

- 1 -

MADYN 2000 Version 3.4

The main new features in MADYN 2000 version 3.4 are:

- 1. Introduction of ALP3T version 4.3 for linear analysis besides ALP3Tversion 3.2. Version 4.3 until now has only been used for the analysis of the nonlinear characteristics of fluid film bearings. The new version allows using the 2-phase flow in the cavitation zones also for linear characteristics. Moreover the analysis is generally more robust.
- 2. Nonlinear non-dimensional bearing characteristics can now be imported from text files for "user defined" and "standard" bearings.
- 3. Shafts can be output in a text file with flexible format defined by SIF (**S**haft Interface File). These files are normally used to define the format for the import of a shaft from a text file.
- The sensitivity of magnetic bearings according to the ISO standard 14839-3 can be calculated. This analysis is a special type of harmonic response analysis called Magnetic Bearing Sensitivity (MBS).
- 5. Licence borrowing: This feature allows borrowing a licence from one computer or server to another computer, typically to a laptop.

In the following these features are described more in detail.

Beside these main features bugs have been corrected, further input checks have been introduced and the following improvements of result and load plots are implemented:

- The number of modes in a figure for compact mode shape plots can be specified.
- The load plot for transient analyses also contains the denotation of the excitation functions in case "Load Values as List" is selected in the plot MADYN menu.



- 2 -

1. ALP3T Version 4.3

1.1 Selection of the Version

The version, which is used to calculate the linear fluid film bearing characteristics (Alp3t vers. 3.2 or vers. 4) can be selected under "Preferences" in the "Extras" menu (see figure below).

MADYN 2000 - DELTA JS	AG - C:\ProjekteLaufend\MADYN_2000\Tests\CURRE 🔲 🗖 🗙
Eile Model Loads Analyses Results	Extras Help
	Interfaces to MADYN Input Temperature Dependent MAT Input Shaft (ASE) from File Shaft Manipulation Input FDC from File Transform Dim. RFB Coeff.
	Preferences Use CD as Default All Figures in "wfigfixtif"-Files Alp3t Delete all the "wfigfixtif"-Files Use Alp3t vers.3.2 Close all Plots Allow Alp3t File Edit Close Plots for Image: Close Plots for
	Licence
	MADYN 2000 - Version 3.4 - 31.12.2009

Figure 1.1.1: Selection of the ALP3T version

1.2 Two Phase Flow for Linear Characteristics

In case version 4.3 of ALP3T is used a 2-phase flow model can be considered in the cavitation zones for "variable adiabatic" and "constant adiabatic" fluid film bearing analyses by activating a check box in the RFB GUI (see figure 1.2.1).

The model in the cavitation zones has some influence on the rotor dynamic bearing coefficients. The extent of the influence depends on the size of the cavitation zones. In the following a comparison is shown for results of a heavily loaded cylindrical bearing with two pads. The specific bearing load is 24.4bar. The geometry of the bearing can be seen in figure 1.2.2, the coefficients calculated by a "variable adiabatic" analysis in figure 1.2.3.



🛃 RFB -	RFBearing (fr	om: C:\\Ver	rsion_3.4\RFB	_Cylindrical 🔳		
Created: 13-0	Oct-2003 17:46:18					
RFBearing	Title: Cylindrical 2 L	obe Bearing		Origin: User Defined	~	
Geometry:	Diameter D [mm] 500	Width B [mm] 450	Pad Type Fixed 🗸	2 Pads S	Show	
	$\Psi = dR/_{D/2} []$	Ratio $\Psi_V = dS/_{dR}$		$\Delta \phi_{\rm F}$ = Range [rad]		
Clearance:	0.0018	1	0	0.05236		
Fluid:	Title: Name: Oil VG32 Sh 🗸	Inlet Temp. [C] 45	Inlet Pressure [N/m ²	2] Fluid Data		Check box to specify 2- phase flow
Analysis:	Type of Analysis: ALP3T_T=v_ad define File for Non-I	✓ 1 Load Case ∨ inear Data Import	2-phase	onlin. Data List Nonlin. R		
Cance	1			Print	it	

