Sensors in LS-DYNA

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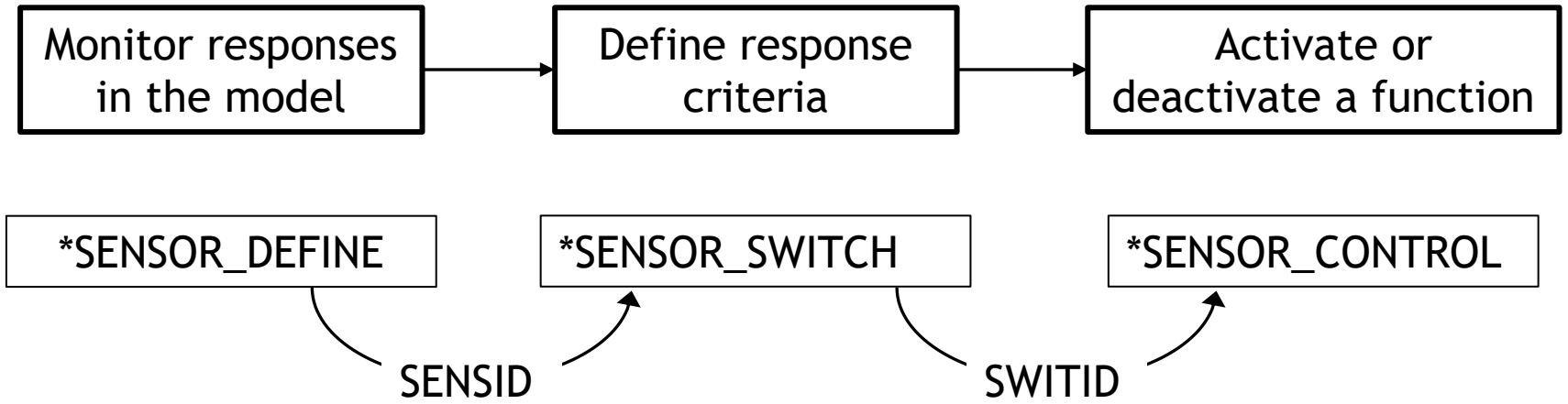
Introduction

- Why use sensors?

- Sensors can be used in LS-DYNA to activate or deactivate entities, such as boundary conditions and contacts, during the simulation.
- It can be included in the simulation where there is a similar sensor system in the physical model
  - Airbags
- It can also be used to make the simulation model more intelligent or self-controlling
  - Change boundary conditions at a certain load or displacement

Introduction

- Sensor setup



- *SENSOR_DEFINE
  - Measures a response
- *SENSOR_SWITCH
  - Compares the value of a sensor to a given criteria
- *SENSOR_CONTROL
  - What function should be toggled on or off

Note: Make sure to use the _ID option
for contacts and boundary conditions etc.
Example: *BOUNDARY_PRESCRIBED_MOTION_RIGID_ID

Sensor keywords

- *SENSOR_DEFINE_...
- _ELEMENT
  - Measure strain, stress, force etc. in elements
  - Set element type (beam, shell, solid etc.)
  - Set component (x, y, z, xy ,yz etc)
  - Set type (strain, stress, force etc)
- _FORCE
  - Measure force in different entities
  - Set force type (contact force, joint force, airbag pressure etc.)
  - Set ID of the measured entity
  - Set direction in which the force is measured
- _FUNCTION
  - Use sensors in *DEFINE_FUNCTION
- _MISC
  - Trace values of miscellaneous items
- _NODE
  - Meseaure a node’s acceleration, velocity, coordinate or temperature

Sensor keywords

- *SENSOR_DEFINE_CALC_MATH
  - Perform mathematical calculations with other defined sensors

SENSID	CALC	SENS1	SENS2	SENS3	SENS4	SENS4	SENS6

FUNCTION	DESCRIPTION	MATHEMATICAL FORM
ABSSUM	Absolute value of the sum of sensor values	$\lvert SENS1 + SENS2 + \cdots \rvert$
MIN	The minimum of sensor values	$\min(SENS1, SENS2, \ldots)$
MAX	The maximum of sensor values	$\max(SENS1, SENS2, \ldots)$
MAXMAG	The maximum of magnitude of sensor values	$\max(\lvert SENS1 \rvert, \lvert SENS2 \rvert, \ldots)$
MINMAG	The minimum of the magnitude of sensor values	$\min(\lvert SENS1 \rvert, \lvert SENS2 \rvert, \ldots)$
MULTIPLY	Multiplication of sensor values; negative for division (performed left to right)	$SENS1 \times SENS2 \times \cdots$
SQRE	Summation of squared values of sensor values	$SENS1^2 + SENS2^2 + \cdots$
SQRTSQRE	Square root of the sum of squared values	$\sqrt{SENS1^2 + SENS2^2 + \cdots}$
SQRT	Summation of square root of sensor values; negative for subtracting values	$\sqrt{\lvert SENS1 \rvert} + \sqrt{\lvert SENS2 \rvert} + \cdots$
SUMABS	Summation of absolute sensor values	$\lvert SENS1 \rvert + \lvert SENS2 \rvert + \cdots$
SUM	Summation of sensor values; negative for subtracting values	$SENS1 + SENS2 + \cdots$

From LS-DYNA manual

Sensor keywords

- *SENSOR_SWITCH

SWITID		SENSID	LOGIC	VALUE	FILTRID	TIMWIN	TDELAY

- SWITID: Switch ID referred by *SENSOR_CONTROL
- SENSID: ID of the sensor which will compared with the value
- LOGIC: Logic operator, less than or greater than
- VALUE: Critical value
- FILTRID: Optional filer using *DEFINE_FILTER
- TIMWIN: Set a duration time in which the critical value must be fulfilled to trigger the swtich
- TDELAY: Optional time delay

