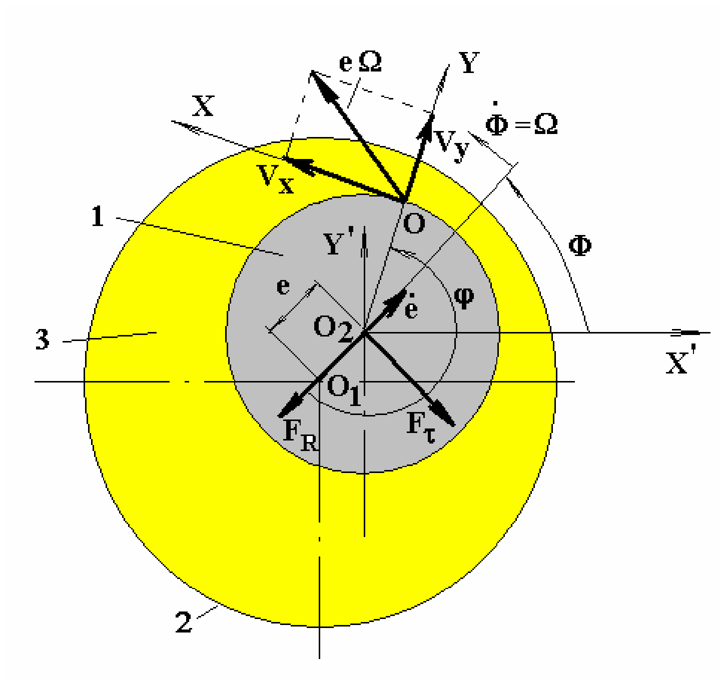
TRANSIENT RESPONSE OF ROTOR MODEL

BACKGROUNDS



1 – vibrator;
2 – case;
3 – clearance with oil

Nomenclature:
δ – clearance, m;
e – orbit radius;
ε=e/δ - eccentricity;
ω - angle rotation speed;
Ω - whirl speed;
R- damper radius, m;
L - damper length, m;
μ – dynamical viscosity, Ns/m^2;
K – stiffness coefficient;
C – damping coefficient

Fig.1 Squeeze-film damper model

Table 1

Approximate models of the damper performances (laminar flow, ε= const)

Type of film	"Short" damper	
	K	*C*
π – film	$\frac{RL^3\mu\omega}{\delta^3}\cdot\frac{2\varepsilon}{(1-\varepsilon^2)^2}$	$\frac{RL^3\mu}{2\delta^3}\cdot\frac{\pi}{(1-\varepsilon^2)^{3/2}}$
2π - film	0	$\frac{RL^3\mu}{\delta^3}\cdot\frac{\pi}{(1-\varepsilon^2)^{3/2}}$
Type of film	**"Long" damper**	
	K	*C*
π – film	$\frac{R^3L\mu\omega}{\delta^3}\cdot\frac{24\varepsilon}{(2+\varepsilon^2)(1-\varepsilon^2)}$	$\frac{R^3L\mu}{\delta^3}\cdot\frac{12\pi}{(2+\varepsilon^2)(1-\varepsilon^2)^{1/2}}$
2π - film	0	$\frac{R^3L\mu}{\delta^3}\cdot\frac{24\pi}{(2+\varepsilon^2)(1-\varepsilon^2)^{1/2}}$

