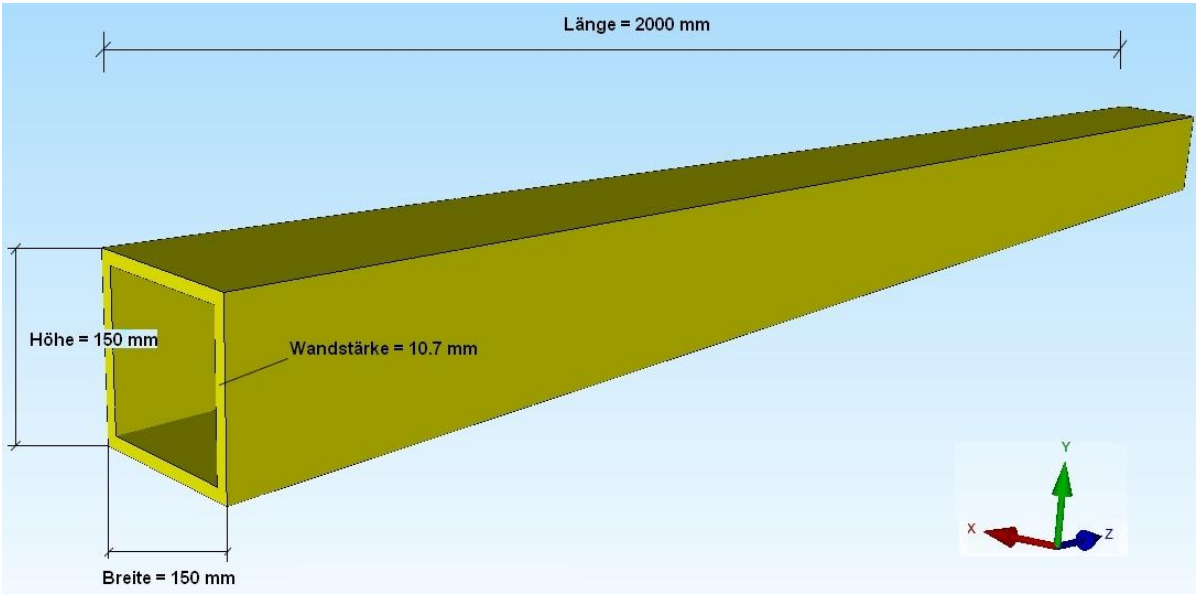
Part 29: Natural Frequencies of an unsupported hollow box with additional masses

The natural frequencies of an unsupported hollow box made of steel with a length of 2000 mm and a square profile of 150 mm x 150 mm x 10.7 mm are calculated with and without additional masses using the FEM system MEANS V12.



Two methods for additional masses

The additional masses can be specified in MEANS V12 either as an additional mesh extension with two solid bodies or with a weight force.
The latter method has the great advantage that only weight forces in N and no material data are required, which means that natural frequencies of FEM models with additional masses of cars and people can also be calculated.

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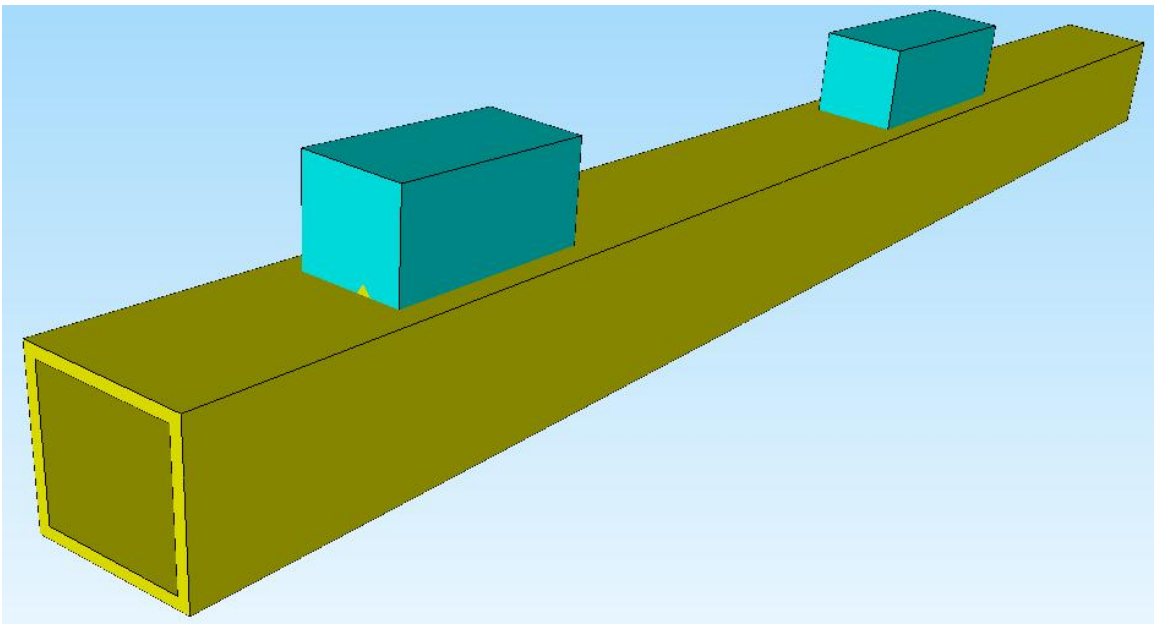
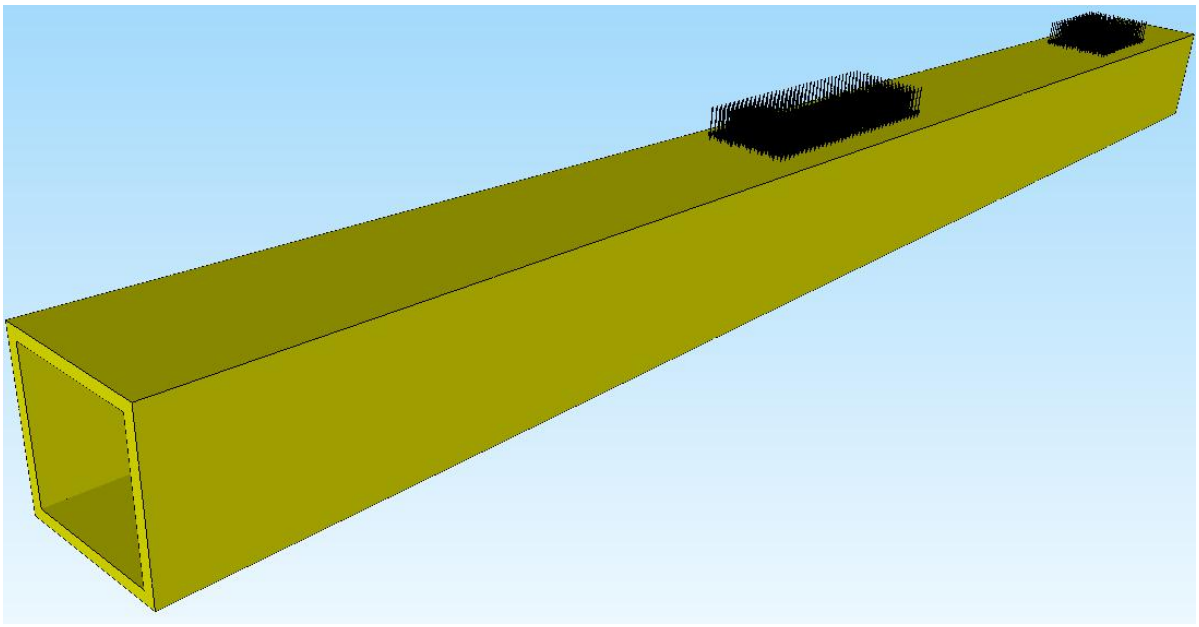


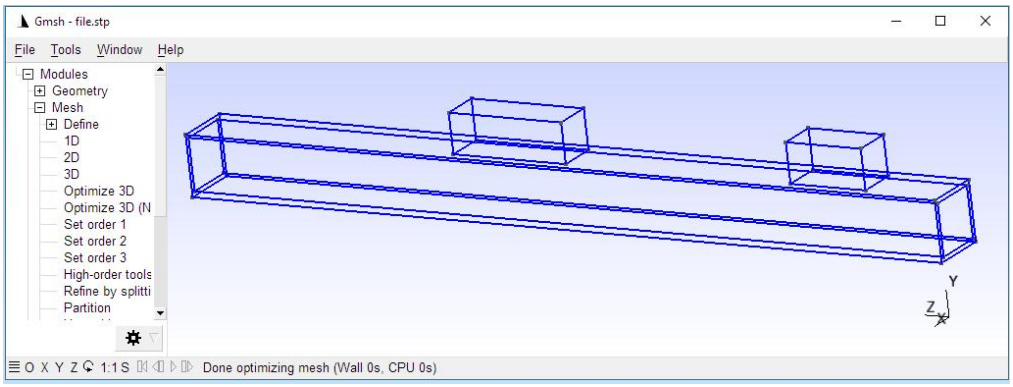
Unsupported hollow box with two additional masses as a mesh extension



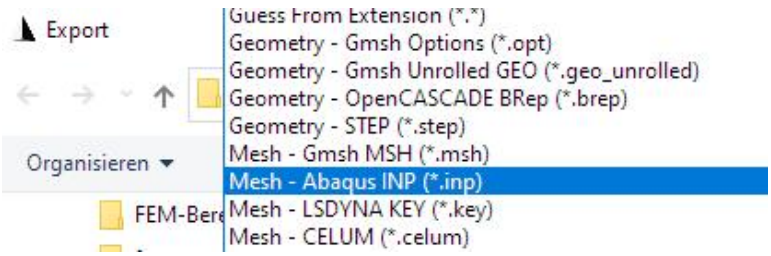
Unsupported hollow box with a weight force for the additional masses

Unsupported hollow box with additional masses as a mesh extension

The CAD model is expanded with 2 solid bodies 100x100x200 and 100x100x300 and meshed in STEP format with the 3D mesh generator GMSH

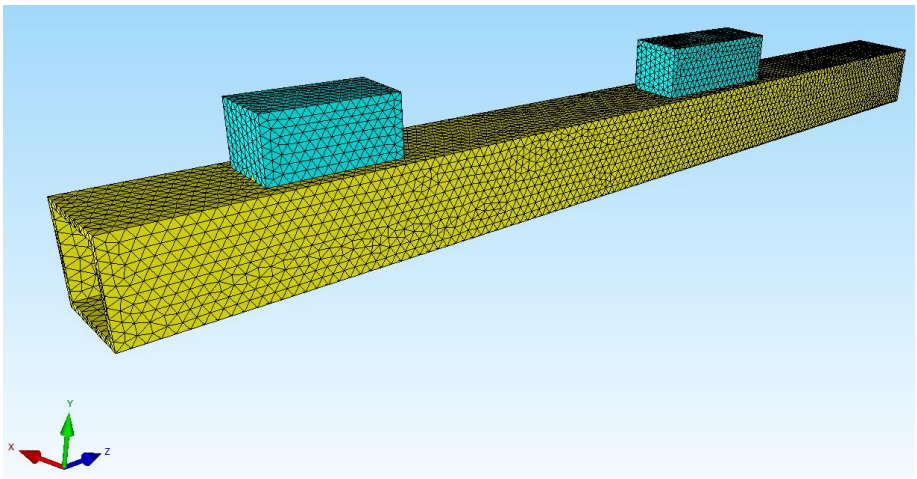


and exported in Abaqus INP format for MEANS V12:

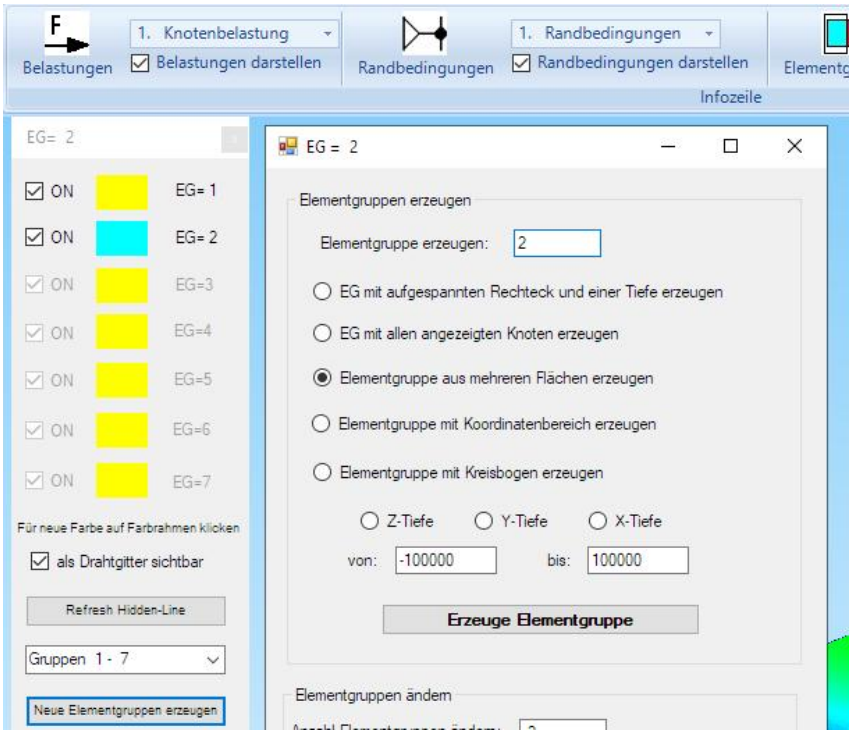


The FEM mesh was imported into MEANS V12 with menu "INP-File Abaqus/Gmsh"

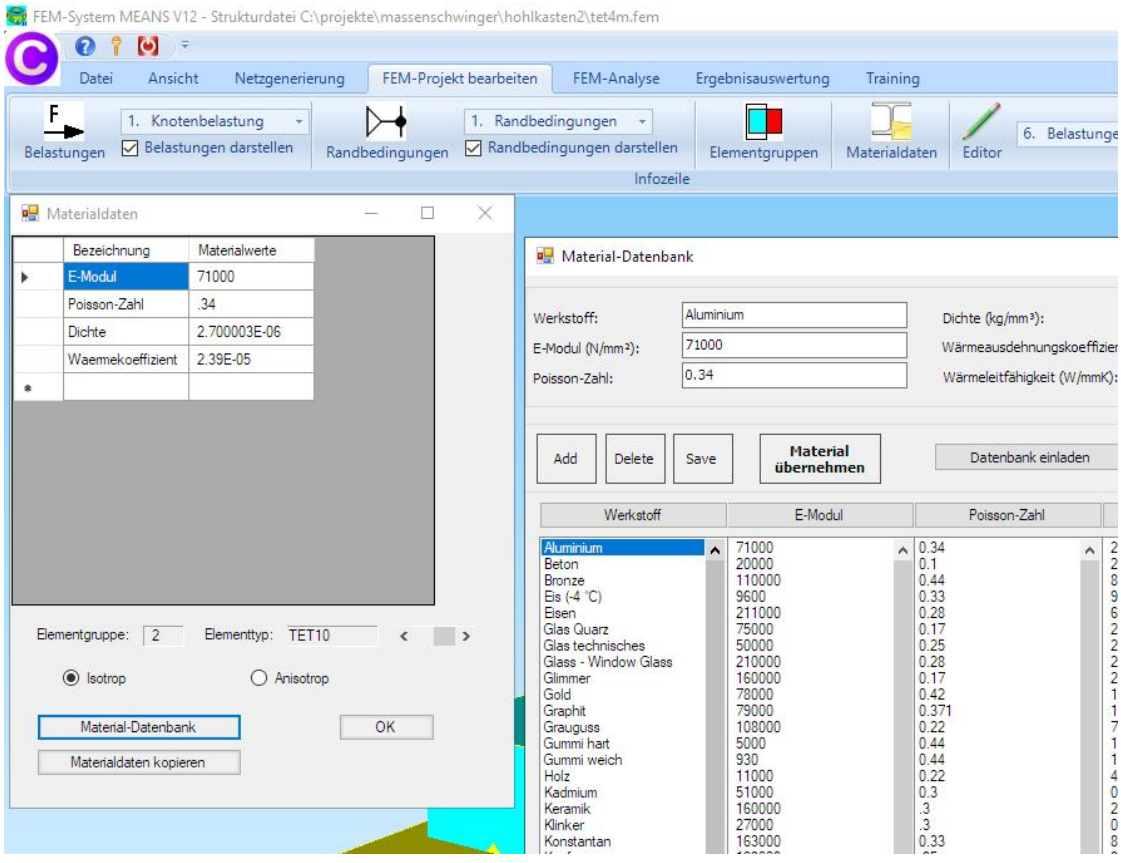
and consists of 37,938 TET10 volume elements and 73,299 nodes



Element group 2 with the additional masses is created with the "Create element group from several surfaces" menu



and with the "Material data" menu, the modulus of elasticity 72000 N/mm², the Poisson number 0.34 and the density 2.7E-6 kg/mm³ for aluminum are taken from the self-extensible material database.



Unsupported hollow box with a weight force

With this method, the weight forces are first calculated from the additional masses:

Weight 1 = 100 mm * 100 mm * 200 mm * density of aluminum

= 0.1m * 0.1m * 0.2m * 2700kg/m³ * 10m/s²

= 540N

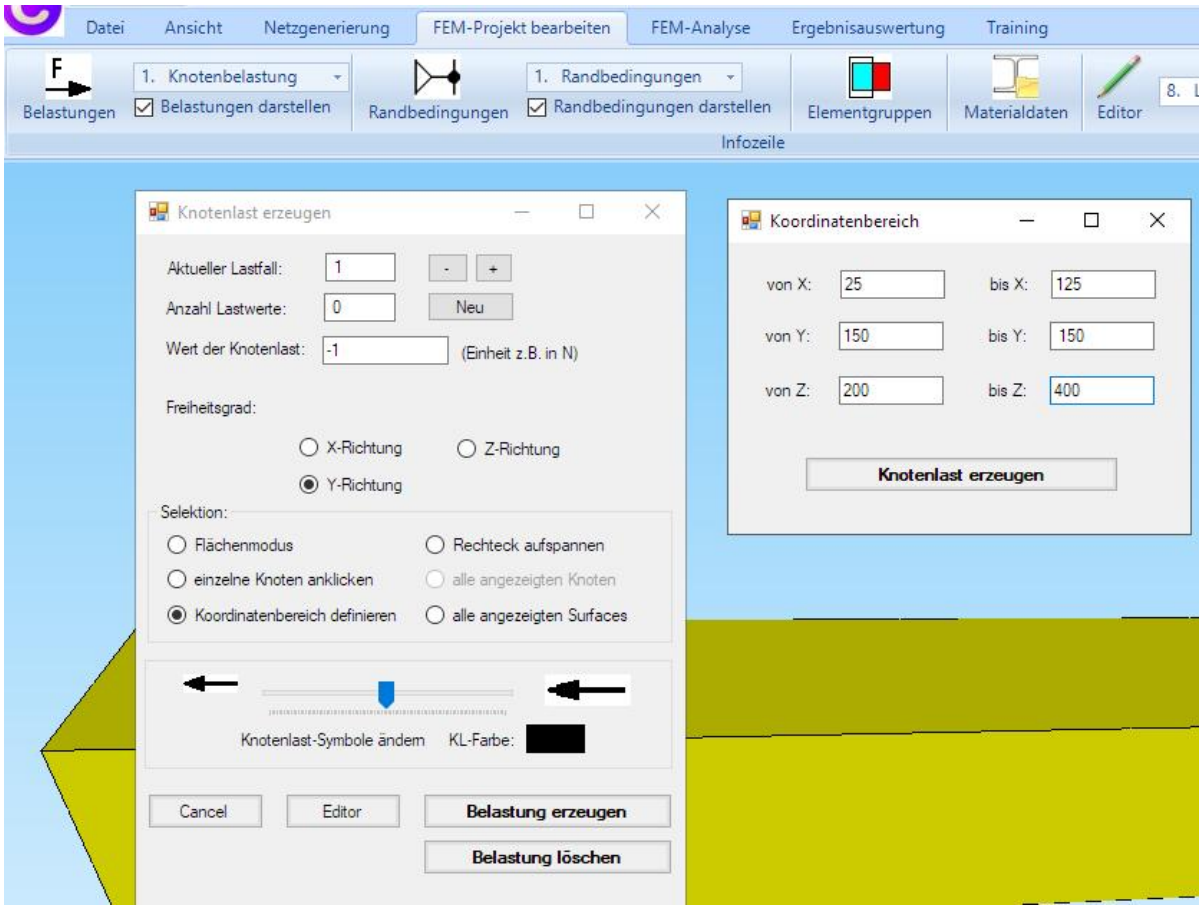
Weight 2 = 100 mm * 100 mm * 300 mm * density of aluminum