Sensor keywords

- *SENSOR_SWITCH_CALC-LOGIC
  - Combine switches and perform a logic calculation on these

SWITID	SWIT1	SWIT2	…	…	…	…	…

- Input the different switches:
  - Positive sensor switch ID for ”AND”
  - Negative sensor switch ID for ”OR”
  - SWIT1 much always be positive

Sensor keywords

- *SENSOR_CONTROL

CNTLID	TYPE	TYPEID	TIMEOFF	NREP	ESTYP
INITSTT	SWIT1	SWIT2	SWIT3	…	…

- CNTLID: Sensor control ID
- TYPE: Entity to be controlled, e.g. contact, motion, spc:s
- TYPEID: ID of the entity to be controlled
- TIMEOFF: Offset the time in curves
- NREP: Repeat of cycles of switches
- ESTYP: Type of element set to be controlled when TYPE = ELESET
- INITSTT: Initial status, on or off
- SWITn: Switches to activate or deactivate the sensor

Sensor keywords

- *SENSOR_CONTROL
  - List of different entities to be controlled:

*AIRBAG	*CONSTRAINED_JOINT
Opening and closing the airbag venting holes	*CONSTRAINED_JOINT_STIFFNESS
Belt pretensioner firing	*LOAD_THERMAL_VARIABLE
Locking the belt retractor	*LOAD_MOVING_PRESSURE
Controlling the slippage of slip ring element	*MAT_ADD_PORE_AIR
*CONTACT	*BOUNDARY_PRESCRIBED_MOTION
*CONTACT_2D	*BOUNDARY_PRESCRIBED_ORIENTATION_RIGID
*CONSTRAINED_NODAL_RIGID_BODY	*LOAD_SEGMENT_SET
*AIRBAG_PARTICLE	*RIGID_WALL
*DEFORMABLE_TO_RIGID_AUTOMATIC	*BOUNDARY_SPC
Element set to erode	*CONSTRAINED_SPOTWELD
*DEFINE_CURVE_FUNCTION	

Sensor output

- Information about the sensors can be found in the message files
- In the beginning:

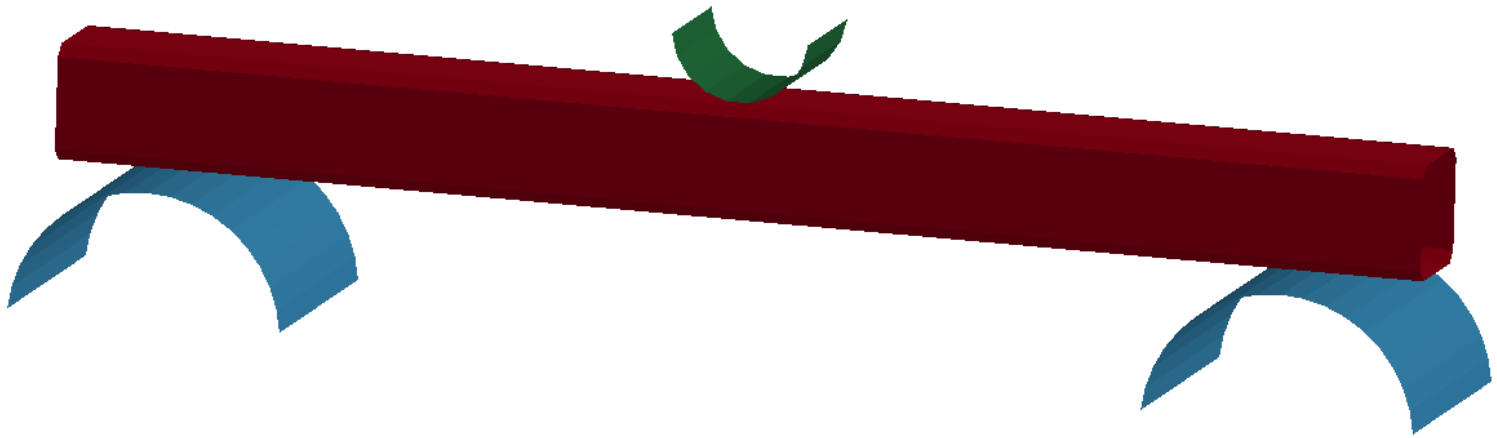
```
*** Status change by Control          1 ***
PRESC-MOT         1 is turned on by switch          1 at 0.0000E+00

*** Status change by Control          2 ***
PRESC-MOT         2 is turned off by switch          1 at 0.0000E+00
```

- During the simulation:

```
   1389 t 2.9981E-03 dt 2.16E-06 write d3plot file            10/08/19 10:06:29
   1621 t 3.4992E-03 dt 2.16E-06 write d3plot file            10/08/19 10:06:29

*** Status change by Control          1 ***
PRESC-MOT         1 is turned off by switch          1 at 3.7282E-03

*** Status change by Control          2 ***
PRESC-MOT         2 is turned on by switch          1 at 3.7282E-03
   1852 t 3.9982E-03 dt 2.16E-06 write d3plot file            10/08/19 10:06:30
   2084 t 4.4993E-03 dt 2.16E-06 write d3plot file            10/08/19 10:06:30
```

Example: Three-point bending

- Prescribed motion of the punch
- Measure the contact force between the punch and beam
- Run 1: Switch off the contact at a certain force
- Run 2: Travel the punch backwards at a certain force



Example: Three-point bending

- Run 1: Switch off the contact at a certain force

- *SENSOR_DEFINE_FORCE

SENSID	FTYPE	TYPEID	VID
1	CONTACT	2	Z

  - FTYPE: Set to CONTACT to measure the contact force (rcforc)
  - TYPEID: Select the contact interface ID 2
  - VID: Z direction