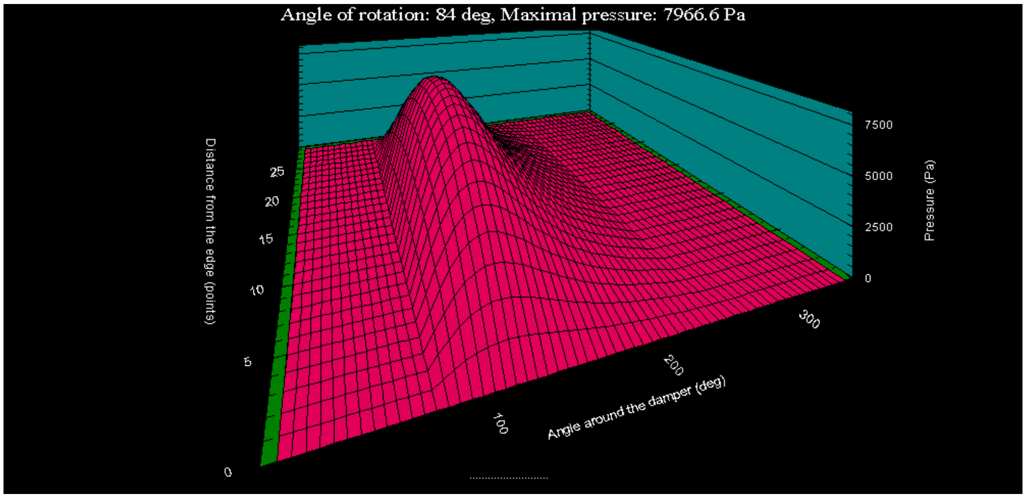


Fig. 2. Pressure distribution in squeeze-film damper
δ =0.228 mm; l = 12.7 mm; D=104.3 mm; μ=0.0217; n = 1000 rpm; ε=0.4
Reynolds boundary conditions

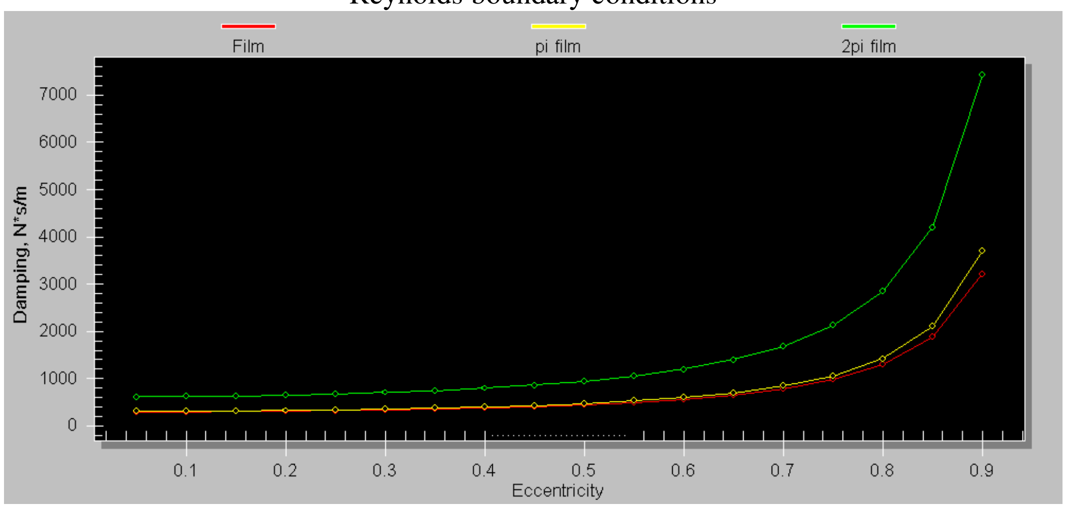


Fig. 3. Damping characteristics of squeeze-film damper
δ =0.228 mm; l = 12.7 mm; D=104.3 mm; μ=0.0217; n = 1000 rpm; ε=0.4;
Red line – Reynolds boundary conditions

