# Part 5: Dynamic Analysis with FEM-System MEANS V11

This is a FEM calculation with FEM-System MEANS V10 of a 440 Hz Tuning Fork with which you can adjust the musical instruments according to the reference tone or it are also used in the medicine for hearing tests.



The dimensions and material data must first be converted to metric units by USA measurement units. The tuning fork model is produced in MEANS V10 without foot and connection as follows:

#### US Measurement:



8.3058 mm

E-Modulus = 200 000 N/mm<sup>2</sup> Poisson ratio = 0.29 Density = 7850 kg/m<sup>3</sup> Thickness = 3.937 mm

16.18 mm

8.09 mm

## **Create Arcs**

Start the program "MEANS V12 for DirectX11" using the desktop icon select the "View" tab and menu "3. Line-Modus" to switch to the Line Modus.

is	Postprocess	ing	Training				
1.	Main View	-		$\odot$	2.	Node-Modus	kground Axis Cross
			Surfaces	Nodes	1.	Surface-Modus	
o Lir	ne				2.	Node-Modus	Es.
					3.	Line-Modus	
					4.	Create Surface Model	
					5.	Switch Surfaces ON/OFF	
					<u> </u>		_

A new menu will appear on the right, select menu "Create Arcs" to create two arcs:

<u>Circular Arc 1:</u> Center: xm = 0, ym = 0, zm = 0Radius = 8.09 Number of Nodes = 16 Start Angle = 270 End Angle = 90

#### **Circular Arc 2:**

Center: xm = 0, ym = 0, zm = 0Radius = 4,153 Number of Nodes = 16 Start Angle = 270 End Angle = 90

	-17	Surface Nodes Lines
Image       Image         Circle       Retangle         New       REDO         Middle-Point       Middle-Point         X direction:       0.00         Y direction:       0.00         Z direction:       0.00         Outer Radius:       4.153         Inner Radius:       0         Number of Nodes:       16         Start Angel:       270         End Angel:       30         Create Arc       Cancel	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Node:         0         New           X:         0         Y:           Y:         0         Z:           Create Nodes         Create Nodes           Create Nodes         Create Nodes           Create Ines         Create Nodes           Copy Range of Nodes         Unit Nodes           Unit Nodes         Check Nodes           Mesh Generators         2D Mesh Grid           EG=         1         New           Load DXF-Lines         UNDO / REDO           Quit Line-Modus         Ret Line-Modus

Also, in Node Modus, switch on the node numbering to see the 34 nodes better:

# Enter 4 single nodes

In line mode, enter the 4 single nodes of the left side one by one with "New" and "Create Nodes":

Node 35 = X = -75.17 Y = 8.09Node 36 = X = -75.17 Y = 4.15Node 37 = X = -75.17 Y = -4.15Node 38 = X = -75.17 Y = -8.09

*35	۳۶ <sup></sup> ۱۶ ۱۶
*36	3#399231200 112 122 11
	$\begin{pmatrix} 7 & 1 \\ 27 \\ 26 \\ 25 \\ 25 \\ 24 \\ 8 \\ \end{pmatrix} $
*37	-181920 <sup>2</sup> 7 <sup>223</sup> 6
-38	1234

#### **Create Lines**

In Lines Modus select menu "Create Lines" menu and create the lines by first clicking on the first node, then clicking on the end node, and selecting "Create Lines" and creating the following 6 lines:

Line 17-35, line 35-36, line 36-34, and line 18-37, line 37-38, line 38-1

	Greate Lines − □ ×     Node 33     3	
	X direction: -77.17 Y direction: -8.09	
35	O Node         1           X direction:         -77.17	
36	Y direction: 4.15 Z direction: 0	3439323400 /11
	all showing Nodes Number of Nodes per Line: 2	27 27 26 25 25 26 24 24 8
37	Create Lines	18192074 6 5
<sup>1</sup> 38	Number of Nodes:         38         OK           Number of Elements:         38         OK	
	Delete Elements: OK	

## 2D Mesh Generator with Extrusion

In Line Mode, select "2D Mesh Generator" with a Mesh Density of "200" and "3D-Extrusion" with Nodes in Z Direction of "7" and a Z-Depth of "3,931" to first generate a triangular mesh and then to extrude a 3D model consisting of 11616 pentahedral elements and 8211 nodes.