- *SENSOR_SWITCH

SWITID		SENSID	LOGIC	VALUE
1		1	GT	3500

  - LOGIC: Greater than
  - VALUE: Critical value 3500 N

Example: Three-point bending

- Run 1: Switch off the contact at a certain force

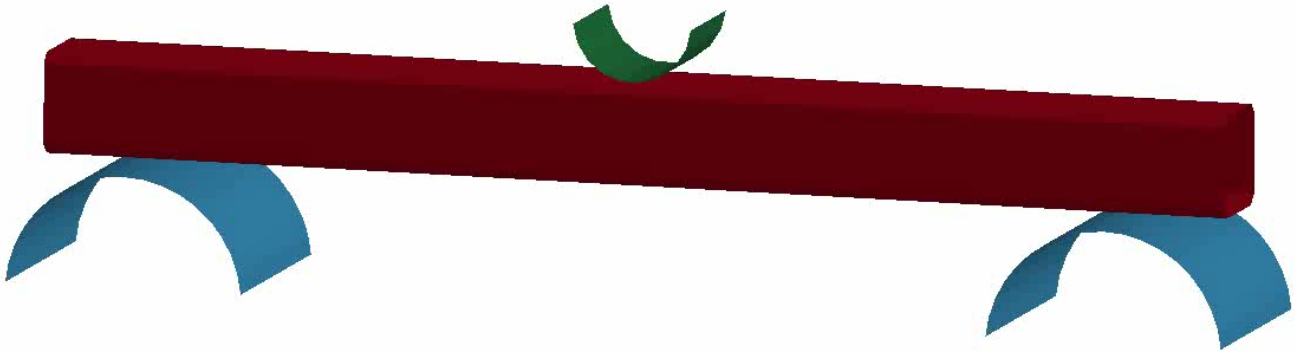
- *SENSOR_CONTROL

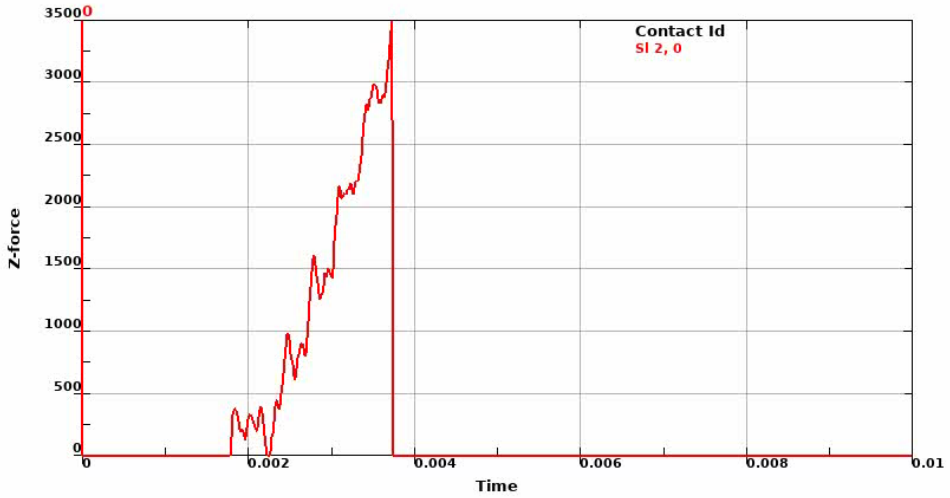
CNTLID	**TYPE**	**TYPEID**
1	CONTACT	2
INITSTT	**SIT1**	
ON	1	

  - TYPE: Entity to be controlled is a contact interface
  - TYPEID: Select the contact interface ID 2
  - INITSTT: Initial status ON
  - SIT1: Switch ID 1 should control this sensor

Example: Three-point bending

- Run 1: Switch off the contact at a certain force






```
  1357 t 2.9290E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1403 t 3.0283E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1450 t 3.1298E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1497 t 3.2314E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1544 t 3.3329E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1590 t 3.4322E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1637 t 3.5338E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1684 t 3.6353E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43

*** Status change by Control         1 ***
  CONTACT         2 is turned off by switch         1 at 3.7282E-03
  1731 t 3.7368E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1777 t 3.8362E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1824 t 3.9377E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1871 t 4.0392E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:43
  1918 t 4.1407E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:44
  1964 t 4.2401E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:44
  2011 t 4.3416E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:44
  2058 t 4.4431E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:44
  2105 t 4.5446E-03 dt 2.16E-06 write d3plot file            11/18/19 11:25:44
```

Example: Three-point bending

- Run 2: Travel the punch backwards at a certain force
- Same setup for *SENSOR_DEFINE and *SENSOR_SWITCH

- *SENSOR_DEFINE_FORCE

SENSID	FTYPE	TYPEID	VID
1	CONTACT	2	Z

  - FTYPE: Set to CONTACT to measure the contact force (rcforc)
  - TYPEID: Select the contact interface ID 2
  - VID: Z direction