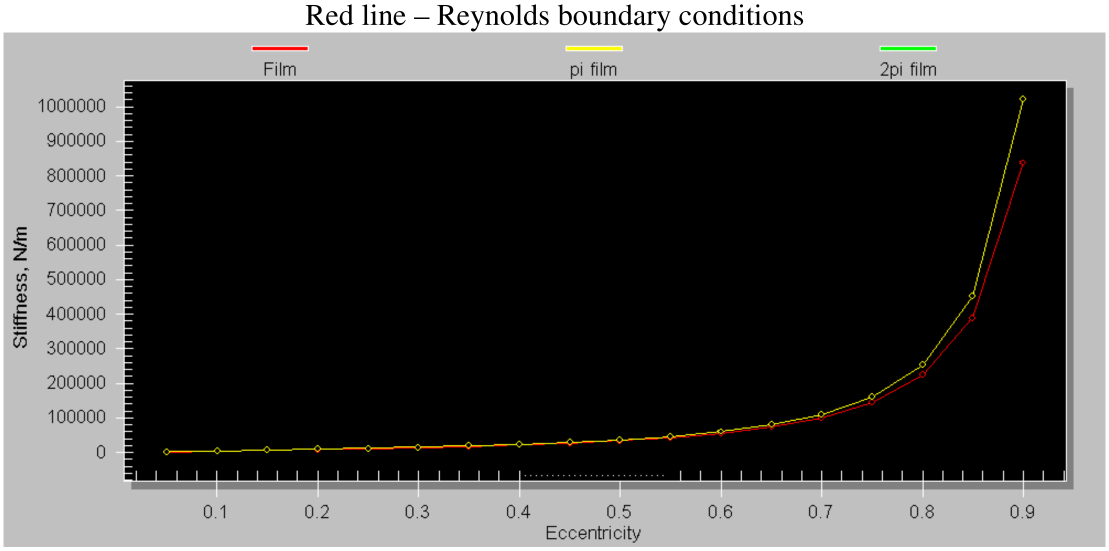


Fig. 4. Stiffness characteristics of squeeze-film damper
δ =0.228 mm; l = 12.7 mm; D=104.3 mm; μ=0.0217; n = 1000 rpm supports; ε=0.4;
Red line – Reynolds boundary conditions

HYDRODYNAMIC FORCES (LAMINAR FLOW)

Table 2

Type of film	"Short" damper	
	F_R	F_τ
π – film	$F_R = \mu \cdot R \cdot \frac{L^3}{\delta^2} \left[\frac{\pi}{2} \cdot \frac{1+2\cdot\varepsilon^2}{(1-\varepsilon^2)^{\frac{5}{2}}} \cdot \dot{\varepsilon} + \frac{2\cdot\Omega\cdot\varepsilon^2}{(1-\varepsilon^2)^2} \right]$	$F_\tau = \mu \cdot R \cdot \frac{L^3}{\delta^2} \left[\frac{2\cdot\varepsilon\cdot\dot{\varepsilon}}{(1-\varepsilon^2)^2} + \frac{\pi}{2} \cdot \frac{\varepsilon\cdot\Omega}{(1-\varepsilon^2)^{\frac{3}{2}}} \right]$
2π - film	$F_K = \pi \cdot \mu \cdot R \cdot \frac{L^3}{\delta^2} \cdot \frac{1+2\cdot\varepsilon^2}{(1-\varepsilon^2)^{\frac{5}{2}}} \cdot \dot{\varepsilon}$	$F_\tau = \pi \cdot \mu \cdot R \cdot \frac{L^3}{\delta^2} \cdot \frac{\varepsilon\cdot\Omega}{(1-\varepsilon^2)^{\frac{3}{2}}}$
Type of film	**"Long" damper**	
	F_R	F_τ
π – film	$F_R = 6 \cdot \mu \cdot L \cdot \frac{R^3}{\delta^2} \left[\frac{\pi\cdot\dot{\varepsilon}}{(1-\varepsilon^2)^{\frac{3}{2}}} + \frac{4\cdot\Omega\cdot\varepsilon^2}{(2+\varepsilon^2)(1-\varepsilon^2)} \right]$	$F_\tau = 12 \cdot \mu \cdot L \cdot \frac{R^3}{\delta^2} \left[\frac{2\cdot\dot{\varepsilon}}{(1-\varepsilon^2)(1-\varepsilon^2)} + \frac{\pi\cdot\varepsilon\cdot\Omega}{(2+\varepsilon^2)(1-\varepsilon^2)^{\frac{1}{2}}} \right]$
2π - film	$F_R = 12 \cdot \pi \cdot \mu \cdot L \cdot \frac{R^3}{\delta^2} \cdot \frac{\dot{\varepsilon}}{(1-\varepsilon^2)^{\frac{3}{2}}}$	$F_\tau = 24 \cdot \pi \cdot \mu \cdot L \cdot \frac{R^3}{\delta^2} \cdot \frac{\varepsilon\cdot\Omega}{(2+\varepsilon^2)(1-\varepsilon^2)^{\frac{1}{2}}}$

