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# RamSeries - Validation Case 35

## Impact-contact dynamic analysis test case

RamSeries

**Version**
**15.1.0**

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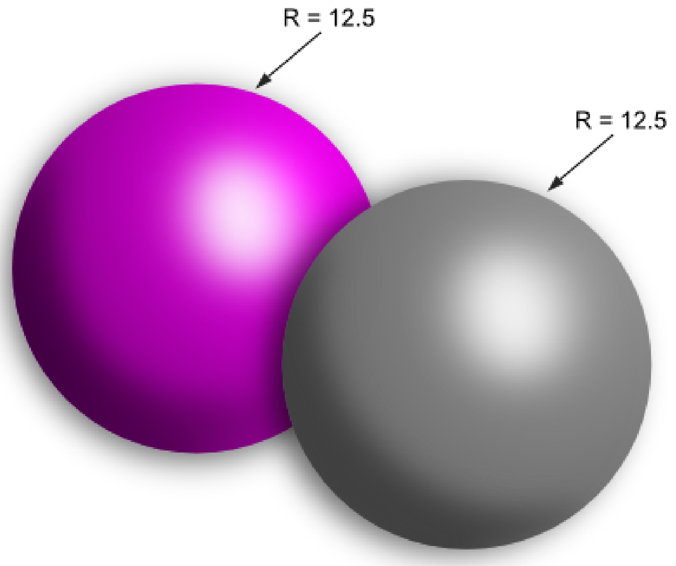
# 1 Validation Case 35 - Hertz Dynamic

## Model description

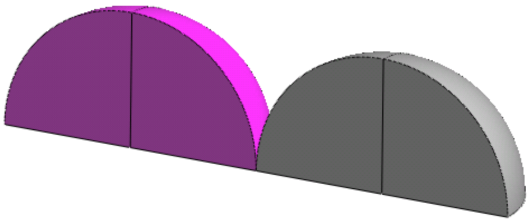
This test case deals with dynamic analysis with contacts. The purpose of this test is to simulate the impact between two spheres and compare stresses with the theoretical ones.

### Geometric model




Dimensions are in mm

Symmetry conditions are applied to reduce time of calculation. Below, the geometric model used to perform this analysis is shown .



## Analysis data

Analysis type: Dynamic Analysis

Geometric constitutive model: Non-Linear geometry

Integration method: Energy conserving

Alpha coef: 0.0

## Non-Linear analysis data

Convergence tolerance: 1e-3

Max iterations: 40

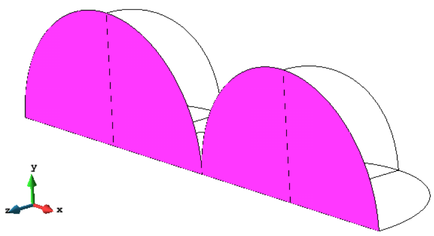
### Constraints

The following elastic constraints must be defined to apply symmetry conditions:

X = 0.0

Y = 0.0

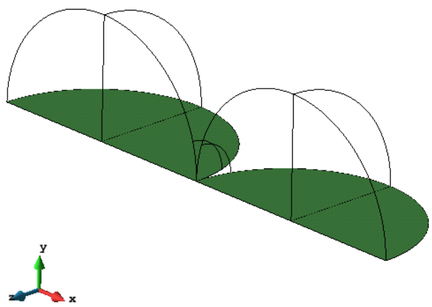
Z = 7e17 N/m$^3$




X = 0.0

Y = 7e17 N/m$^3$

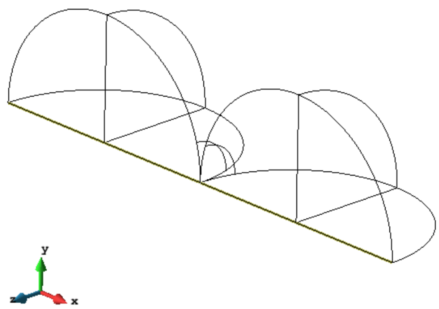
Z = 0.0




X = 0.0

Y = 7e17 N/m$^3$

Z = 7e17 N/m$^3$



### Initial conditions

The initial conditions to cause an impact between both spheres are shown below:

Displacement X = -1.5e-4 mm

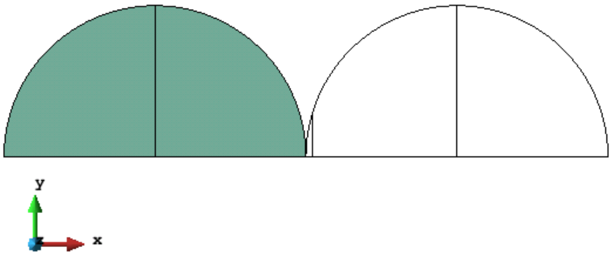
Displacement Y = 0.0 mm

Displacement Z = 0.0 mm

Velocity X = 0.6 m/s

Velocity Y = 0.0 m/s

Velocity Z = 0.0 m/s




### Material properties

These are the material properties of both spheres:

- Young's Modulus = 70e9 N/$m^3$
- Poisson's Rate = 0.22
- Specific weight = 25000 N/$m^3$

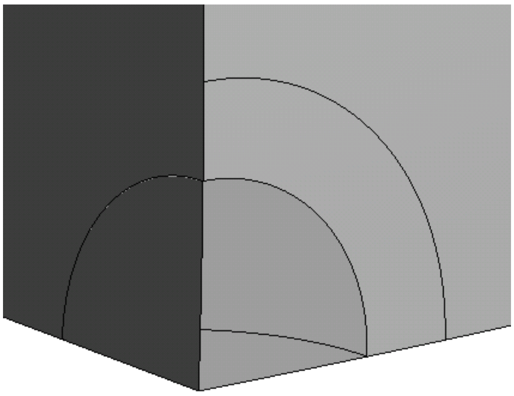
### Contacts

For running the analysis faster, simplified contacts method can be selected in

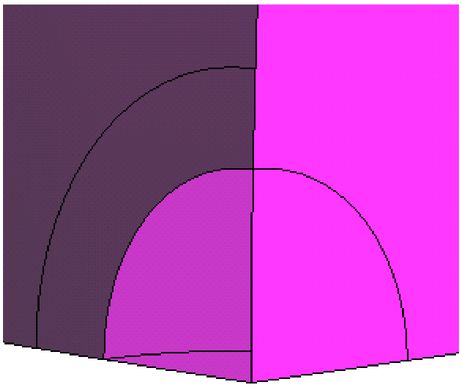
**Data ▶ Structural general data ▶ Advanced ▶ Contacts data**

Surfaces definition

For obtaining the highest accuracy of the results without spending too much time, the contact area of the spheres, another area around the contact zone, and arees in the symmetric planes have been demarcated. The radius of contact zone is 0.34 mm and the radius of area around the contact zone is 0.5 mm. Both contact arees must be selected as master and slave.



Slave surface: contact surface of sphere that is displaced



Master surface: contact surface of sphere that is not moved

## Results

### Analytical results

According to Reference [1], when two spheres of the same material and radii impact, the radii of the circular contact area can be calculated with the next equation:

$$r_c = r\left(\frac{v}{V}\right)^{\frac{2}{5}}\left[\left(\frac{5\pi}{16}\right)\left(\frac{(1-p)^2}{(1-2p)}\right)\right]^{\frac{1}{5}}$$

$r_c$: radius of compressed area.

p: Poisson's rate

r: sphere's radius [m]

v: initial velocity [m/s]

V: velocity of propagation of waves of compression [m/s]

$$V = \sqrt{\frac{E}{\rho}}$$

E: Young's modulus [N/m$^2$]

ρ: density [kg/m$^3$]

Moreover, the duration of impact can be calculated with the next equation:

$$t = 2.9432\left[\left(\frac{25\pi^2}{8}\right)\left(\frac{(1-p)^4}{(1-2p)^2}\right)\right]^{\frac{1}{5}}\frac{r}{v^{1/5}V^{4/5}}$$

When the radius of compressed area is known, it is possible to calculate the force applied between both spheres according to Reference [2]:

$$F = \frac{r_c^3 4E^*}{3R^*}$$

where

$$\frac{1}{E^*} = \frac{1-p_1^2}{E_1} + \frac{1-p_2^2}{E_2}$$

$$\frac{1}{R^*} = \frac{1}{R_1} + \frac{1}{R_2}$$

And finally, normal pressure can be calculated with the next equation [2]:

$$pr_{max} = \frac{3F}{2\pi r_c^2}$$

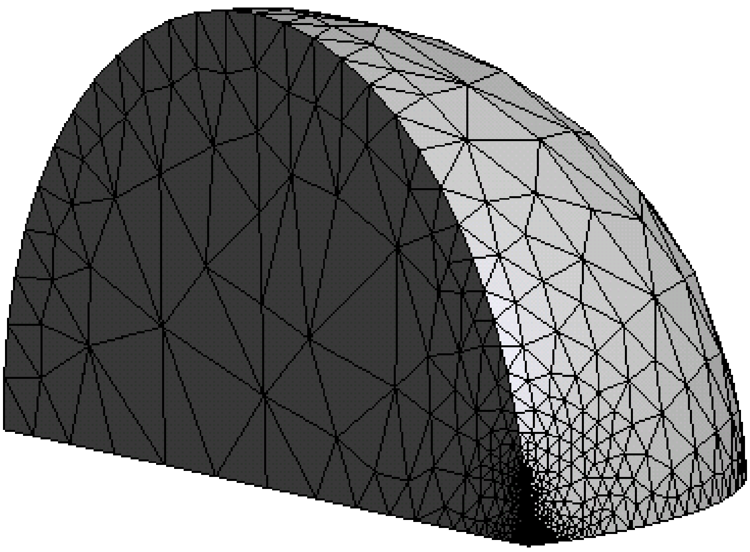
Therefore, the analytical results in a case of impact in the conditions shown in the previous section are:

- Radius of compressed area: 0.34 mm
- Duration of impact: 9e-5 s
- Normal pressure: 1258 MPa

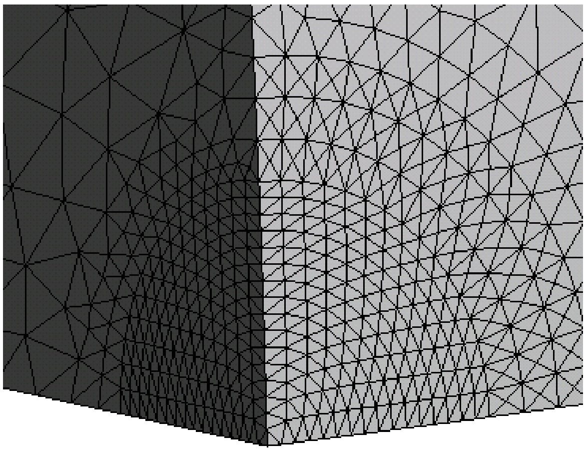
## Mesh

Below, the mesh's parameters used in this analysis are explained:

In the contact areas and in the area in the symmetry planes close to the contact areas, a structural mesh of triangles is used. The size of these elements is 0.05 mm, the transition is 0.5 and the rest of the model is meshed with an unstructured mesh of tetrahedra with a size of 2.7 mm.



General view of the mesh of one sphere.



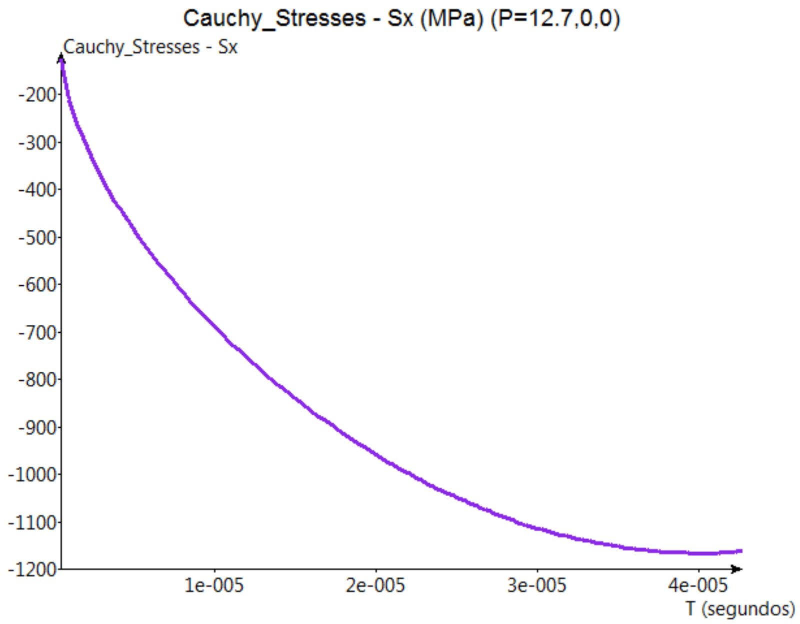
Detail of the mesh of the contact zone. As it can see, contact zone and the area in the symmetric planes are meshed with structural mesh

## Numerical results

- Temporal evolution of normal pressure

Below, the temporal evolution of normal pressure is shown.

Normal pressure = [σ]·n where n is the normal vector of element contact surface and [σ] is the Stress tensor. In this model, the X global axis is the normal direction of contact, so Sx Cauchy is equal to normal pressure.