- *SENSOR_SWITCH

SWITID		SENSID	LOGIC	VALUE
1		1	GT	3500

  - LOGIC: Greater than
  - VALUE: Critical value 3500 N

Example: Three-point bending

- Run 2: Travel the punch backwards at a certain force

- *SENSOR_CONTROL

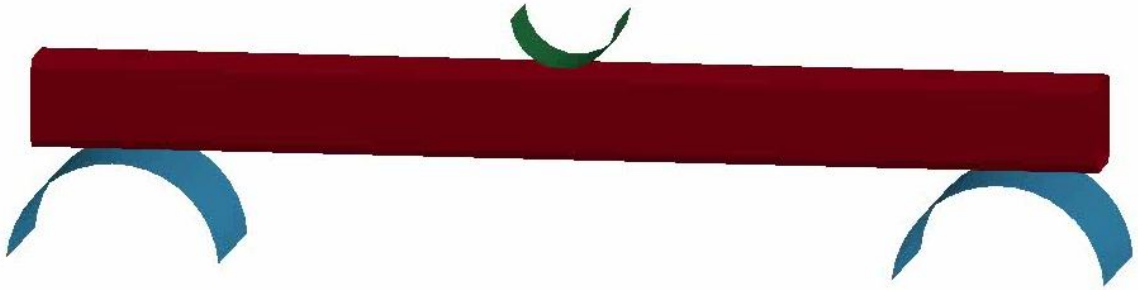
CNTLID	TYPE	TYPEID	
1	PRESC-MOT	1	
INITSTT	**SIT1**		
ON	1		
CNTLID	**TYPE**	**TYPEID**	**TIMEOFF**
2	PRESC-MOT	2	**1**
INITSTT	**SIT1**		
OFF	1		

As the load curve starts on 0, an offset is needed to start the load curve at the time when the sensor is activated

```
*BOUNDARY_PRESCRIBED_MOTION_RIGID_ID
$#      id                                                          heading
         1
$#     pid       dof       vad      lcid        sf       vid     death     birth
         3         3         2         2     -20.0         01.00000E28       0.0
$#      id                                                          heading
         2
$#     pid       dof       vad      lcid        sf       vid     death     birth
         3         3         0         3       1.0         01.00000E28       0.0
```

Example: Three-point bending

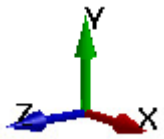
- Run 2: Travel the punch backwards at a certain force

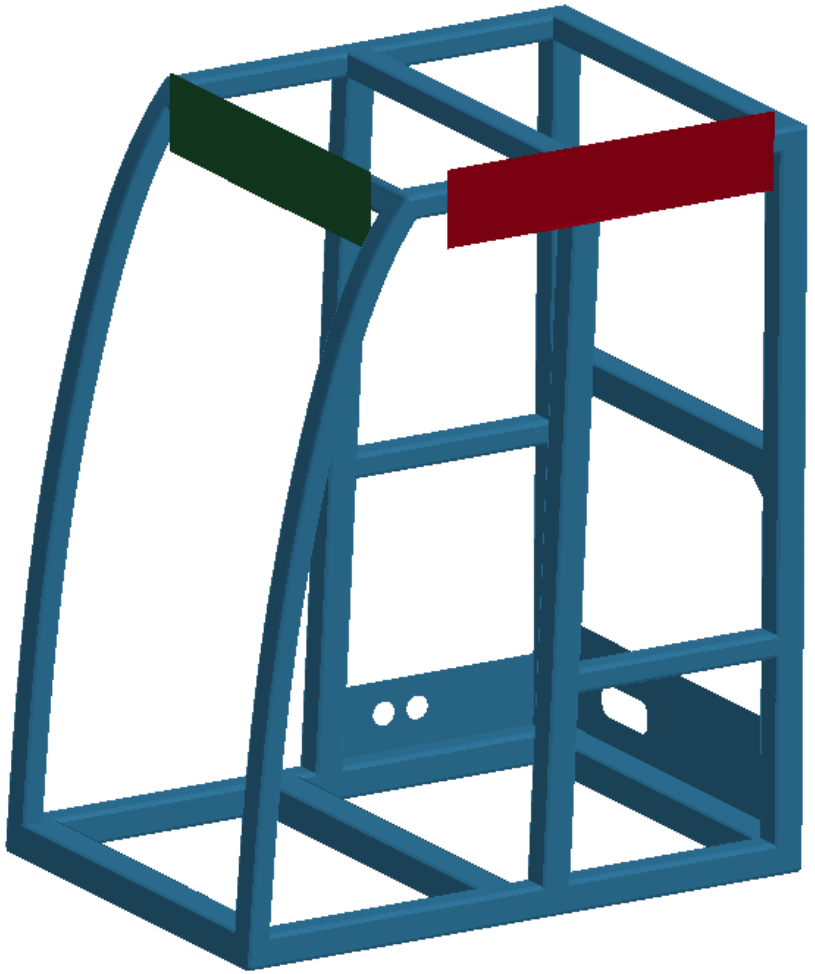



```
   1544 t 3.3329E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1590 t 3.4322E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1637 t 3.5338E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1684 t 3.6353E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55

*** Status change by Control          1 ***
PRESC-MOT         1 is turned off by switch          1 at 3.7282E-03

*** Status change by Control          2 ***
PRESC-MOT         2 is turned on by switch          1 at 3.7282E-03
   1731 t 3.7368E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1777 t 3.8362E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1824 t 3.9377E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
   1871 t 4.0392E-03 dt 2.16E-06 write d3plot file            11/18/19 13:41:55
```

Example: ROPS implicit

- ROPS (Roll Over Protection System) test of a cabin
- Two load cases:
  - 1. Lateral – Force and energy criteria
  - 2. Longitudinal – Force criteria
- The longitudinal load case should start when the lateral loading is complete, and the cabin is unloaded.
- Use sensors to control the loading boundary conditions





Example: ROPS implicit

- Sensor setup - Lateral load case

***SENSOR_DEFINE_FORCE**

SENSID	FTYPE	TYPEID	VID
1	CONTACT	19000111	X

***SENSOR_DEFINE_MISC**

SENSID	MTYPE		
2	MATSUM	INTERNAL	2

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE
1		1	LT	-2E+5
2		2	GT	2.5E+7