Figure 1.2.1: RFB GUI

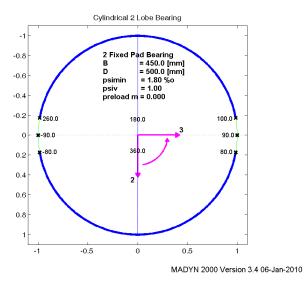


Figure 1.2.2: Bearing geometry of the examples



- 4 -

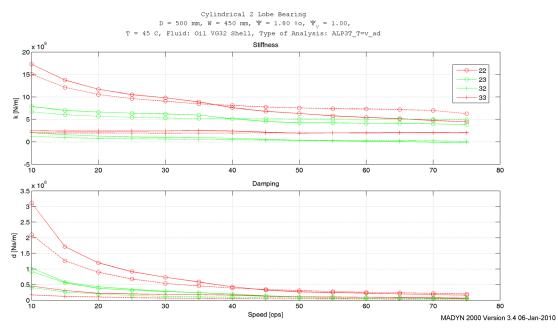


Figure 1.2.3: Rotor dynamic bearing coefficients with two phase flow (solid lines) and single phase flow (dashed lines)

The two phase flow model has been introduced for the analysis of the nonlinear bearing characteristics in version 3.1. This model yields much smoother fields for the non-linear force and thus causes fewer problems in the time integration for the non-linear equations of the rotor bearing system. This was the main reason for its introduction. Now it is possible to calculate consistent linear coefficients to the non-linear characteristics. Concerning the physical validity of the results please refer to /1/.



2. Import of Nonlinear Bearing Characteristics

For user defined and standard bearings nonlinear characteristics can be imported. The respective buttons in the RFB GUIs (see the figure below) start a dialogue to select a text file.

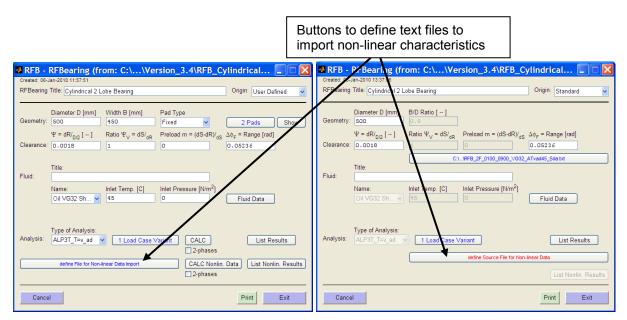


Figure 2.1: RFB GUIs for user defined and standard bearings

The text file must contain a list with the same columns as the list created by ALP3T (see figure 2.2).

luid Film Bearing Non-Linear Results:													
eps	gamma	FR/eta	eta_rel	So	alpha	betal1	beta12	beta21	beta22	gamma11	gamma12	gamma21	gamma22
0.0000	0.0	132.1397	0.0262	0.0016	9.3361	1.270e+01	5.292e+00	-8.244e+00	4.197e+01	2.383e+00	-5.808e+00	2.130e+01	4.534e+00
0.0050	90.0	153.2195	0.0201	0.1557	20.5937	1.588e+01	6.817e+00	-1.113e+01	5.290e+01	3.476e+00	-7.710e+00	2.820e+01	5.629e+00
0.1045	90.0	23,7289	0.1402	0.3899	12.2536	3.220e+00	6.899e-01	-1.544e+00	6.942e+00	5.143e-01	-1.144e+00	3.590e+00	9.012e-01
0.2040	90.0	19,1045	0.1925	0.6349	8,9718	3.093e+00	6.523e-01	-8,569e-01	5.449e+00	7.297e-01	-8.241e-01	2.945e+00	1.133e+00
0.3035	90.0	15.3666	0.2601	0.7950	11.0139	2.969e+00	8.300e-01	-4.415e-01	4.665e+00	1.040e+00	-5.607e-01	2.732e+00	1.316e+00
0.4030	90.0	13.1525	0.3206	0.9914	14.2008	3.140e+00	1.103e+00	-1.396e-01	4.391e+00	1.515e+00	-2.944e-01	2.885e+00	1.661e+00
0.5025	90.0	11.7555	0.3736	1.2383	18.1149	3.602e+00	1.473e+00	1.515e-01	4.403e+00	2.253e+00	5.913e-02	3.359e+00	2.135e+00
0.6020	90.0	10.8354	0.4175	1.5538	21.7735	4.137e+00	1.878e+00	4.903e-01	4.550e+00	3.372e+00	6.105e-01	4.182e+00	2.848e+00
0.7015	90.0	9.7656	0.4629	1.8836	24.9728	4.665e+00	2.271e+00	8.372e-01	4.687e+00	4.977e+00	1.436e+00	5.390e+00	3.755e+00
0.8010	90.0	8,7104	0.5070	2.3695	29.2549	6.395e+00	3.063e+00	1.265e+00	5.131e+00	8.290e+00	2.906e+00	7.578e+00	5.159e+00
D.8458	90.0	8.5776	0.5180	2.7757	32.3333	5.520e+00	3.715e+00	3.525e+00	5.533e+00	1.174e+01	4.274e+00	9.490e+00	6.271e+00
0.8955	90.0	8.5990	0.5231	3.4380	36.6524	7.562e+00	4.880e+00	4.737e+00	6.203e+00	1.974e+01	7.156e+00	1.348e+01	8.219e+00
0.9154	90.0	8.6841	0.5258	3.8355	38,8003	9.069e+00	5.543e+00	5.354e+00	6.542e+00	2.577e+01	9.241e+00	1.624e+01	9.451e+00
0.9353	90.0	8.8322	0.5238	4.3563	41.2814	1.127e+01	6.445e+00	6.172e+00	7.003e+00	3.537e+01	1.246e+01	2.042e+01	1.120e+01
0.9552	90.0	9.0560	0.5187	5.0921	44.2182	1.464e+01	7.674e+00	7.249e+00	7.585e+00	5.215e+01	1.788e+01	2.715e+01	1.382e+01
0.9651	90.0	9.1893	0.5171	5.5482	45.9918	1.712e+01	8.519e+00	7.963e+00	7.969e+00	6.563e+01	2.200e+01	3.220e+01	1.556e+01
0.9751	90.0	9.3861	0.5131	6.1746	47.9389	1.853e+01	9.539e+00	9.359e+00	8.390e+00	8.624e+01	2.828e+01	3.954e+01	1.813e+01
0.9801	90.0	9.5260	0.5087	6.5881	49.0083	2.032e+01	1.013e+01	9.918e+00	8.638e+00	1.010e+02	3.284e+01	4.465e+01	1.998e+01
0.9851	90.0	9.6777	0.5052	7.0458	50.1462	2.254e+01	1.086e+01	1.058e+01	8.925e+00	1.200e+02	3.846e+01	5.093e+01	2.208e+01
n neen	60.0	0 7.401	0 50.49	7 2264	ED 0007	2 /126101	1 127-101	1 105-101	0.112+100	1 227-102	4 227-101	E E20x101	2 2425101