EXAMPLES OF CALCULATIONS AND OUTPUTS – LINEAR SPRING SUPPORTS

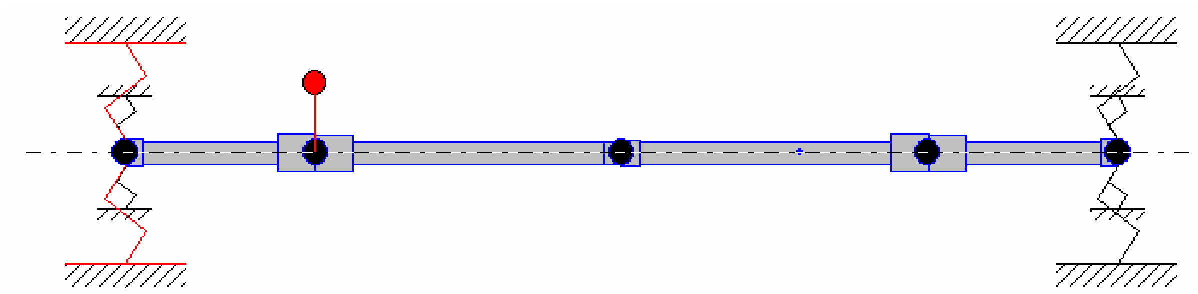


Fig. 5. Rotor model with disks and two supports

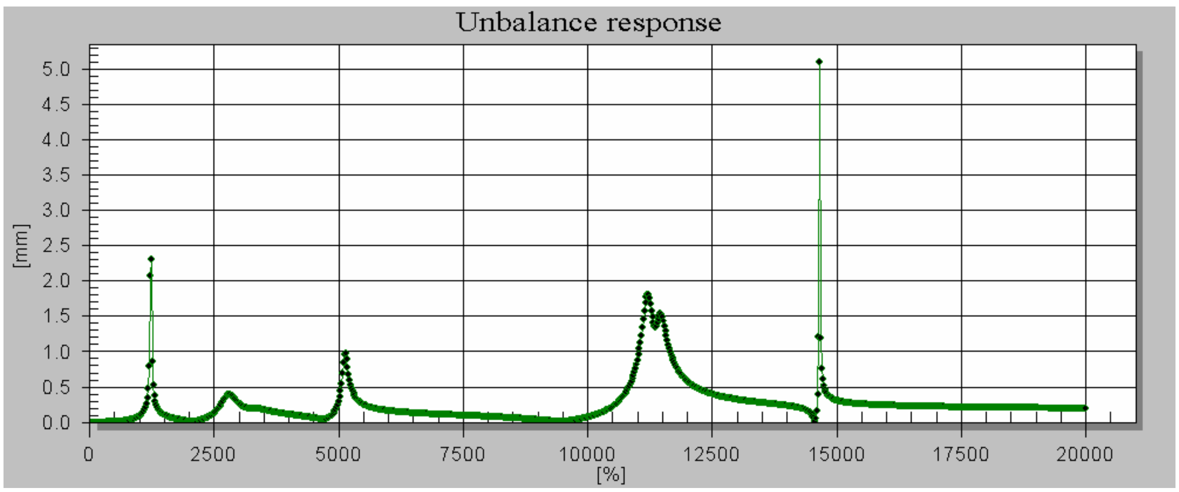


Fig. 6. Unbalance steady-state response plot (unbalance section)