Force criteria

Energy criteria

***SENSOR_SWITCH_CALC_LOGIC**

SWITID	SWIT1	SWIT2		
3	1	2		

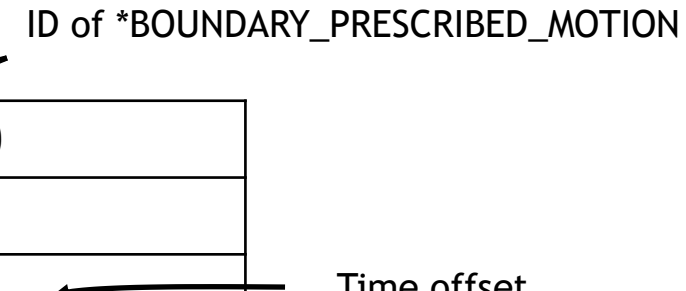
To satisfy both force and energy criteria

Example: ROPS implicit

- Sensor setup - Lateral load case

***SENSOR_CONTROL**

1	PRESC_M	1	0
ON	3		
2	PRESC_M	11	1
OFF	3		



- *BOUNDARY_PRESCRIBED_MOTION ID#1 -> Push the barrier, initially active. Switched off by Switch #3
- *BOUNDARY_PRESCRIBED_MOTION ID#11 -> Pull back the barrier, initially inactive. Switched on by Switch #3

Example: ROPS implicit

- Sensor setup - Longitudinal load case

***SENSOR_DEFINE_FORCE**

SENSID	FTYPE	TYPEID	VID
11	CONTACT	19000112	Z

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE
111		11	GT	-2E+5
112		11	LT	-2E+5

Switches for controlling the longitudinal loading

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE
11		1	GT	-2
12		2	GT	1.5E+7

Switches for activating the longitudinal loading.
From lateral loadcase:
Low force and high energy

***SENSOR_SWITCH_CALC_LOGIC**

SWITID	SWIT1	SWIT2		
13	11	12	111	

Switch 13 is on if the lateral load case is done and the longitudinal force is not met

Example: ROPS implicit

- Sensor setup - Longitudinal load case

***SENSOR_CONTROL**

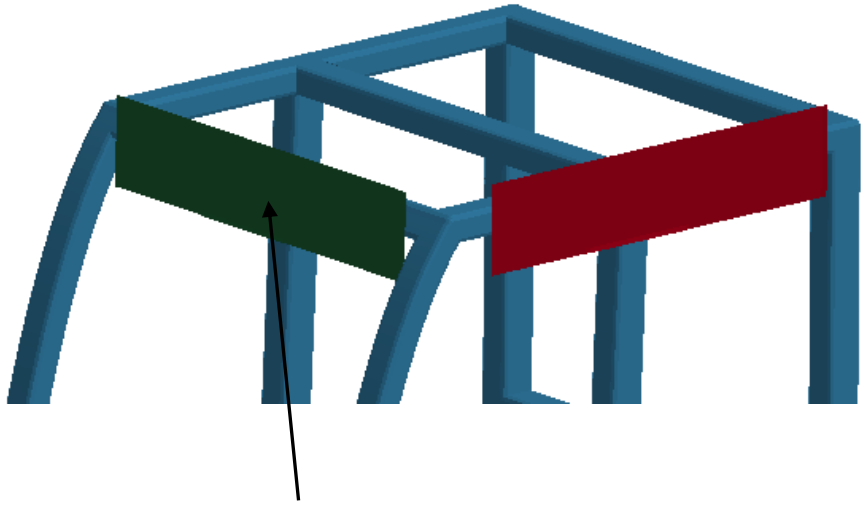
3	PRESC_M	21	1
OFF	13	112	
3	PRESC_M	22	1
OFF	112		

- *BOUNDARY_PRESCRIBED_MOTION ID#21 -> Push the barrier, initially inactive. Switched on by Switch #13 and off by Switch #112
- *BOUNDARY_PRESCRIBED_MOTION ID#22 -> Pull back the barrier, initially inactive. Switched on by Switch #112

Example: ROPS implicit

- Sensor setup - Longitudinal load case

- To make the barrier for the longitudinal load case follow the geometry, a tied contact is used.
- When the lateral load case is completed, the contact is switched off.



Longitudinal barrier

***SENSOR_CONTROL**

5	CONTACT	19000101	
ON	112		

Example: ROPS implicit

- Define termination time
- Use *TERMINATION_CONTACT to stop the analysis when the longitudinal force goes to zero.

