

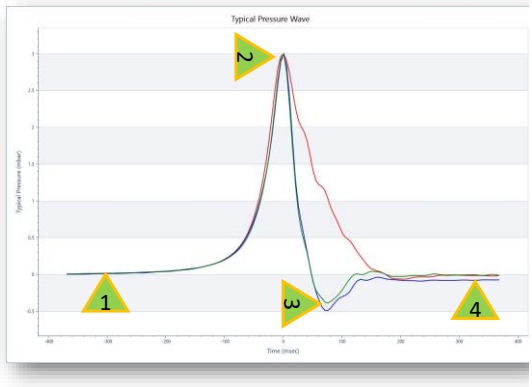
"We fill the cabin with air (pressure) and observe how it escapes."

Evacuation can be considered as leaks by design or controlled leaks.

1. **Red**: No leaks, pressure is constant…
2. **Orange:** Small leak, slow return to zero…
3. **Magenta**: More leaks, faster return to zero…
4. **Light Blue:** More leaks, slight overshoot (vacuum)…
5. **Brown:** Big leaks, important overshoot.



A09. Pressure Wave
5. Application: Cabin Efficiency



Definition (1)

The Typical Pressure wave is compared.

As it concerns the normalized curve, all amplitudes are identical.

1. **Rising**: Observe that all pressure increases in a relatively similar way. Little to no influence from extractor.
2. **Pressure Peak**: is identical for all.
3. **Vacuum Peak**: A bigger vacuum peak often indicates a faster evacuation or faster return to normal pressure.
4. **Normal:** Pressure stabilizes back to ambient.

A10. Plop

A10. Plop

1. Points of Interest

Definition

Represents the speed during unlatching of the door.

This can be performed from outside, results match a realistic opening event, subject to more user variation.

From the inside, superior repeatability.

Points of Interest

1. **Closed**: Door is in latched position.
2. **Maximum Speed**: A maximum speed is observed after pulling the door handle.
3. **End Point**: The door sits at rest when energy from the seals and latch has been dissipated.

Some criteria relate to the fact the door comes to rest outside the secondary latch point. The door can actually be opened. If not, the user has to pull handle again to open.

STS103, Slide 43

43

A11. Wiggle

STS103, Slide 44

44

A11. Wiggle
1. Points of Interest

Definition

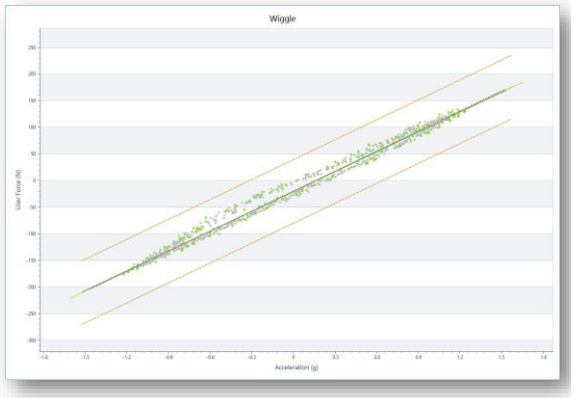
Represents the data of the wiggle test in the form of Force vs Acceleration.

The function is not to represent the inertia, but to evaluate the quality of the runs regarding: intensity, linearity and symmetry.

Observations

1. **Linearity**: All points should by definition be on a line, due to friction there will be a hysteresis.

2. **Symmetry**: A good measurement – both positive motion and negative motion or in and out motion – should be symmetrical. A banana shape will most likely result in additional uncertainty.



STS103, Slide 45

45

A11. Wiggle
1. Points of Interest

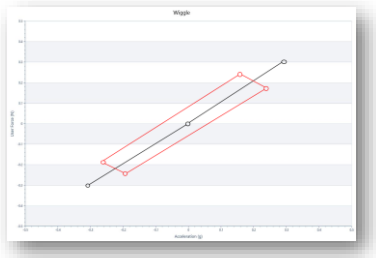
Force = Mass × Acceleration

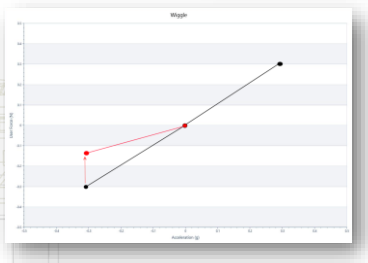
Linear relation between force and acceleration.