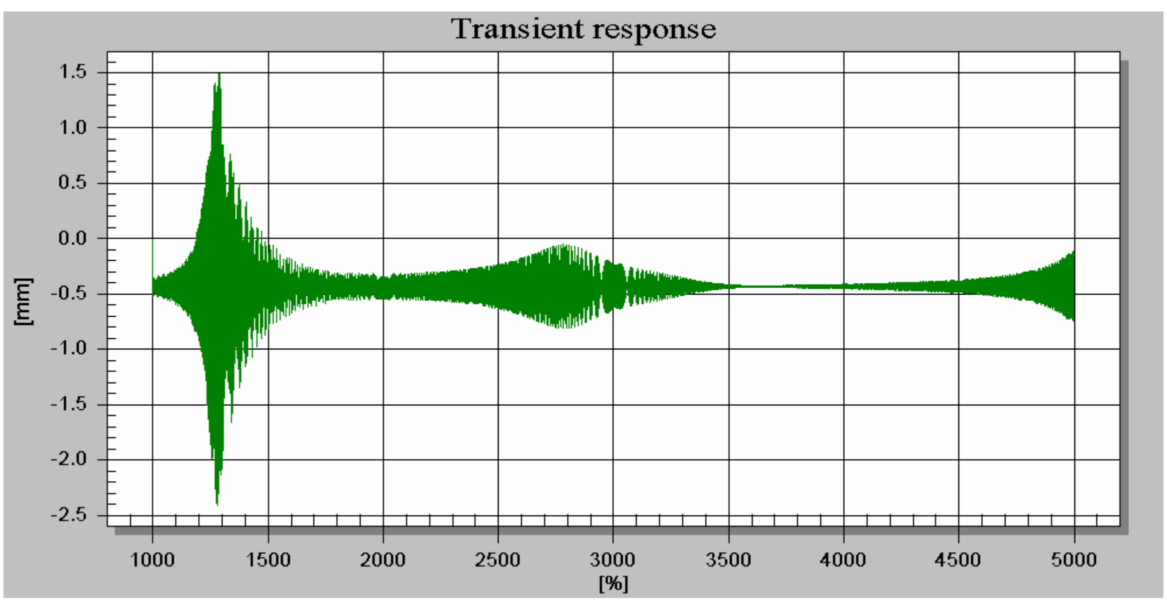


Fig. 7 Unbalance transient response plot
(ordinary Runge-Kutta method/time step 0.001 s/unbalance section)

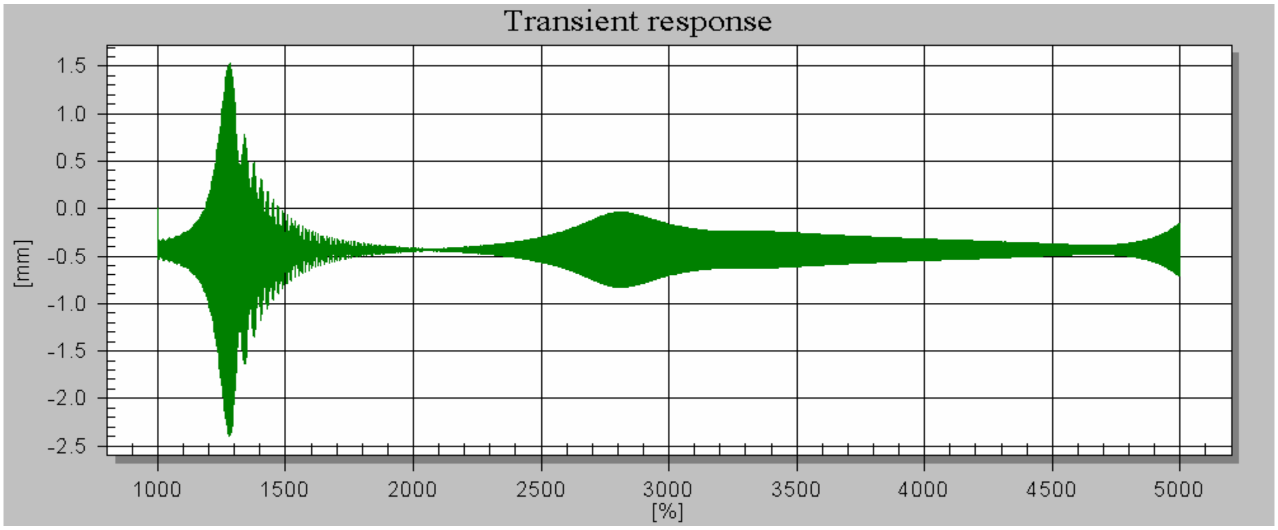


Fig. 8 Unbalance transient response plot
(ordinary Runge-Kutta method/time step 0.0001 s/unbalance section)