***TERMINATION_CONTACT**

CID	ACTIM	DUR	THRES	DOF
19000112	1.0	0.05	1	3

Contact ID

Activation time.
Earliest termination time will be 1.0 + 0.05

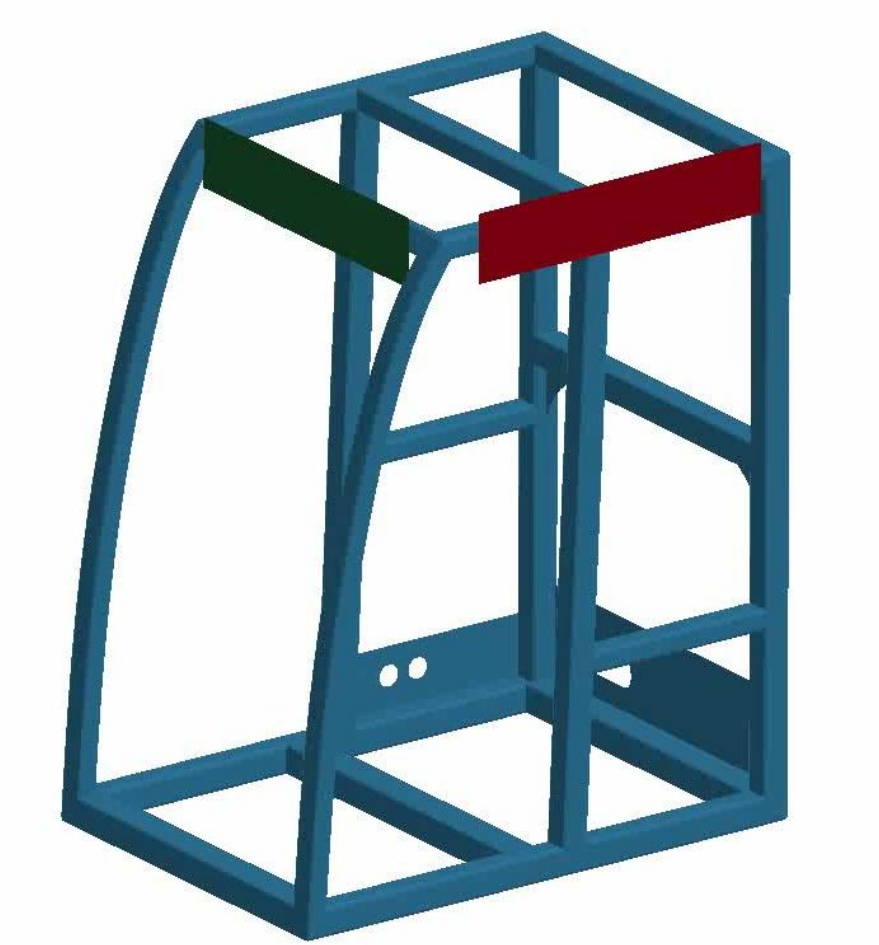
Duration of zero force required to stop analysis

Threshold force for “zero”

Direction

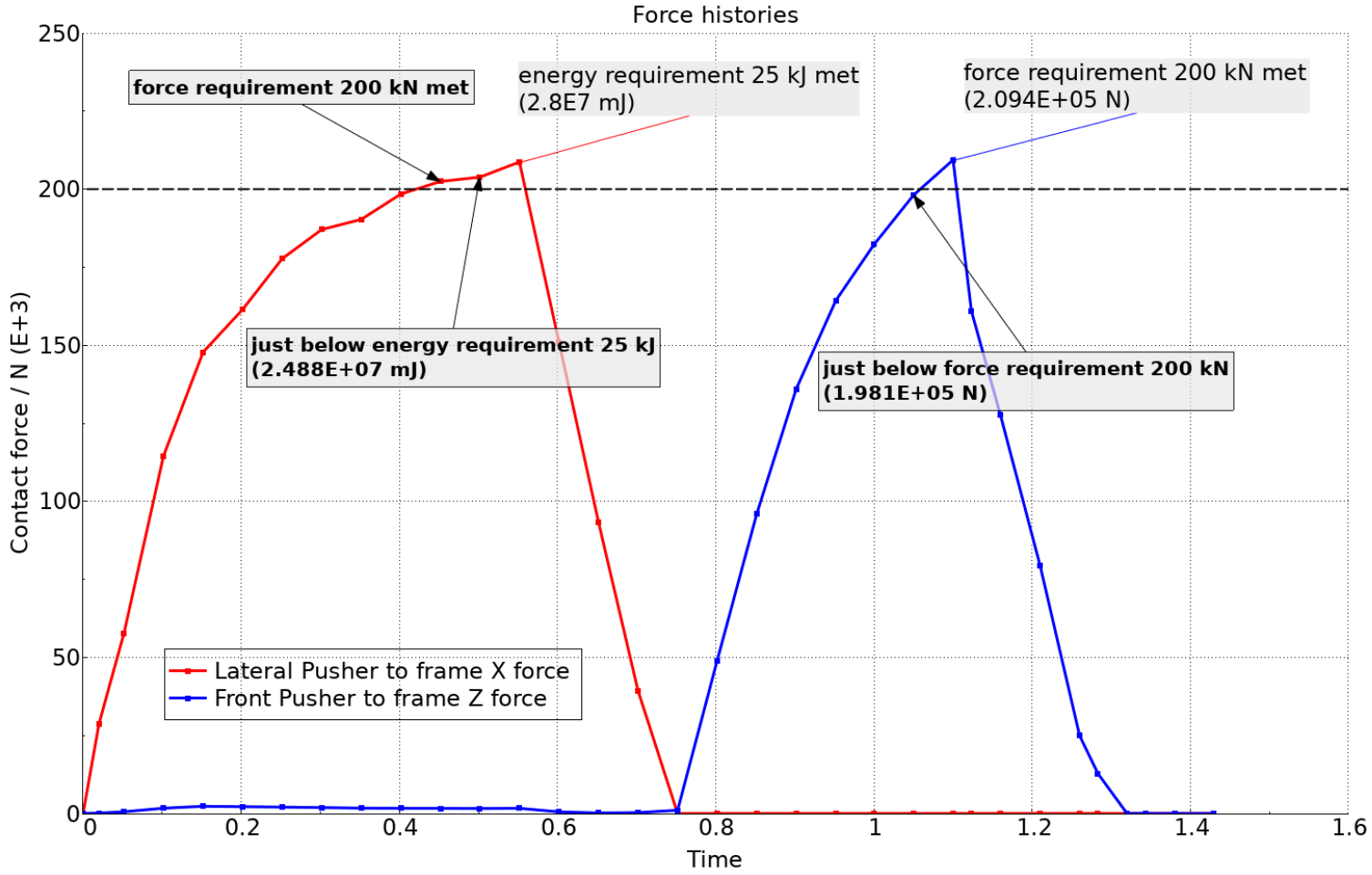
Example: ROPS implicit

- Results



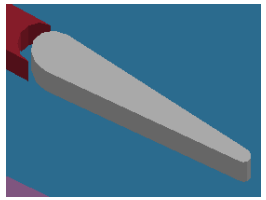
Example: ROPS implicit

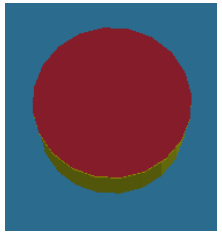
- Force history

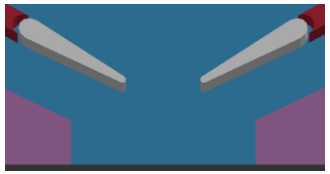


Example: Pinball game

- Sensors are used to create a self-playing pinball game.
  - The flippers are moved when the ball enters an area in front of the flippers.
  - The top of the bumpers are flipped when the ball gets in contact with the bumper.
  - The simulation ends when the ball falls down in the drain.