= 0.1m * 0.1m * 0.3m * 2700kg/m³ * 10m/s

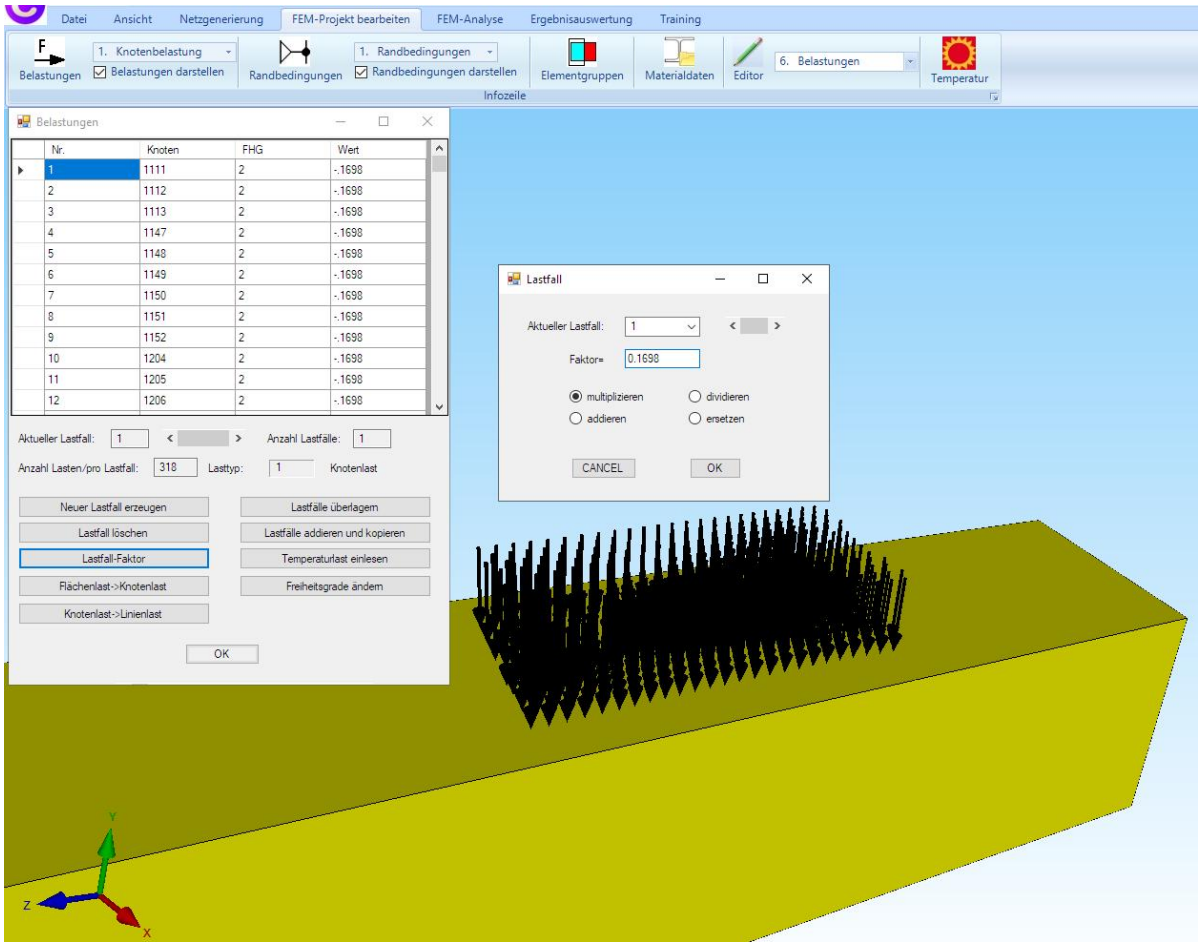
= 810N

Create a Point Load

Select the tab "Edit FEM Project" and "Point Load" and create a load with the value = -1 in the Y-direction with the selection "Define coordinate range" and define the following area:

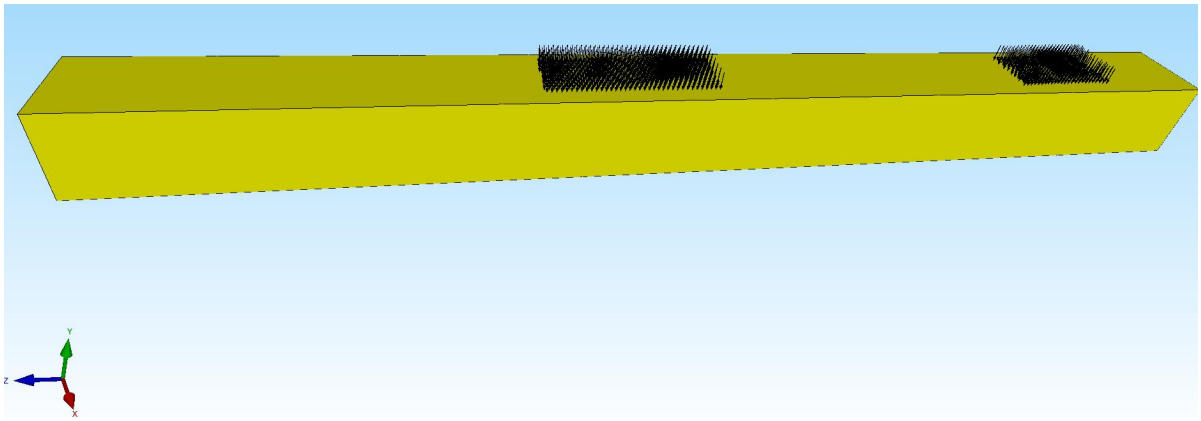


Then select "Loads" and "Editor" and calculate the individual value from 540 N / 318 = 0.1698 N, which then has to be multiplied by -1 using the "Load Case Factor" menu.



Follow the same steps for weight force 2 with the following coordinate range:

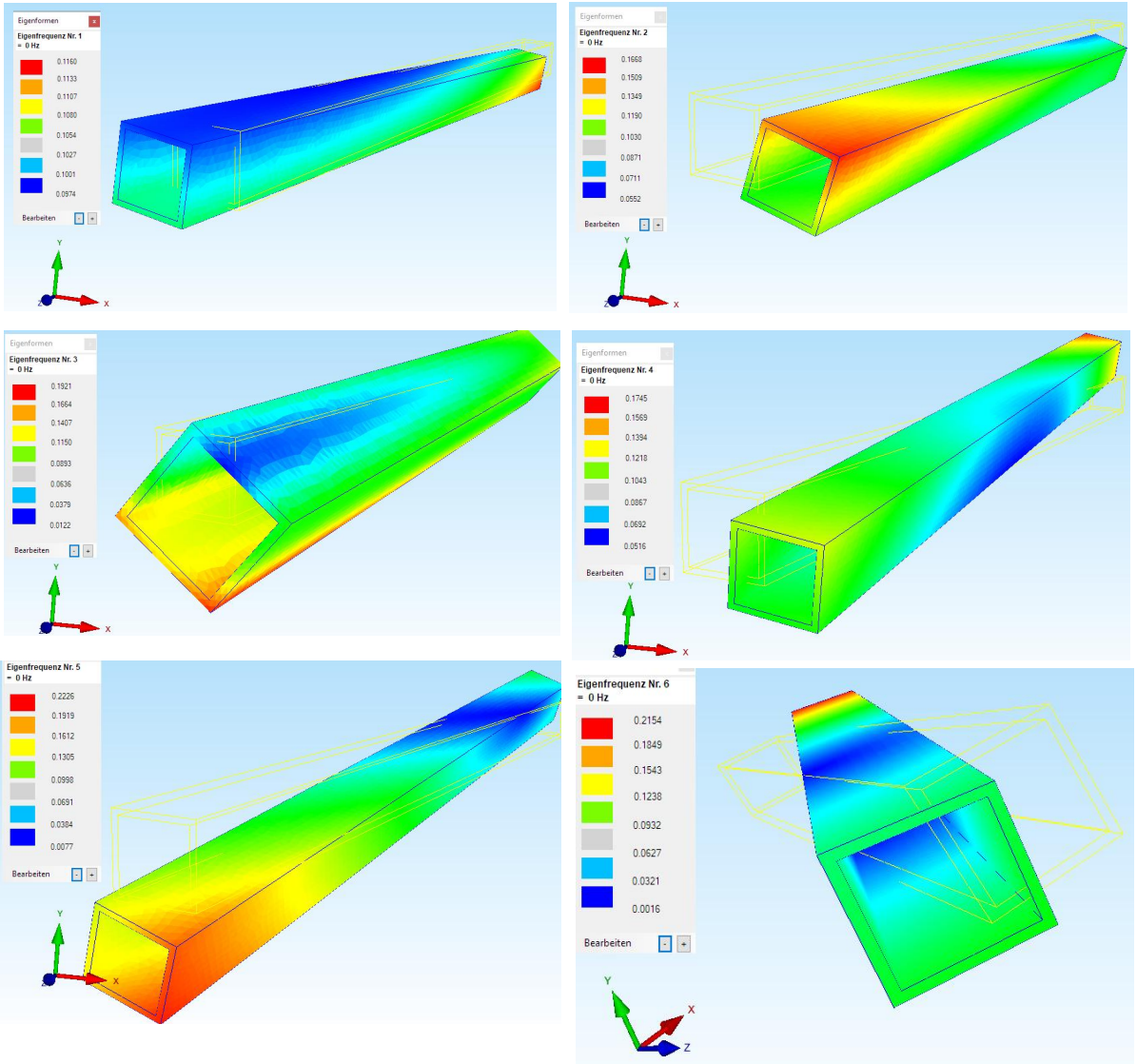
X from	25	to	125
Y from	150	to	150
Z from	1000	to	1300



Results

Natural frequencies of the unsupported hollow box without additional masses

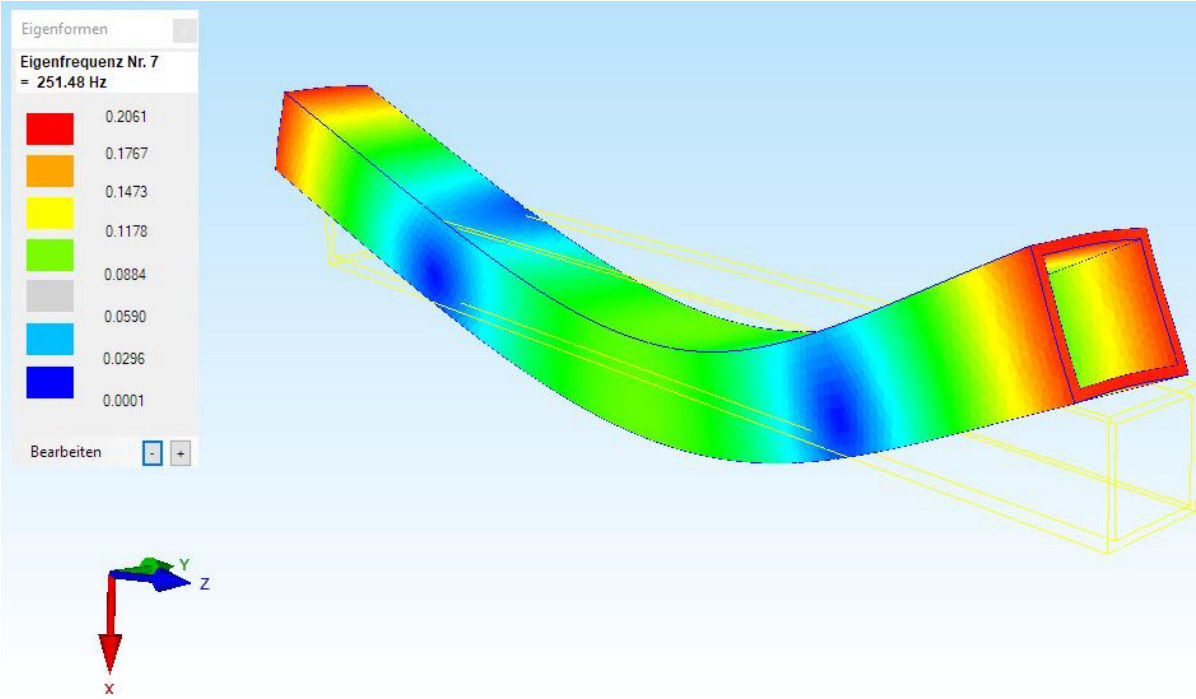
As a special case of multiple eigenvectors, the six rigid body modes (natural frequencies of 0.0 Hz) are usually not calculated in their pure form, but as a linear combination of the three translational and three rotational degrees of freedom:



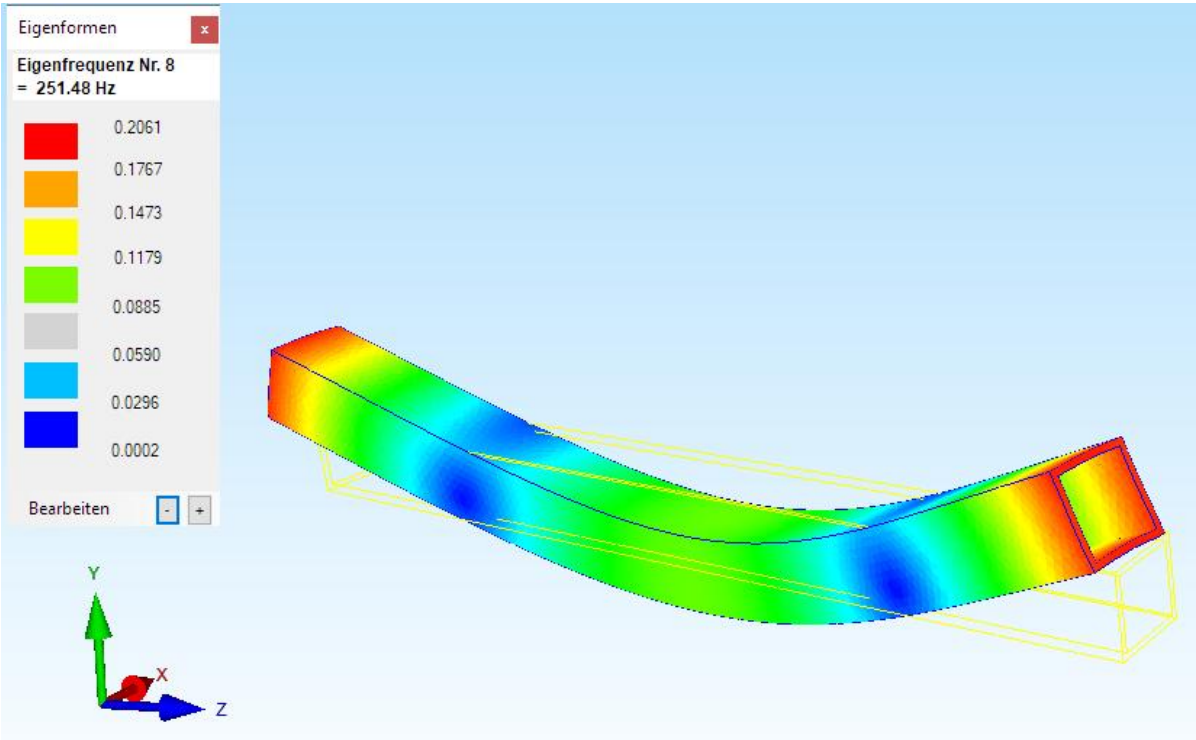
In a static analysis, even a single rigid body mode would lead to the calculation being aborted (load cannot be absorbed) or at least to ambiguous solutions (no associated load). The number of rigid body media corresponds to the degree of static underdetermination, so that natural frequency analyzes can also be used to detect missing boundary conditions.

The determined eigenvectors 7 and 8 (first bending vibration) as well as 9 and 10 (second bending vibration) coincidentally correspond to the main axes:

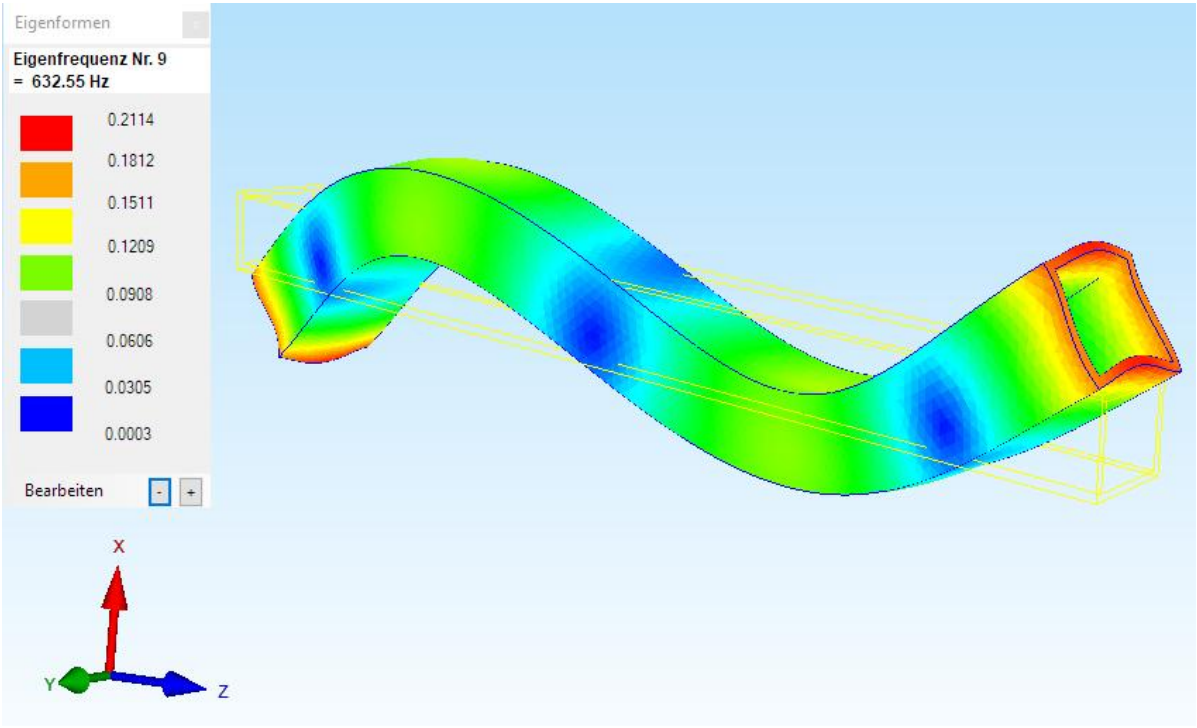
Natural Frequency No. 7 = 251.48 Hz in the X-Z-Plane



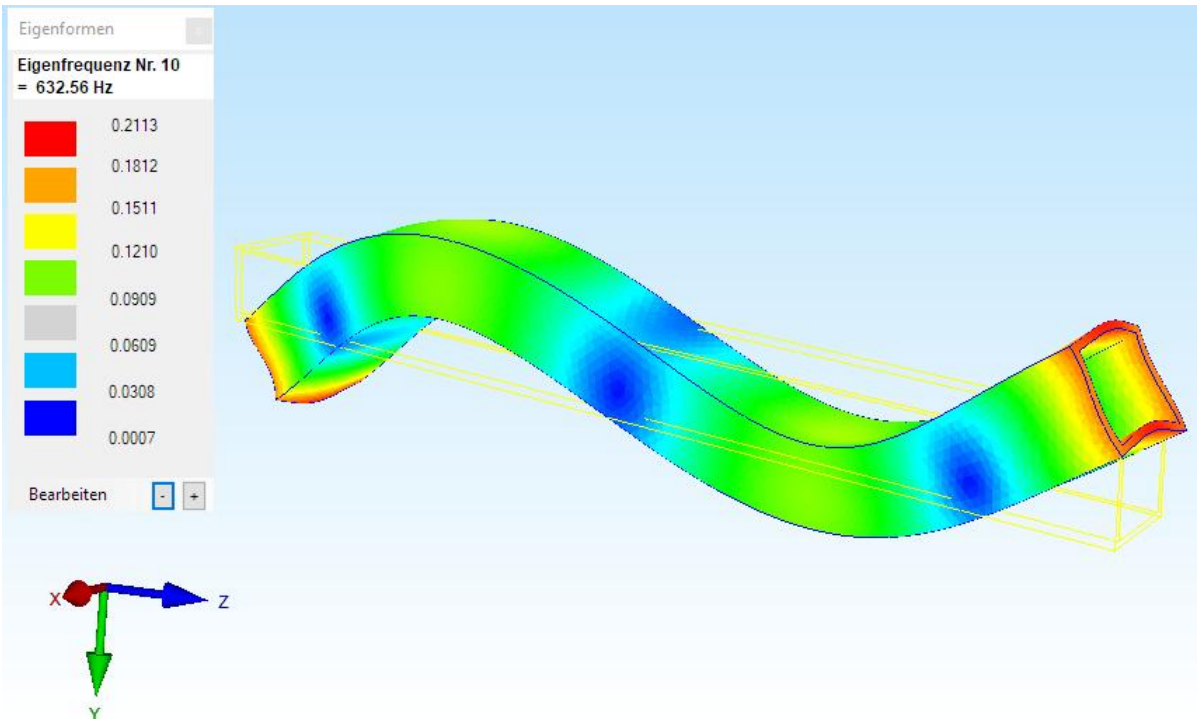
Natural Frequency No. 8 = 251.48 Hz in the Y-Z-Plane



Natural Frequency No. 9 = 632.55 Hz in the X-Z-Plane



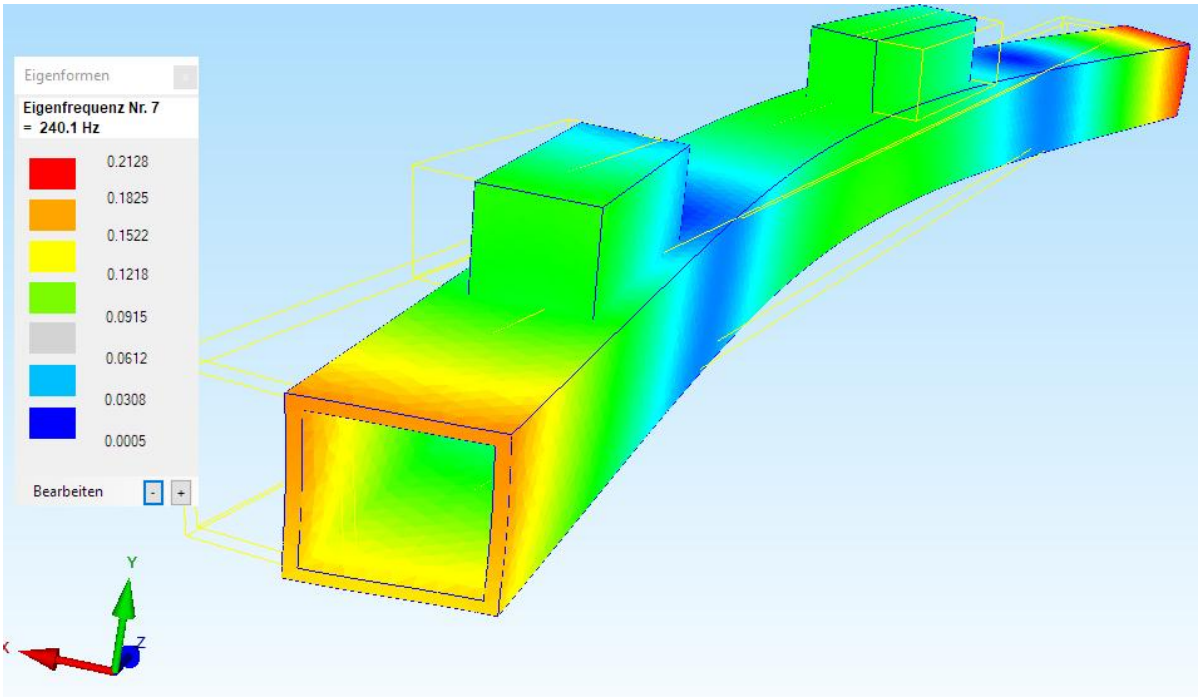
Natural Frequency No. 10 = 632.56 Hz in the Y-Z-Plane