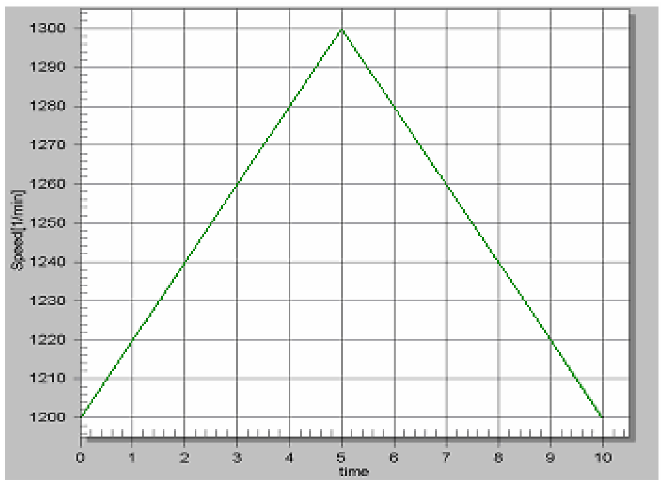


Fig 9 Rotor speed diagram

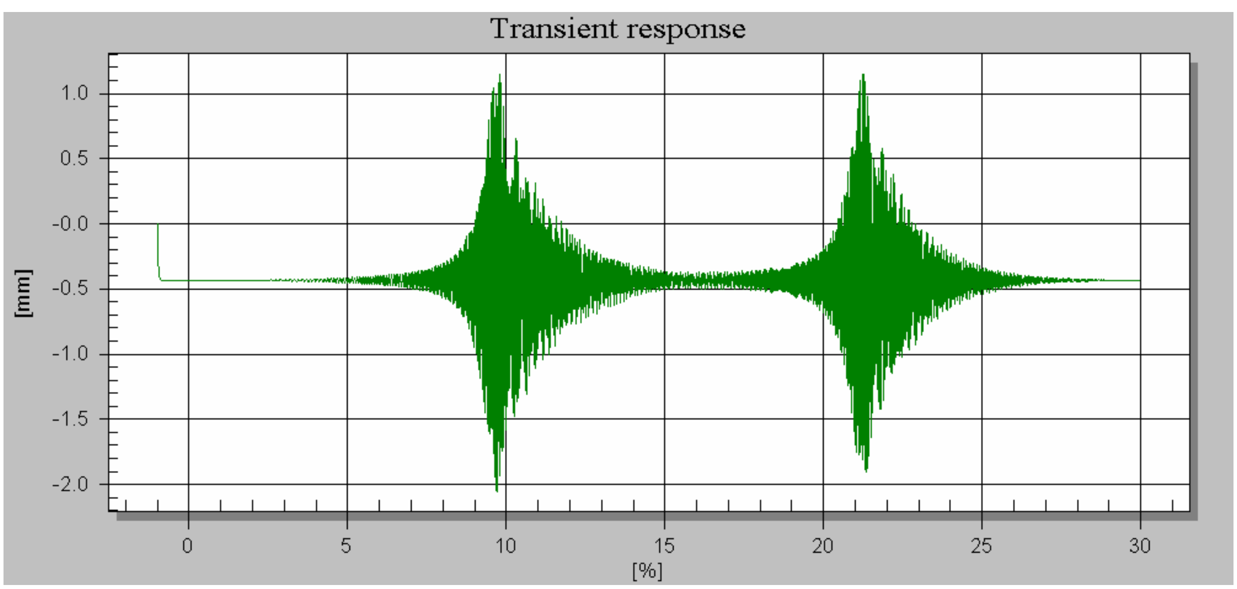


Fig 10 Acceleration and deceleration transient response plot
(/unbalance section)