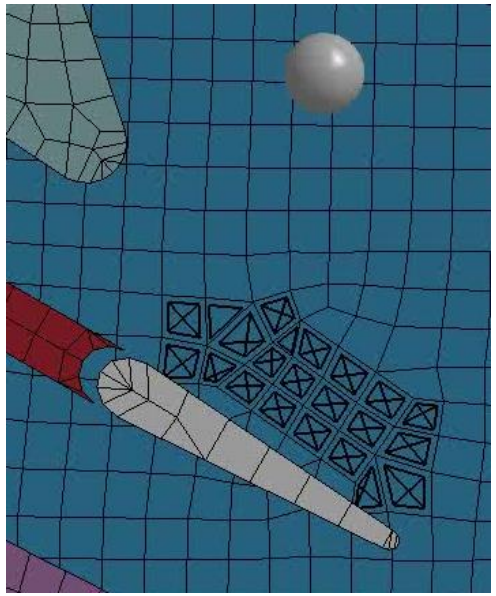






Example: Pinball game

- Sensor setup: Flippers



***SENSOR_DEFINE_FORCE**

SENSID	FTYPE	TYPEID	VID
2	CONTACT	5	Z

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE		TIMWIN
6		2	GT	1E-5		
2		2	LT	1E-5		0.1

The ball must be outside the area for 0.1 s before the switch activates. This is enough time for the flipper to go back to nominal position.

***SENSOR_CONTROL**

CNTLID	TYPE	TYPEID	TIMEOFF	NREP
1	PRESC-MOT	1	1	-1
INITSTT	**SIT1**	**SIT2**		
OFF	6	2		

The sensor cycle is repeated for infinite number of times.

Example: Pinball game

- Sensor setup: Bumpers

***SENSOR_DEFINE_FORCE**

SENSID	FTYPE	TYPEID	VID
5	CONTACT	8	X
6	CONTACT	8	Y

***SENSOR_DEFINE_CALC-MATH**

SENSID	CALC	SENS1	SENS2
11	MAXMAG	5	6

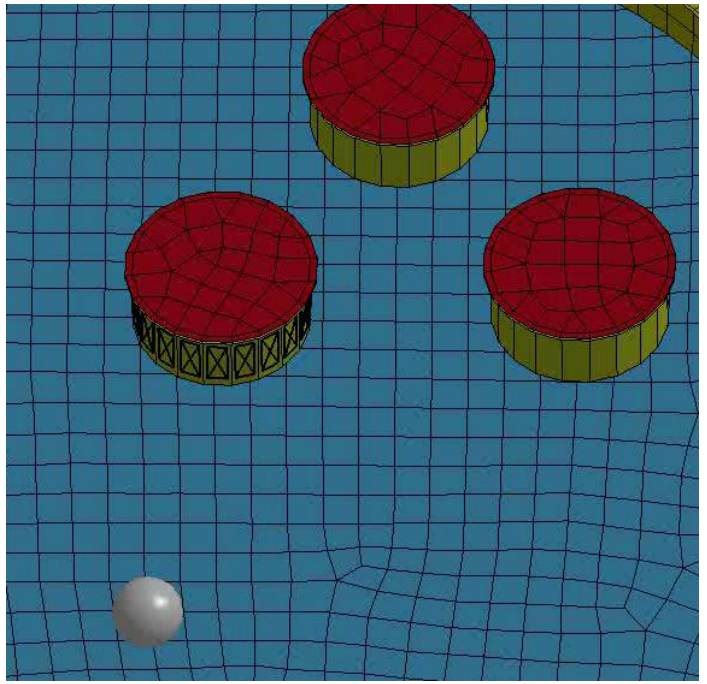
$$\max(|SENS1|, |SENS2|)$$

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE		TIMWIN
9		11	GT	1E-5		
12		11	LT	1E-5		0.03