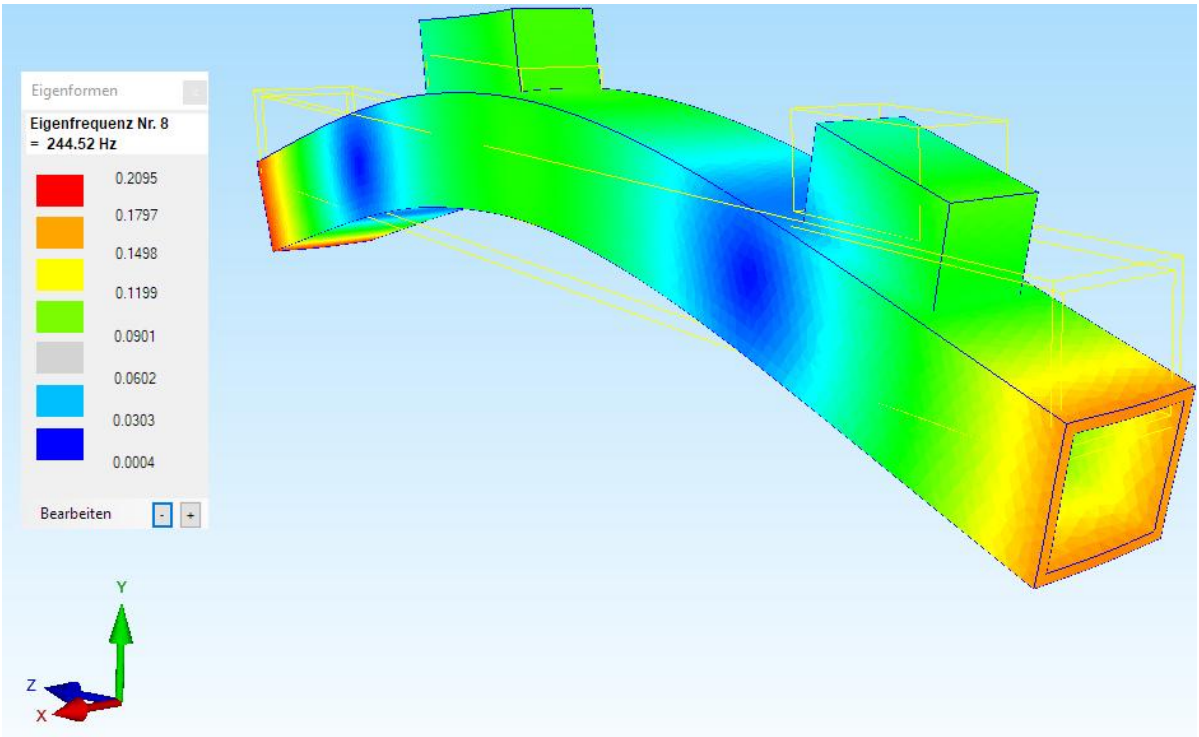
The natural frequencies calculated with MEANS V12 agree very good with the literature „FEM-Formelsammlung Statik und Dynamik“ ISBN 978-3-8348-0980-3 from Lutz Nasdala on Side 53.

Natural Frequencies of the hollow box with additional masses

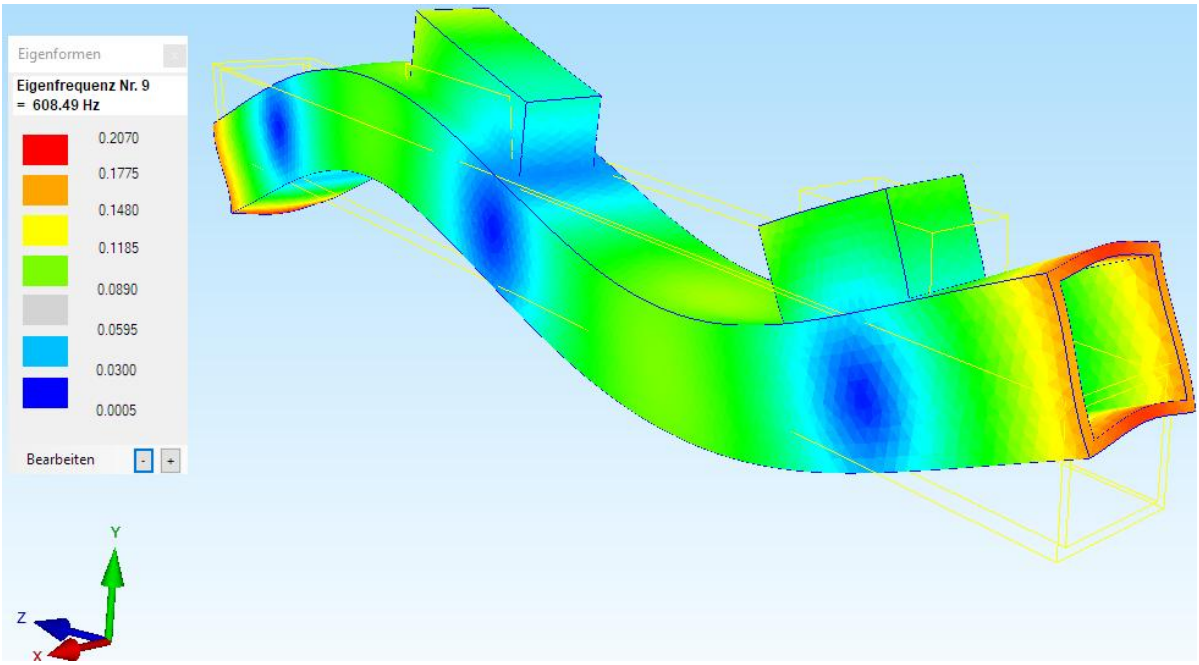
Natural Frequency No. 7 = 240.1 Hz in the X-Z-Plane



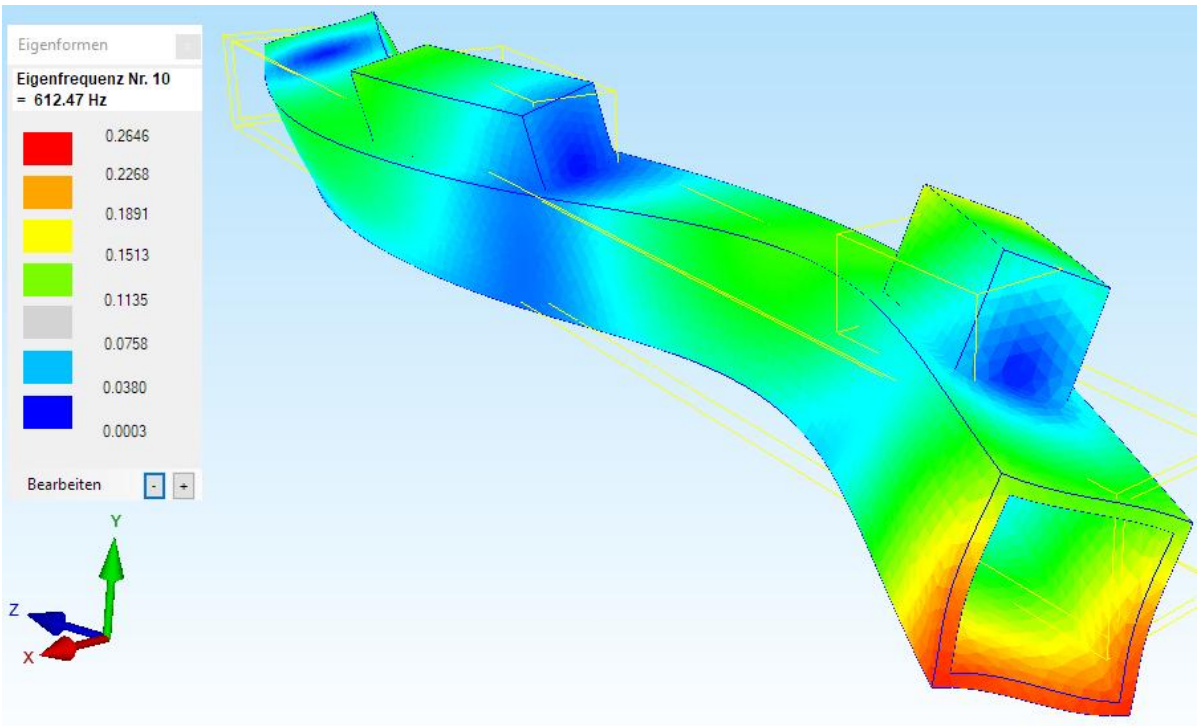
Natural Frequency No. 8 = 244.52 Hz in the Y-Z-Plane