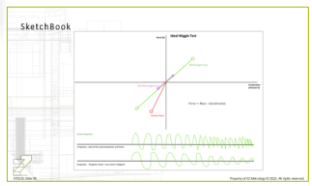
Observations

1. **Linearity**: All points should by definition be on a line. Due to friction there will be a hysteresis.

2. **Symmetry**: A good measurement – both positive motion and negative motion or in and out motion – should be symmetrical. A banana shape will most likely result in additional uncertainty.

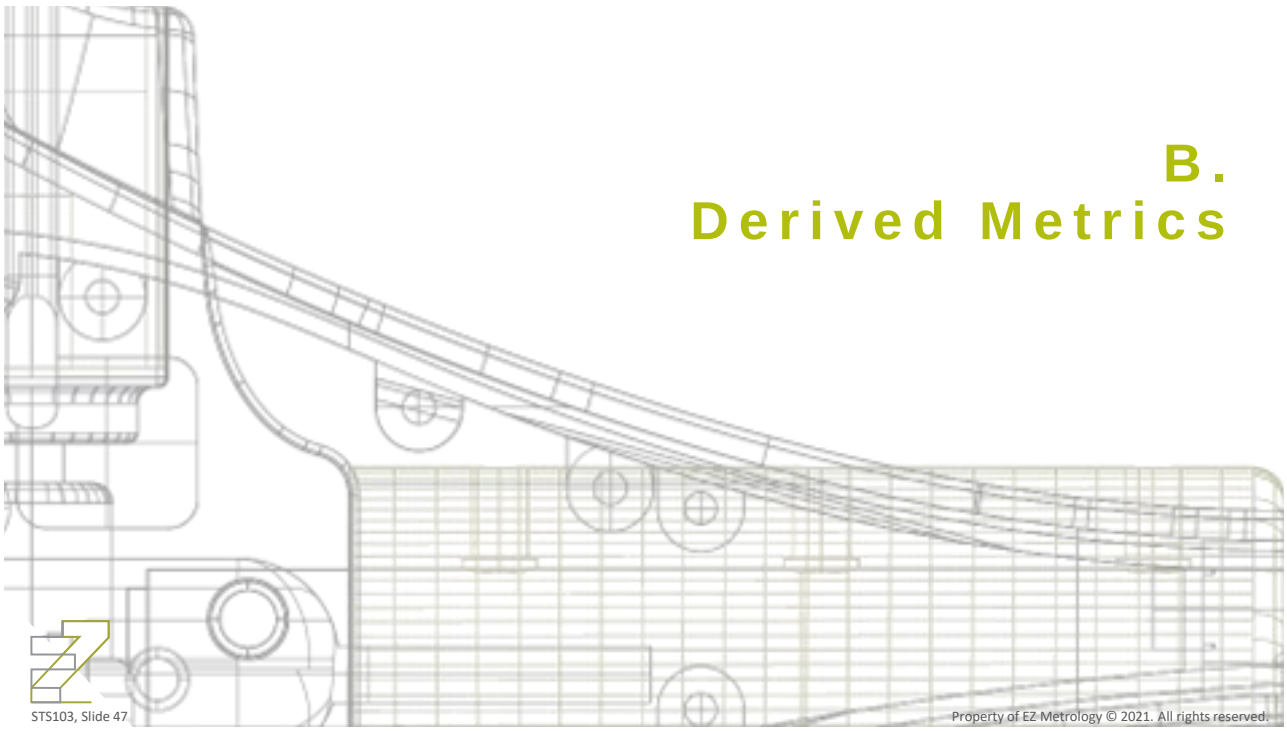






STS103, Slide 46

46



B.
Derived Metrics

47

B. Metrics
1. List of Metrics

01 General

Closing Type

Minimum closing speed is determined by the check mechanism or by the latch point.
(Latch Dominant, Check Dominant, Self Closing)

02 Closing Dynamics

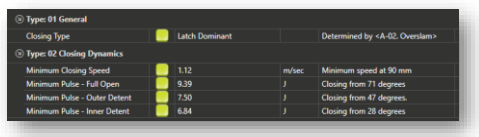
Minimum Closing Speed (*)

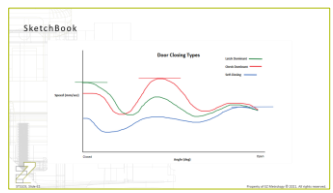
Minimum Speed at which the door latches.