***SENSOR_CONTROL**

CNTLID	TYPE	TYPEID	TIMEOFF	NREP
5	PRESC-MOT	5	1	-1
INITSTT	**SIT1**	**SIT2**		
OFF	9	12		



Example: Pinball game

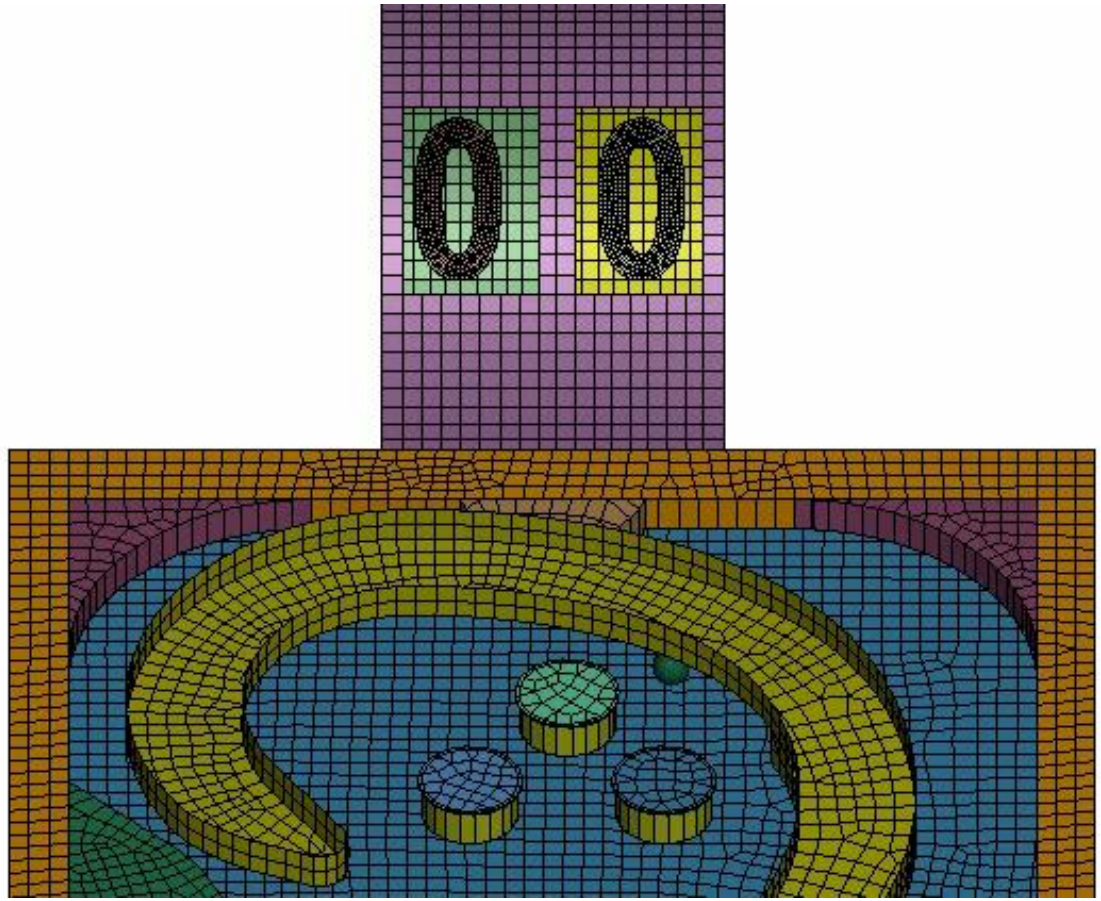
- Sensor setup: Points

***SENSOR_SWITCH_CALC_LOGIC**

SWITID	SWIT1	SWIT2	SWIT3
18	9	-10	-11
19	12	13	14

***SENSOR_CONTROL**

CNTLID	TYPE	TYPEID	TIMEOFF	NREP
5	PRESC-MOT	10	1	-1
INITSTT	**SIT1**	**SIT2**		
OFF	18	19		



Example: Pinball game

- Sensor setup: Drain

***SENSOR_DEFINE_FORCE**

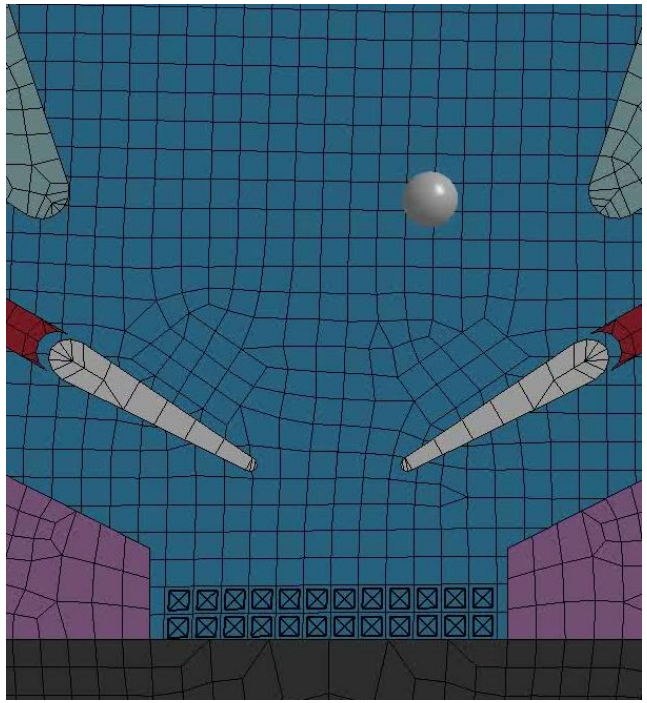
SENSID	FTYPE	TYPEID	VID
15	CONTACT	12	Z

***SENSOR_SWITCH**

SWITID		SENSID	LOGIC	VALUE
17		15	GT	1E-5

***TERMINATION_SENSOR**

SWITID
17



```
   4500 t 8.9980E-02 dt 2.00E-05 write d3plot file           03/26/20 14:34:48
   5000 t 9.9980E-02 dt 2.00E-05 flush i/o buffers           03/26/20 14:34:48
   5000 t 9.9980E-02 dt 2.00E-05 write d3plot file           03/26/20 14:34:48
   5500 t 1.0998E-01 dt 2.00E-05 write d3plot file           03/26/20 14:34:49
   6000 t 1.1998E-01 dt 2.00E-05 write d3plot file           03/26/20 14:34:50

*** termination due to sensor_switch   17 ***
   6486 t 1.2972E-01 dt 2.00E-05 write d3dump01 file         03/26/20 14:34:51
   6486 t 1.2972E-01 dt 2.00E-05 write d3plot file           03/26/20 14:34:51

N o r m a l    t e r m i n a t i o n                        03/26/20 14:34:51
```

Example: Pinball game

Thank you!

DYNA MORE

Your LS-DYNA distributor and more