Figure 2.2: Non-linear bearing characteristic



3. Shaft Output via SIF

A flexible format for importing shafts can be defined in a so called SIF file. SIF stands for **S**haft Interface **F**ile. The same interface file can now be used to export a shaft to a text file. The context menu of the shaft GUI, which is opened by a right mouse click, now has the additional items "Export with SIF" and "Export with default SIF" (see figure 3.1). The first item asks for a SIF file, in case of the second item the default SIF file stored in the preferences folder is used. The SIF MATLAB mat files must be created beforehand from a SIF text file (same procedure as for the import).

SFT - Shaft (default)	
Created: 06-Jan-2010 15:14:40	
Number: 1 Title: Shaft Title	Speed: 50.00 rps
Material with	h: 25 Stations & 24 Sections
Denotation: Steel	Load Material
	Menu items to
El. Modulus [N/m ²] Poisson's Ratio Density [kg/m ³]	add Magnetic Bearing export the shaft
2.059e+011 0.3 7850	
Strength: Yield S. [N/m ²] Ultimate S. [N/m ²]	Сору
	Paste
	Load
TLA case:> DoF = [1 0 0 1 0 0]	Save
4) · Lateral 1-23 · FREE (*)	Save as
	MIF creation
	Export with SIF
Cancel	Export with default SIF it *

Figure 3.1: Shaft GUI with the context menu and two new items for the export via SIF

The SIF text file and exported shaft text file of the demonstration example on the MADYN 2000 CD in the folder "Shaft_Input_w_EXCEL" are shown on the following page.



- 7 -

SIF text file from which a SIF mat file must be created:

Shaft

Conical	Length	IDsb	IDmb	IDst	ODsb	ODmb	ODst	М	Thetap	Thetae	Centre	addmass	addinertiap	addinertiab	Temperature	Denotation
-	MM	MM	MM	MM	MM	MM	MM	KG	KG_M^2	KG_M^2	MM	KG/M	KG_M^2/M	KG_M^2/M	С	-
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SFT																

Exported text file of the shaft model:

Shaft	Shaft Title																
* #	Conical	Length	IDsb	IDmb	IDst	ODsb	ODmb	ODst	М	Thetap	Thetae	Centre	addmass	addinertiap	addinertiab	Temperature	Denotation
*	[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[kg]	[kg m^2]	[kg m^2]	[mm]	[kg/m]	[kg m^2/m]	[kg m^2/m]	[C]	[-]
1	0	166.7	0	0	0	130	130	130	0	0	0	0	0	0	0	40	
2	0	23.3	0	0	0	130	130	130	0	0	0	0	0	0	0	40	
3	0	60	0	0	0	130	130	130	0	0	0	0	0	0	0		'Coupling connection'
4	0	200.5	0	0	0	140	140	140	0	0	0	0	0	0	0	40	11
5	0	15	0	0	0	156	156	156	0	0	0	0	0	0	0	40	
6	0	45	0	0	0	172.5	172.5	172.5	0	0	0	0	0	0	0	40	
7	0	44.5	0	0	0	172.5	172.5	172.5	0	0	0	0	0	0	0	40	'DE bearing'
8	0	73	0	0	0	200	200	200	0	0	0	0	0	0	0	40	11
9	0	226.4	0	0	0	247.4	247.4	247.4	50	3	1.5	-100	1500	150	75		'End windings'
10	0	205.1	0	0	0	247.4	247.4	247.4	0	0	0	0	1500	150	75	40	
11	0	205.1	0	0	0	247.4	247.4	247.4	0	0	0	0	1500	150	75	40	
12	0	205.1	0	0	0	247.4	247.4	247.4	0	0	0	0	1500	150	75		'Centre of lamination'
13	0	205.1	0	0	0	247.4	247.4	247.4	0	0	0	0	1500	150	75	40	
14	0	226.4	0	0	0	247.4	247.4	247.4	0	0	0	0	1500	150	75	40	
15	0	147	30	30	30	200	200	200	50	3	1.5	100	0	0	0		'End windings'
16	0	50	30	30	30	172.5	172.5	172.5	0	0	0	0	0	0	0	40	
17	0	82	30	30	30	149	149	149	0	0	0	0	0	0	0	40	
18	0	136.5	30	30	30	149	149	149	0	0	0	0	0	0	0	40	
19	0	60	30	30	30	149	149	149	0	0	0	0	0	0	0	40	
20	0	32	30	30	30	149	149	149	0	0	0	0	0	0	0	40	
21	0	44	30	30	30	131	131	131	0	0	0	0	0	0	0	40	
22	0	44	30	30	30	131	131	131	0	0	0	0	0	0	0		'NDE bearing'
23	1	140	30	30	30	131	131	131	0	0	0	0	0	0	0	40	
23	1	0	30	30	30	120	120	120	0	0	0	0	0	0	0	40	
24	0	84	30	30	30	90	90	90	0	0	0	0	0	0	0	40	



- 8 -

4. Magnetic Bearing Sensitivity MBS

This type of harmonic response analysis allows checking the magnetic bearing sensitivity according to ISO 14839-3. The analysis is defined by a new type of load called "Magnetic Bearing Sensitivity". Figure 4.1 shows how to open the load GUI from the system explorer. The load GUI itself is shown in figure 4.2. The MBS load GUI contains a list of all actuators of the system and their directions for selection to calculate the sensitivity.

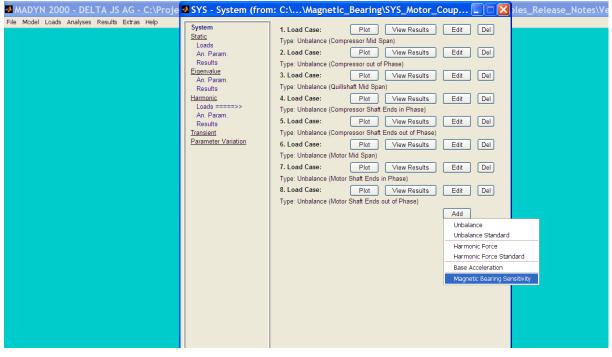


Figure 4.1: Opening the load GUI for MBS

🛿 MBS - MagBearingSens (from: Harmonic)										
Created: 06-Jan-2010 16:19:07										
MagBearingSens: 1 v Title:										
No results are calculated for this Load Case: Options										
Shaft 1 (Motor & Cplg Hub), Station 6 (NDE Actuator), Dir.2 (selected) Shaft 1 (Motor & Cplg Hub), Station 6 (NDE Actuator), Dir.3 Shaft 1 (Motor & Cplg Hub), Station 24 (DE Actuator), Dir.2 (selected) Shaft 1 (Motor & Cplg Hub), Station 24 (DE Actuator), Dir.2 Shaft 3 (Compressor & Cplg Hub), Station 10 (Actuator), Dir.3 Shaft 3 (Compressor & Cplg Hub), Station 10 (Actuator), Dir.3 Shaft 3 (Compressor & Cplg Hub), Station 35 (Actuator), Dir.3										
TT: Actuator part of bearings with tilting translation controllers										
*: Actuator part of several bearings Select Delete Select All Delete All										
Cancel Delete < Add << >> Add > Exit *										

Figure 4.2: MBS load GUI



- 9 -

The analysis GUI is shown in figure 4.3. It now contains a check box for the new analysis type "Magnetic Bearing Sensitivity". Other parameters are similar to the harmonic force response analysis HAF.