Minimum Pulse

Minimum User Energy to close the door.
(Fully Open, Outer Detent, Inner Detent)

(*) Definition at what 'speed' is determined in convention.





48

B. Metrics
1. List of Metrics

03 Latch and Seal System

Typical Overslam (*)

Overslam at reference speed. (Dynamic stiffness of the seal)

Striker Alignment

How many mm the striker is too low (+) or too high (-) vs latch. (Legend will indicate the direction)

Latch Point - Static

Minimum measured overslam from push test for the latch to engage.

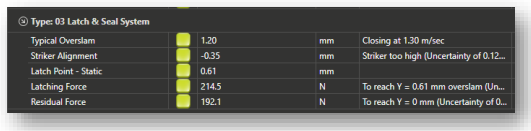
Latch Force

Minimum measured force during Push for the latch to engage.

Residual Force

Force measured at location of final rest point.

(*) Definition at what 'speed' is defined in convention.



B. Metrics
1. List of Metrics

04 Hinge System

Door Rise

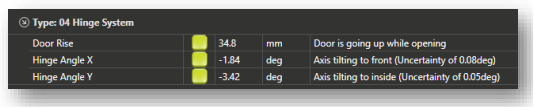
Vertical travel of the door at hem edge when the door is fully opened.

Hinge Angle X

The angle between the rotation axis of the door and gravity in x direction. The direction is indicated in the legend. To Front (-) and To rear (+).

Hine Angle Y

The angle between the rotation axis of the door and gravity in y direction. The direction is indicated in the legend. Inboard(-) and Outboard (+).



B. Metrics
1. List of Metrics

05 Check System

Angle of Door

Angle at which the door opens.
(Full Open, Outer Detent, Inner Detent)

Sweep Energy Opening

Energy (Force × Travel) required to move the door to open position.

Sweep Energy Closing

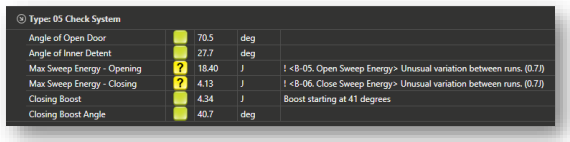
Energy (Force × Travel) required to move the door from open to near close position.

Closing Boost

The amount of energy the door check puts into the door before latching.

Closing Boost Angle

At what angle does the check start to provide the closing boost energy.



51

B. Metrics
1. List of Metrics

06 Door Geometry

Inertia

Measured inertia of the door.

Door Middle Radius

Measured radius of the door, from hinge point to hem edge.

07 Cabin Dynamics

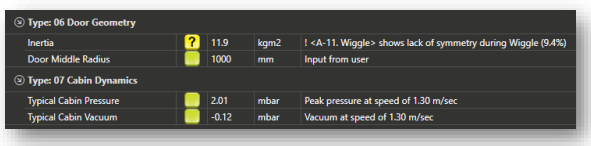
Typical Cabin Pressure (*)

Cabin Peak Pressure at reference Speed.

Typical Cabin Vacuum (*)

Cabin Peak Vacuum at reference Speed.

(*) Definition at what 'speed' is defined in convention.



52

B. Metrics
1. List of Metrics

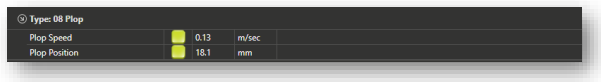
08 Plop

Plop Speed

Maximum Door Speed when unlatching.

Plop Position

Position where the door comes to a stop after unlatching.



C. Review

C. Review
1. Chapter 3

Topics addressed during this chapter:

A Graphs understanding the graphs and associated metrics

Apply a known variation and observe the changes and the dependencies, some examples with predictable outcome:

- Crank the window down a small distance (5mm)
- Move strike in or out
- Jack up the car
- Grease the door check