Natural Frequency No. 9 = 608.49 Hz in the Y-Z-Plane

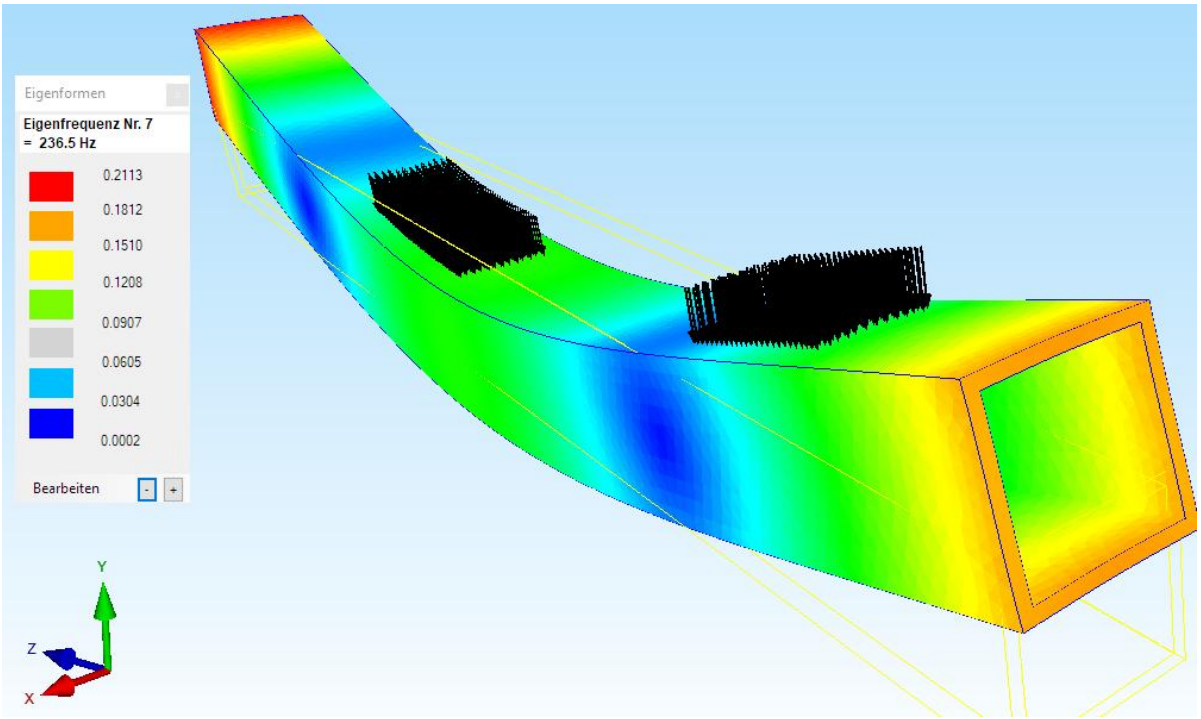


Natural Frequency No. 10 = 612.47 Hz in the X-Z-Plane

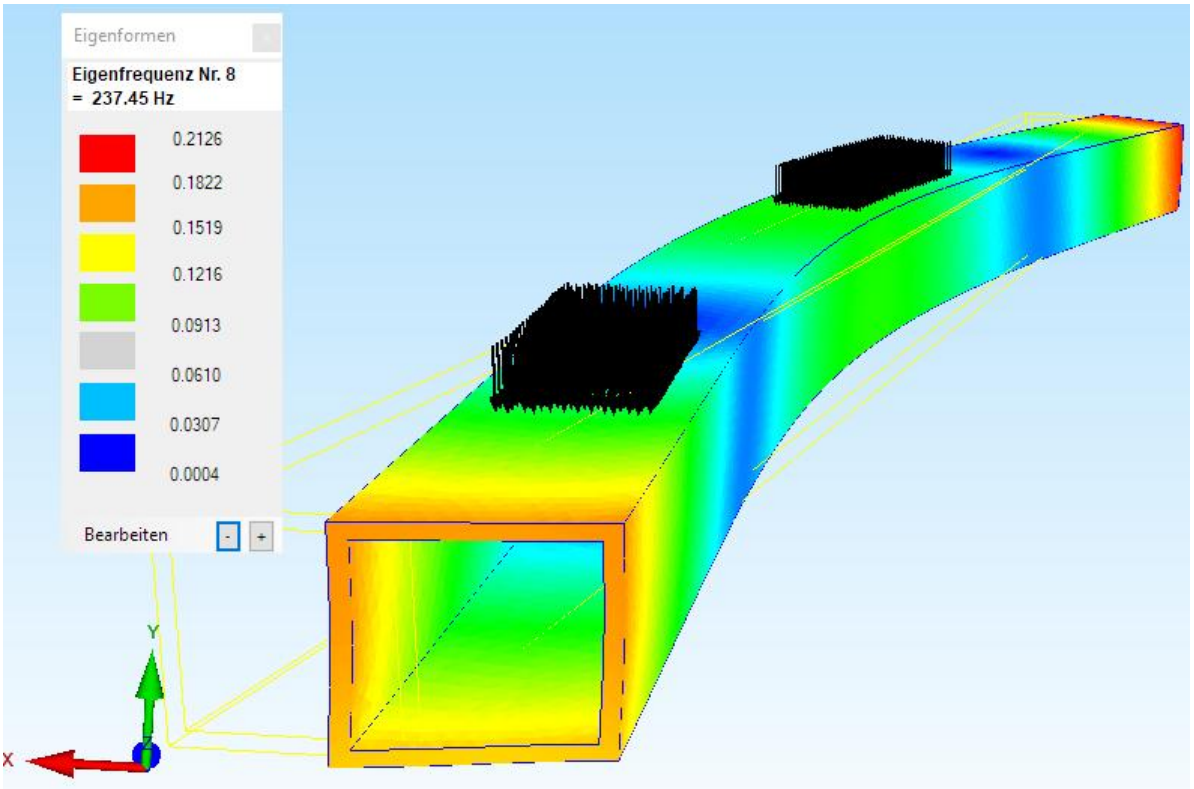


Natural Frequencies of the hollow box with a weight force

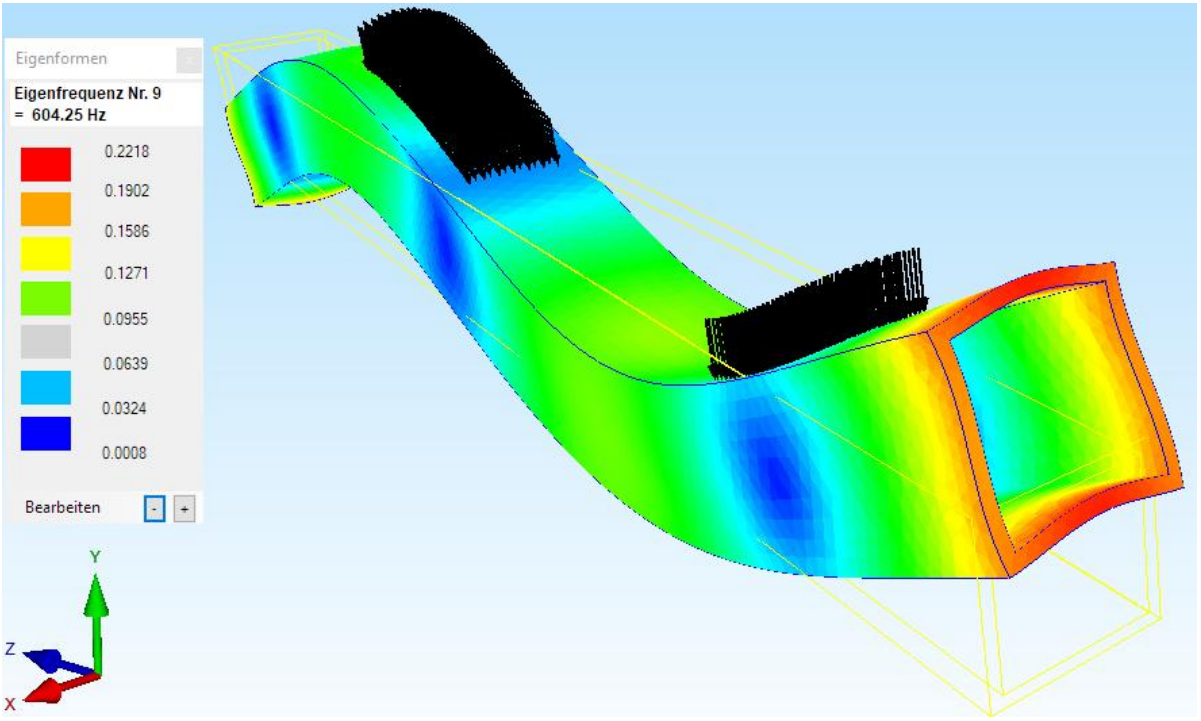
Natural Frequency No. 7 = 236.5 Hz in the Y-Z-Plane



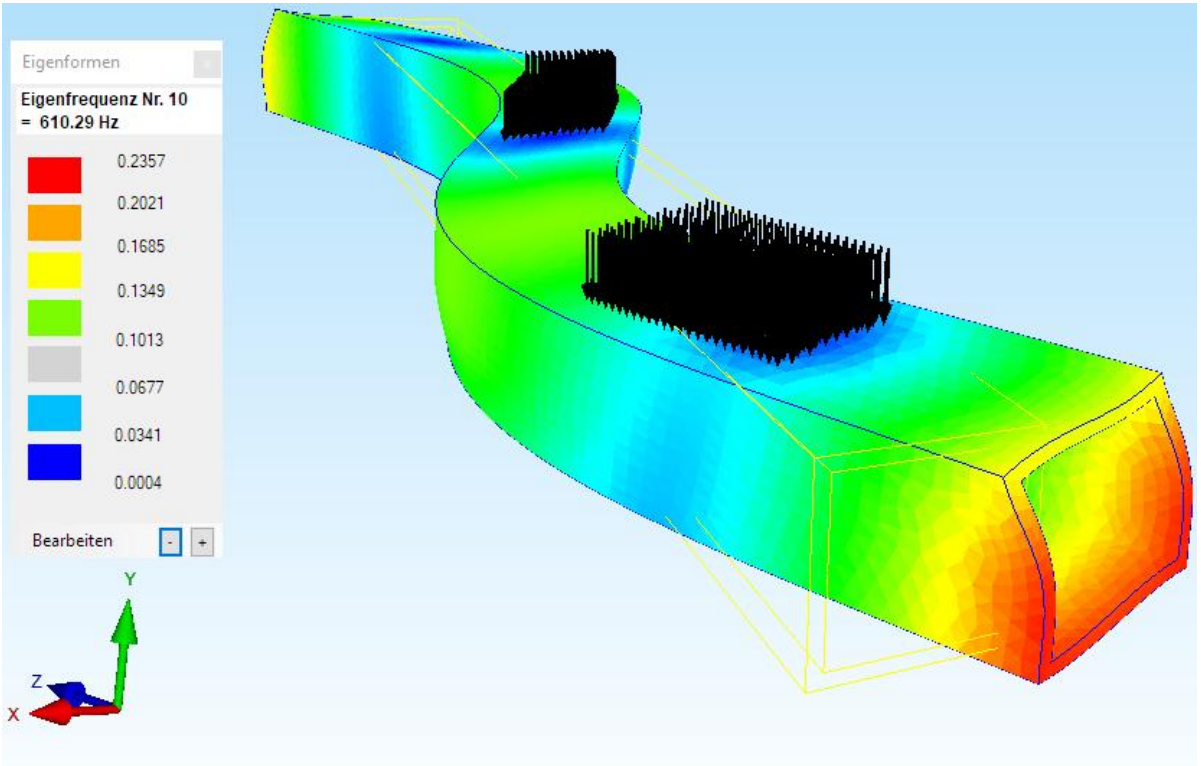
Natural Frequency No. 8 = 237.45 Hz in the X-Z-Plane



Natural Frequency No. 9 = 604.25 Hz in the Y-Z-Plane

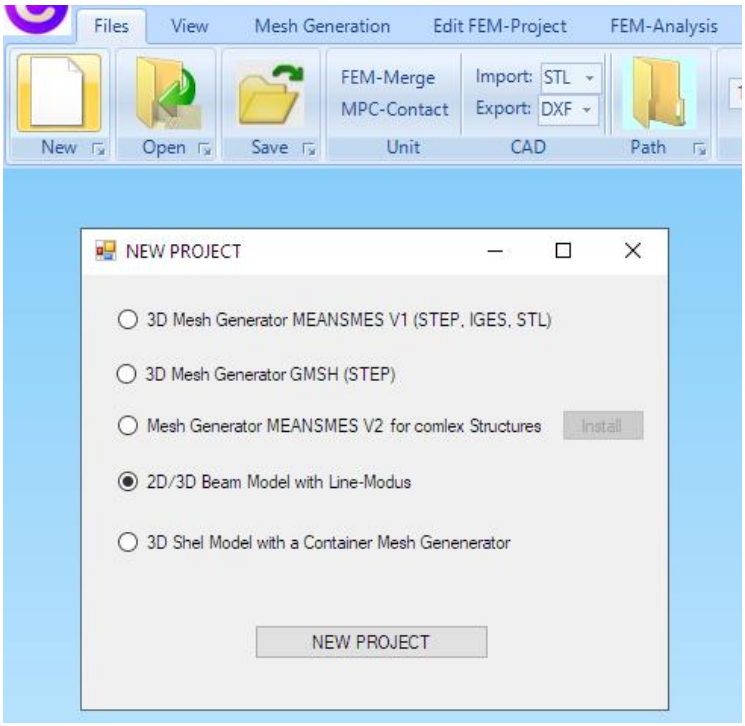


Natural Frequency No. 10 = 610.29 Hz in the X-Z-Plane



Hollow Box generate with a structured Hexahedron mesh

To generate a structured hexahedron mesh as opposed to an unstructured tetrahedron mesh with Netgen or Gmsh, the following steps can be performed in the Line-Modus with the 3D mesh grid generator.
Select "New“ and menu „2D/3D Beam Model with Line-Modus“ and first enter the outer profile 150 x 150 and then the inner profile 139.3 x 139.3 of the hollow box.