🛃 2D Mesh Generation		-	$\times$
from Element Group: 1	until Element Group: 1		
Element Typ: TRI3S	~		
Mesh Density: 200	~		
Snap Radius: .005			
QUAD-Meshing			
☑ 3D-Extrusion			
Nodes in Z Directio	n: 7		
Z-Depth:	3.931		
Check Nodes	Refine Mesh	1	
Cancel Help	MESH GENERATIO	ON	



## **QUAD Meshing**

Select "2D Mesh Generator" again and select "QUAD-Meshing" to generate a triangular mesh for using it as a template in NETGEN.

💀 2D Mesh Generation	_		$\times$
from Element Group: 1 until Element Group: 1			
Element Typ: TRI3S ~			
Mesh Density: 200 ~			
Snap Radius: .005			
QUAD-Meshing			
3D-Extrusion			
Nodes in Z Direction: 5			
Z-Depth:			
		_	
Check Nodes Refine Mesh			
Capacity Halo		_	
Caricei Heip MESH GENERATIO	N		

The generated triangular mesh is now displayed as a converted STL model in NETGEN.



Select "Generate Mesh" with the mesh density "very fine" and generate a QUAD mesh with 5124 nodes and 5157 QUA4S elements.

7% NETGEN - file.stl		
File Geometry Mesh View Refinement Special Help		
Quit Generate Mesh Stop	Mesh	- Zoom All Center
y E_x	N	letgen 4.9.11
Points: 5124 Elements: 0 Surf Elements: 5175		

Use menu "File" and "Export Mesh" to export the FEM mesh under the name "test.fem" to the default debug quadmesh directory so that it can be automatically converted and imported into MEANS V12.

C v v Programme > FEM-System_MEANS_V10 > Debug > quadmesh v 4 quadmesh durchsuchen							
Organisieren 🔻 Neuer Ordner 🔠 👻 🔞							
📱 Zuletzt besucht 🔺	Name	Änderungsdatum	Тур	Größe			
- B111 - 1	BinLPlugin.dll	10.09.2008 15:59	Anwendungserwe	5 KB			
Bibliotheken	🚳 BinPlugin.dll	10.09.2008 15:59	Anwendungserwe	5 KB			
	🚳 BinTObjPlugin.dll	10.09.2008 15:59	Anwendungserwe	19 KB			
Dokumente	BinXCAFPlugin.dll	10.09.2008 15:59	Anwendungserwe	5 KB			
	🧾 dialog	19.06.2009 08:34	TCL-Datei	94 KB			
Videos	drawing	11.09.2009 20:38	TCL-Datei	3 KB			
• · · · ·	📮 file	09.12.2016 14:49	Zertifikatvertrauen	386 KB			
😽 Heimnetzgruppe	file.stp	27.10.2016 16:25	STP-Datei	31 KB			
	📮 file2	09.12.2016 14:49	Zertifikatvertrauen	386 KB			
Computer	FWOSPlugin.dll	10.09.2008 15:59	Anwendungserwe	35 KB			
Lokaler Datenträg	menustat	11.09.2009 22:41	TCL-Datei	32 KB			
🏭 Lokaler Datenträg	🚳 mscmd.dll	10.09.2008 16:01	Anwendungserwe	24 KB			
Nature V	MSVCP70.DLL	06.10.2002 20:37	Anwendungserwe	476 KB			
Dateiname: test.f	em						
Dateityp: All Fi	les (*.*)						

After the model check, a QUAD mesh with 6201 nodes is created.