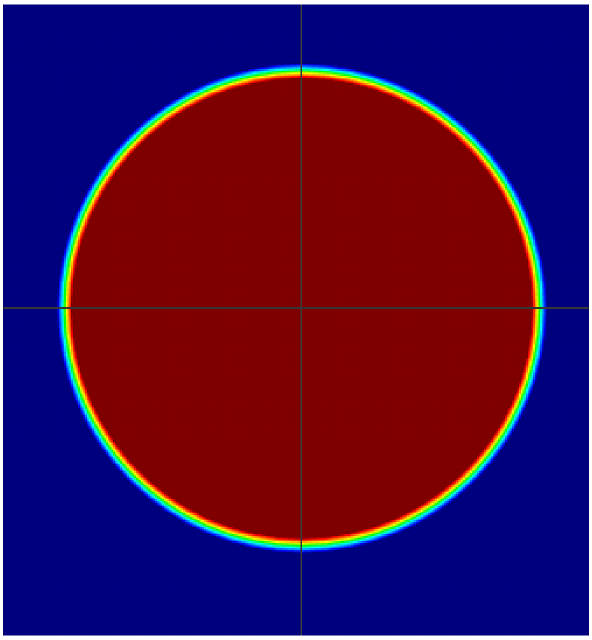



Temporal evolution of Sx component of Cauchy stress

As the previous graph shows, the highest compressive stress is reached at 4e-5 s.

- Radius of contact area:

At 4e-5 s, the radius of contact zone is 0.32 mm, so the error in the radius contact zone compared with the analytical results is 6%.



Contact zone. The contact area is colored red. Radius of contact area: 0.32 mm

- Normal pressure:

The next table contains the X component of Cauchy stress of some points in the contact zone (master surface) at 4e-5 s calculated in the numerical analysis, and these values are compared with the analytical result.

Axis Y:

| Radius [mm] | Analytical result [MPa] | Numerical result [MPa] | Error [%] |
|---|---|---|---|
| 0.000 | -1258 | -1167 | 7 |
| 0.064 | -1235 | -1131 | 8 |
| 0.129 | -1165 | -1082 | 7 |
| 0.193 | -1037 | -953 | 8 |
| 0.258 | -823 | -735 | 11 |

Axis Z:

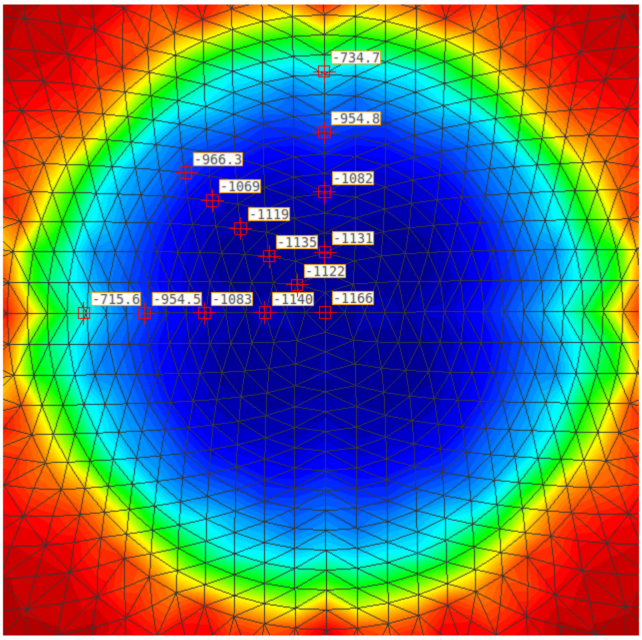
| Radius [mm] | Analytical result [MPa] | Numerical result [MPa] | Error [%] |
|---|---|---|---|
| 0.000 | -1258 | -1167 | 7 |
| 0.064 | -1235 | -1140 | 8 |
| 0.129 | -1165 | -1083 | 7 |
| 0.193 | -1037 | -955 | 8 |
| 0.258 | -823 | -716 | 13 |

Axis YZ:

| Radius [mm] | Analytical result [MPa] | Numerical result [MPa] | Error [%] |
|---|---|---|---|
| 0.000 | -1258 | -1167 | 7 |
| 0.043 | -1248 | -1120 | 10 |
| 0.085 | -1218 | -1135 | 7 |
| 0.128 | -1166 | -1119 | 4 |
| 0.170 | -1091 | -1069 | 2 |
| 0.213 | -983 | -961 | 2 |

Sumarize of results:

| Error in the center of contact zone | 7 % |
|---|---|
| Average of error | 7 % |
| Maximum error | 13 % |




Sx Cauchy Stress at 4e-5 s. The values shown are contained in the previous tables. Master contact surface

## References

[1] A. E. H. Love. A treatise on the mathematical theory of elasticity. Dover, 1944. Pags. 198-201.

[2] Johnson, K. L, Contact mechanics. Cambridge University Press, 1985. Pags. 85-97.

## Validation Summary

| CompassFEM version | 15.1.0 |
|---|---|
| Tdyn solver version | 15.1.0 |
| RamSeries solver version | 15.1.0 |
| Benchmark status | Successfull |
| Last validation date | 27/11/2018 |