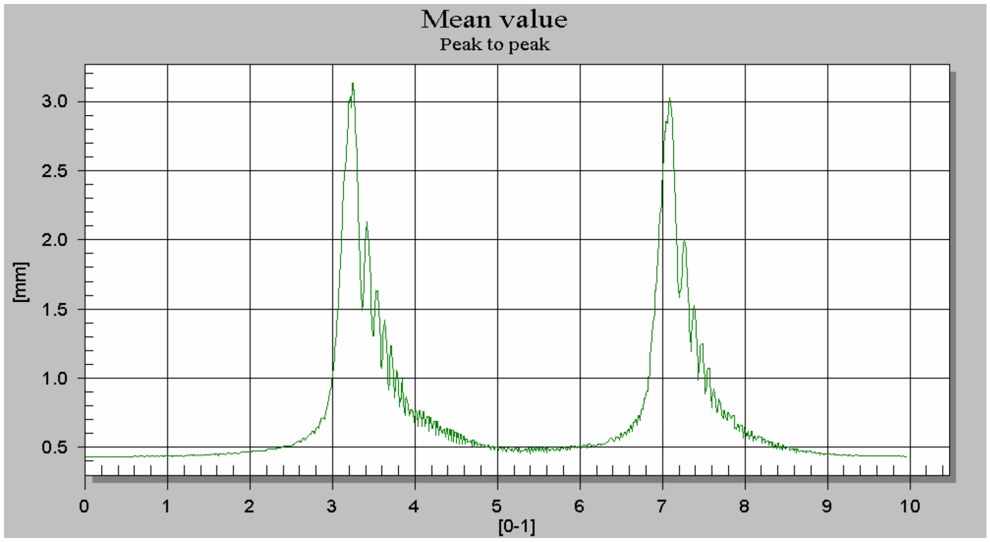


Fig 11 Acceleration and deceleration transient response plot
(peak to peak /unbalance section)

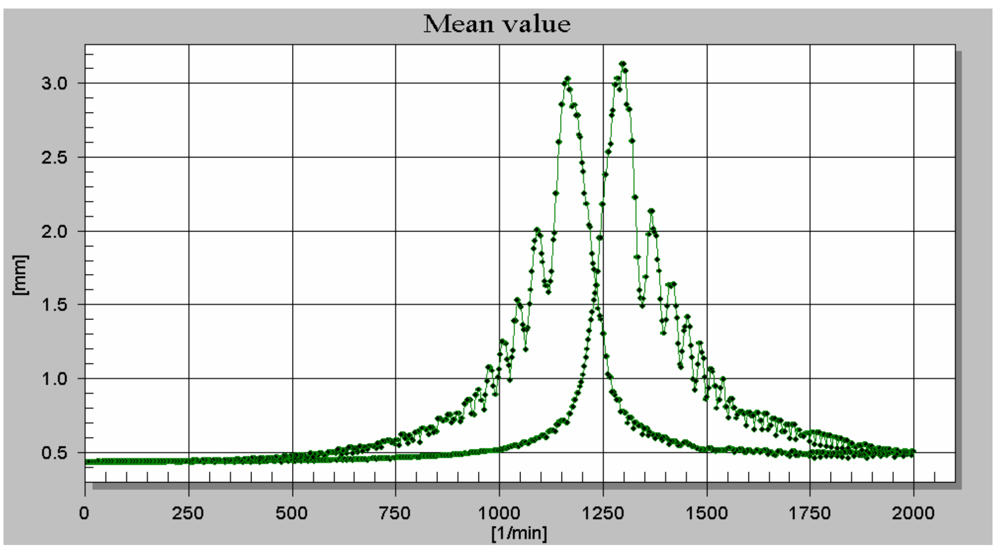


Fig 12 Overlapped acceleration and deceleration rotor transient response plot
(peak to peak/unbalance section)