#### Hexahedral model

Select menu "QUAD-Meshes, Refine, Delete..." again and the register "Extrusion" to generate a Hexaeder mesh with 39944 HEX8 elements and 43407 nodes. Use the following setting:

🖳 Qua	Quad Meshing / Refine / Converter / Extrusion						14	_		×
Triangle	Quads	Refine	Converter	Extrusion	Rotation	Delete				
			(For Ext	trusion you i	need a 2D	mesh with Z=0)				
				Density	in Z directi	ion= 7				
				Elevatio	on in Z <mark>d</mark> ire	ction= 3.931				
	DXF		UNDO		Cr	reate a 3D Mesh		C	ancel	

## **Create Boundary Conditions**

Create a Range of Nodes in Node Modus and choose "Edit FEM-Project" tab and menu "Boundary Conditions" and clamped fixed the Range of Nodes with the Selection "All displayed nodes" in the X, Y and Z direction.



## **Dynamic Analysis**

Select the "FEM Analysis" tab and "2. Dynamics" and calculate the lowest 15 eigenfrequencies with the Quick Solver with the following setting.



#### Calculate the eigenvalue with the quick quick solver:

INP-Interface for F	E-Solvers	
Normal Precisio	C3D8 (8-node linear isoparametric element)     show C3D4 and solve intern with a refining mesh of 8 x C3D4     C3D20 (20-node quadric isoparametric element)	
Path for INP-Solver	: D:\Program Files\FEM-System_MEANS_V10\Debug\inpsolver\inpsolver32bit.t	Browser
Path for INP Files:	C:\projekte\stimmgabel\hex88.INP	
	Select Solver   In-Core-Solver  Out-of-Core-Solver	
	Start FEM-Solver with INP-Interface	
	Settings Help + Infos Cancel	

#### **Results comparison**

The eigenfrequencies calculated with different meshes and element types are compared with the eigenfrequencies of the FEM system LS-DYNA. The result comparison shows good agreement with almost all element types. The greatest deviations occur with the linear tetrahedral element TET4. But if the same TET4 mesh is calculated with the TET4X8 developed by HTA software, the results will improve over 30%



Eigenfrequenz Nr. 2 = 2823 Hz



LS-DYNA



Eigenfrequenz Nr. 4 = 8438 Hz



Elementtyp	Knoten	Elemente	1. Biegesch.	2. Biegesch.	3. Biegesch.	Torsionssch.
LS-DYNA	?	?	450 HZ	2 823 Hz	7 460 Hz	8 438 Hz
Dreieck	18 379	8 764	452 Hz	2843 Hz	7 539 Hz	-
Viereck	7 366	2 081	453 Hz	2 846 Hz	7 456 Hz	-
TET4	18 539	87 744	471 Hz	3 072 Hz	8 149 Hz	9 659 Hz
TET4X8	132 085	701 952	456 Hz	2 897 Hz	7 594 Hz	8 800 Hz
TET10	132 085	87 744	449 Hz	2 817 Hz	7 401 Hz	8 413 Hz
HEX8	43 407	34 944	450 Hz	2 839 Hz	7 422 Hz	8 400 Hz
HEX20	164 781	39 944	449 Hz	2 816 Hz	7 346 Hz	8 322 Hz
PEN6	59 150	94 596	451 Hz	2 839 Hz	7 446 Hz	8 444 Hz
PEN15	278 301	94 596	449 Hz	2 818 Hz	7 340 Hz	8 315 Hz

# Eigenfrequency No. 4 = 449 Hz (first bending Eigenfrequency)



Eigenfrequency No. 8 = 2817 Hz (second bending Eigenfrequency)



Eigenfrequency No. 12 = 7382 Hz (third bending Eigenfrequency)



Eigenfrequency No. 13 = 8398 Hz (first torsion Eigenfrequency)