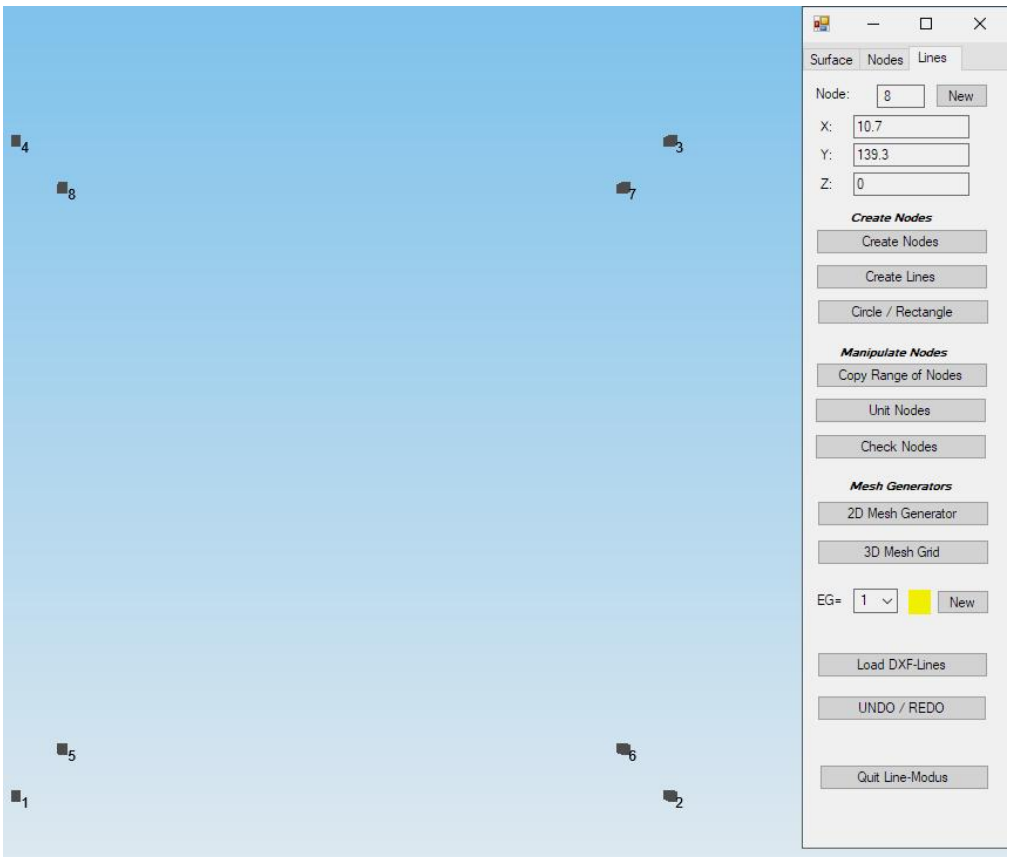
Outer profile:

Choose "New" to create node 1 with the coordinates 0,0,0 and menu "Create single node".
Choose "New" to create node 2 with the coordinates 150,0,0 and menu "Create single node".
Choose "New" to create node 3 with the coordinates 150,150,0 and menu "Create single node".
Choose "New" to create node 4 with the coordinates 0,150,0 and menu "Create single node".

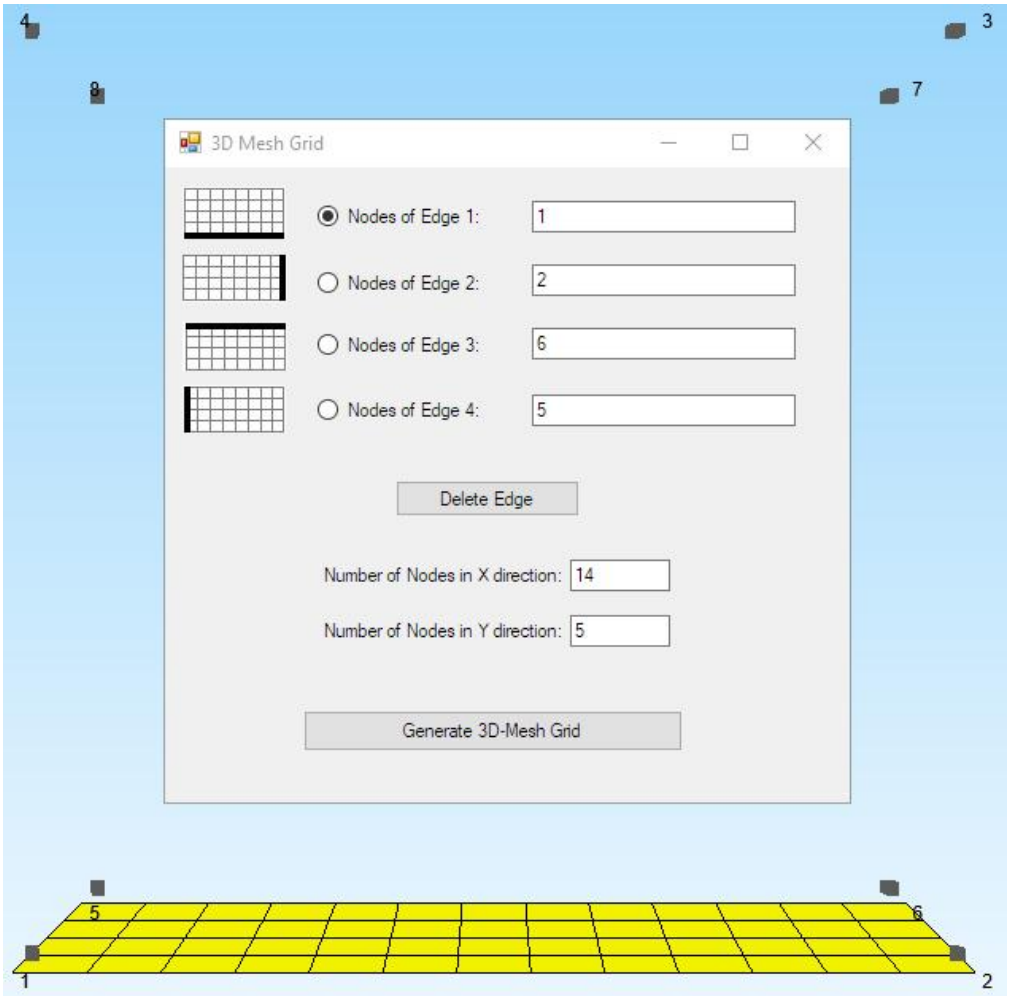
Inner profile:

Choose "New" to create node 5 with the coordinates 10.7,10.7,0 and "Create single node" menu.
Choose "New" to create node 6 with the coordinates 139.3,10.7,0 and menu "Create single node".
Choose "New" to create node 7 with the coordinates 139.3,139.3,0 and menu "Create single node".
Choose "New" to create node 8 with the coordinates 10.7,139.3,0 and menu "Create single node".

You should see the following eight nodes:

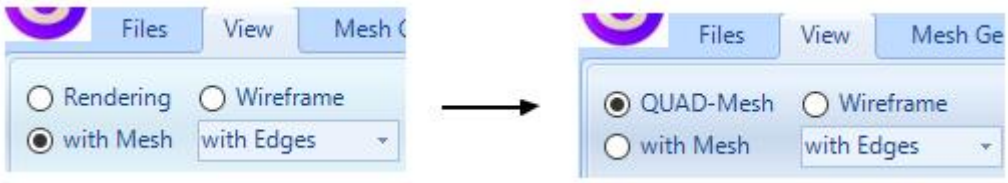


Right select "3D Mesh Grid" and give following 4 edges 1, 2, 6 and 5 as well

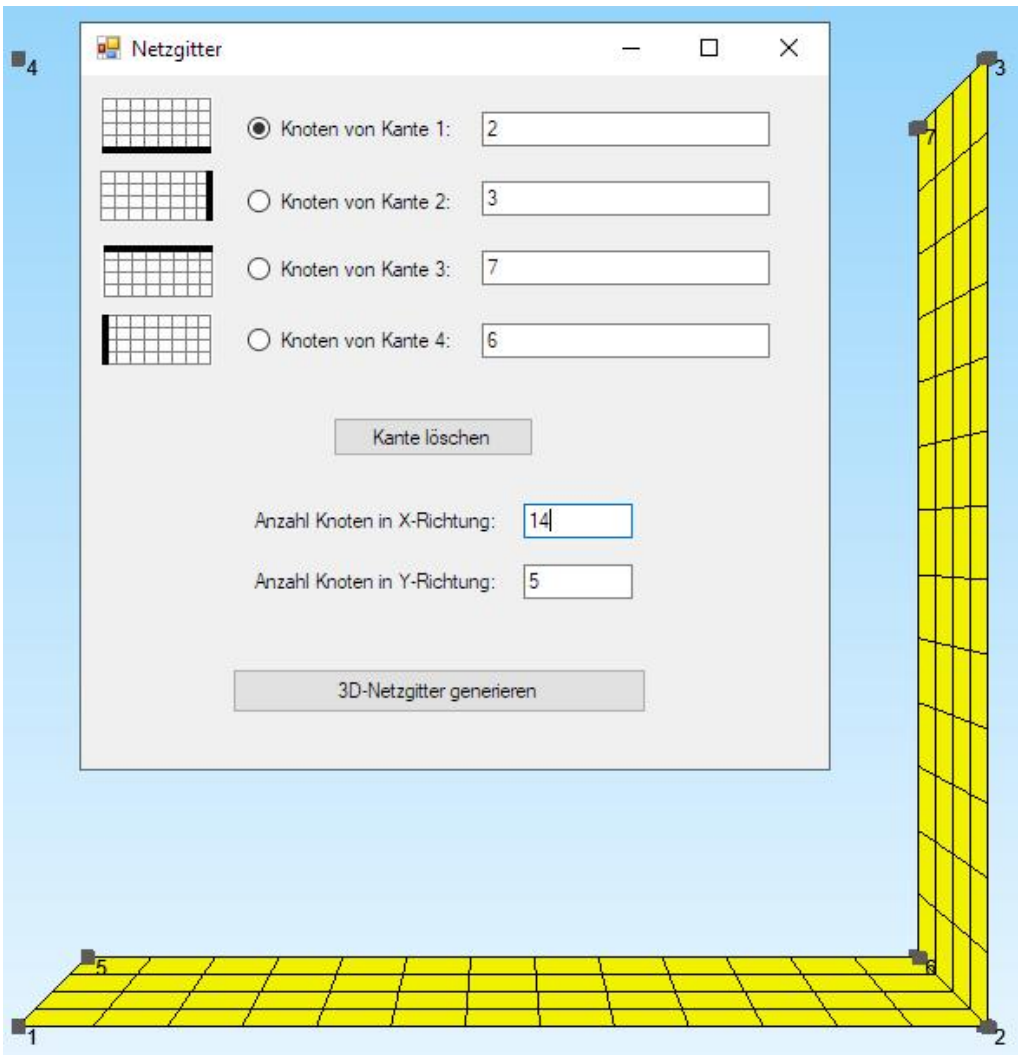


enter the mesh density in X-direction = 14 and in Y-direction = 5.