AHR - AnHARCond (from: Harmonic)	
Created: 06-Jan-2010 16:35:42	
AnHARCond: 3 Vitle:	
	No results are calculated for this Analysis: Options
● Ignore RFB/FRB	Magnetic Bearing Sensitivity
◯ Loads from Static Results	Synchronous Excitation
O Direct Loads Input	Define Excitation Frequencies: Start Value: 1 Hz
	End Value: 1000 Hz
	Step df/f: 0.1
	Linear Row
	Rel. Speed: 100.00 %
	Struct. Damp.: 1 %
	Result Selection Change Selection
	Select Load Cases and Calculate
Cancel Delete	< Add << << >> >> Add > Exit *

Figure 4.3:Harmonic response analysis GUI

The result of the magnetic bearing sensitivity analysis is a transfer function. The sensitivities of all actuators of the magnetic bearing demonstration example are shown in figure 4.4. According to ISO 14839-3 the allowable level for newly commissioned machines is less than 3, which is fulfilled in the current case. For more details see the latest MADYN 2000 documentation and the ISO standard /2/.

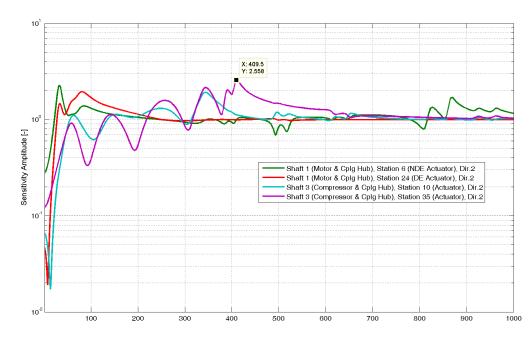


```
- 10 -
```

Motor Coupling Compressor

Harmonic Response Analysis Load case: MagBearingSens Analysis: 06-Jan-2010 16:43:06 - 1387 exc.freq(s) Result Type: Magnetic Bearing Sensitivity

Struct. Damping: 1 % Relative Speed: 1.000



MADYN 2000 Version 3.4 06-Jan-2010

Figure 4.4: Magnetic bearing sensitivities



- 11 -

5. Licence Borrowing

Licences can be borrowed to another computer. For the borrowing computer the following requirements must be fulfilled:

- MADYN 2000 must be installed.
- The computer must have a licence for zero users. This licence must be requested from DELTA JS.

To borrow a licence a special program must be started from the WINDOWS start menu (see the following figure) on the lending computer.

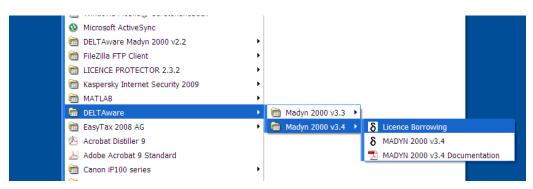


Figure 5.1: Starting the licence borrowing program

The lending computer must have a normal single PC licence or a concurrent licence. Moreover it must have all access rights to the licence file on the borrowing computer. The window of the licence borrowing program with two panes for the lending and borrowing computer is shown in figure 5.2. When transferring a licence, the number of licences on the lending computer is reduced by one. When transferring the licence back it is added again. Please refer to the latest MADYN 2000 documentation for more details.

δΛ	ADYN 2000	Licence Borrowing				
LLE M LL C LL T M	Inder Licence File IADYN 2000 Version: C:\Programme\Gemein icences: Justomer: icence Type: rial: IADYN 2000 Version:	3.4 nsame Dateien\DeltaJS Shared\licence\3.4.0 1 DELTA JS licence per 1 computer no limit	DJSMD2Licence.lic	Borrower Licence File Select Select Icences: Borrower Licence Licences: Borrowed up to: Licence File ID:	File>	
B	orrowers:					
s	tatus:		Transf << Trans	er >> sfer Back	for 1 days	
						Done

Figure 5.2: Window of the licence borrowing program



- 12 -

6. References

- /1/ Andreas Fuchs: Schnelllaufende Radialgleitlagerungen im instationären Betrieb, Dissertation TU Braunschweig und FVV Bericht Frankfurt, 2002.
- /2/ ISO Standard 14839-3: Mechanical vibration Vibration of rotating machinery equipped with active magnetic bearings – Part 3: Evaluation of stability margin