Select the View tab and click Rendering and click again “with mesh” then “Quad Mesh” appears and the Quad-Mesh can be seen.



Repeat the step with edges 2, 3, 7 and 6 and with the mesh density in X-direction = 14 and in Y-direction = 5.



Repeat the step with the edges 8, 7, 3 and 4 and with the mesh density in X-direction = 14 and in Y-direction = 5.

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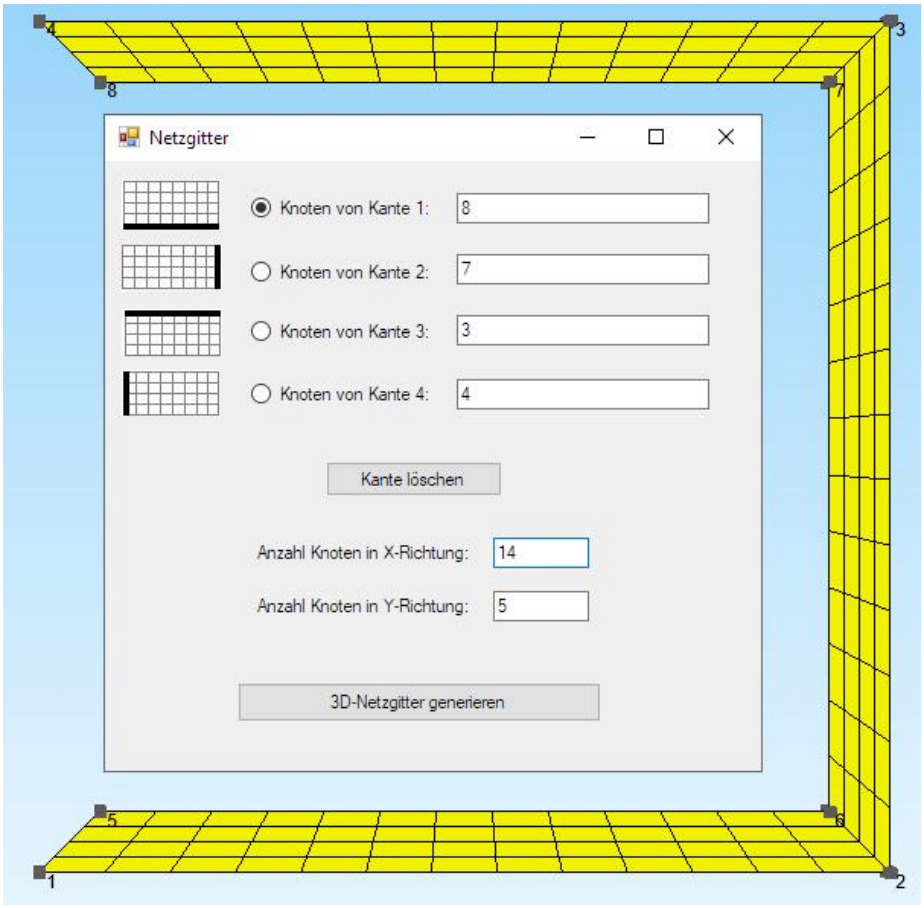
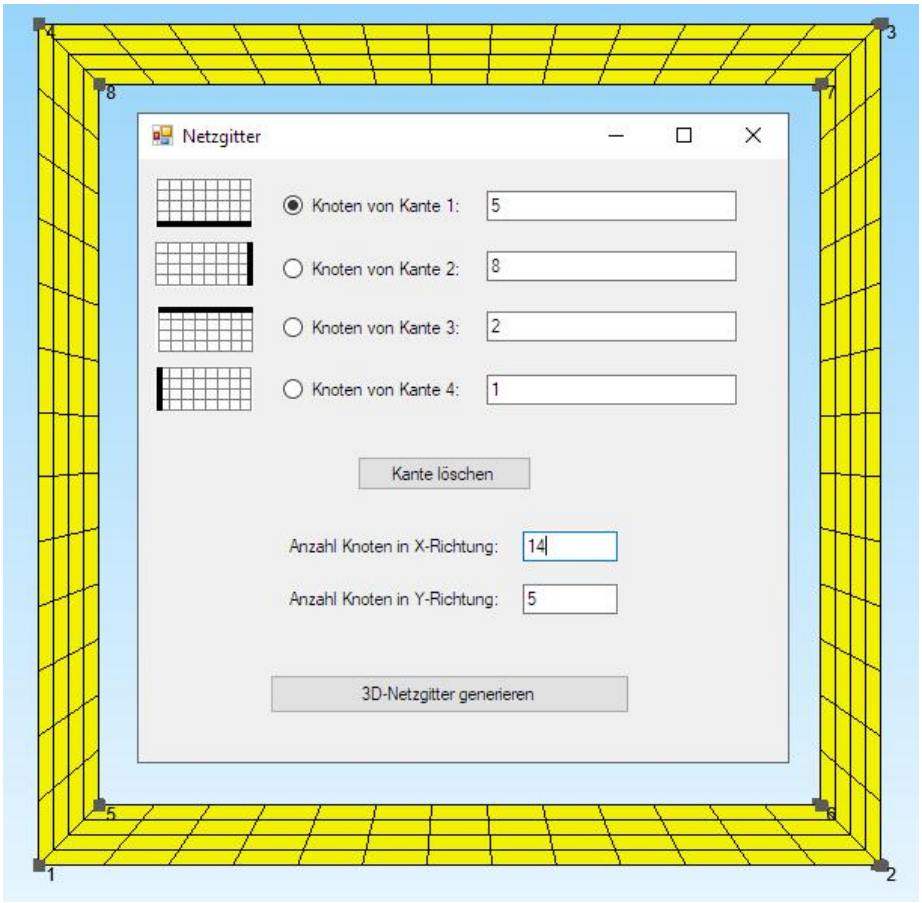
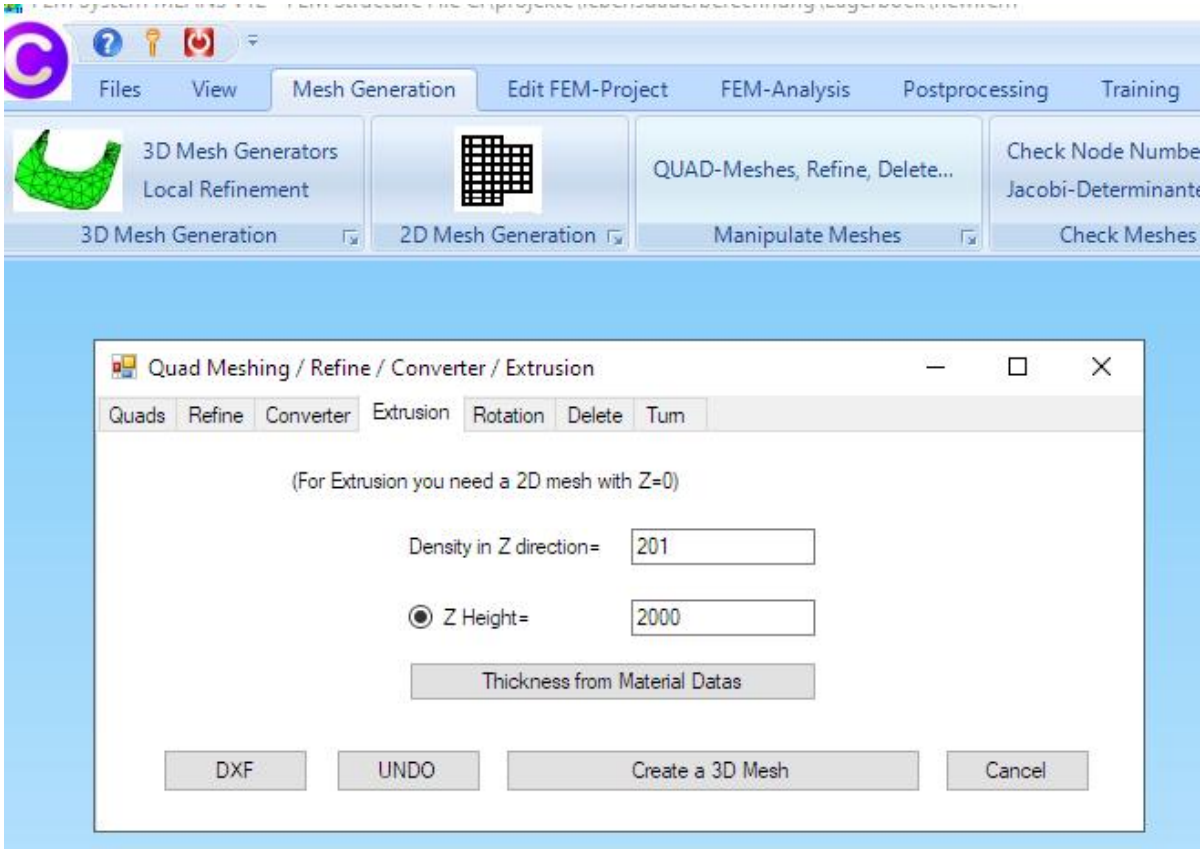


Repeat the last step with edges 5, 8, 2 and 1 and with mesh density in x direction = 14 and in y direction = 5.



Then select an extrusion with the "Mesh Generation" tab and the "Quad Meshes, Refine, Delete" menu and select the "Extrusion" tab in the new dialog box.



With „Density in Z direction = 201“ and „Z-Height = 2000“ a structured Hexahedron Mesh with 41 600 HEX8-Elements and 52 260 Nodes is created.