EXAMPLES OF CALCULATIONS AND OUTPUTS – DAMPER SUPPORTS

Spring supports replaced by two squeeze-film dampers

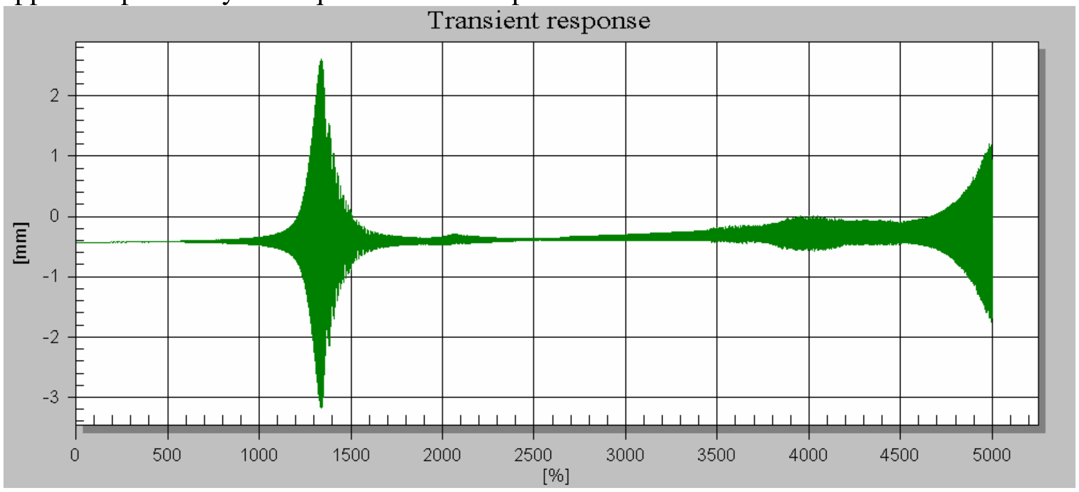


Fig. 13 Unbalance transient response plot (unbalance section)

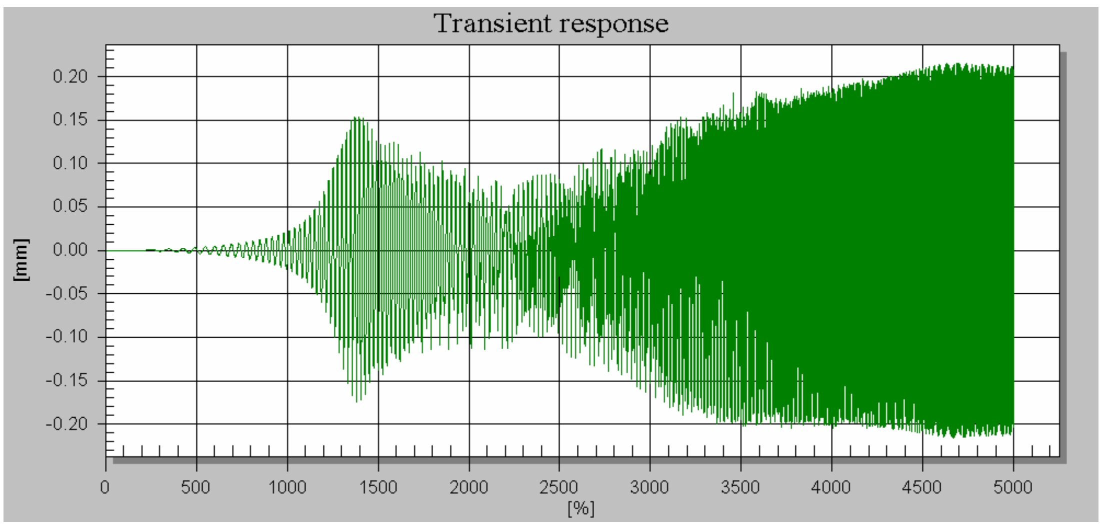


Fig. 14 Unbalance transient response of rotor (damper section)

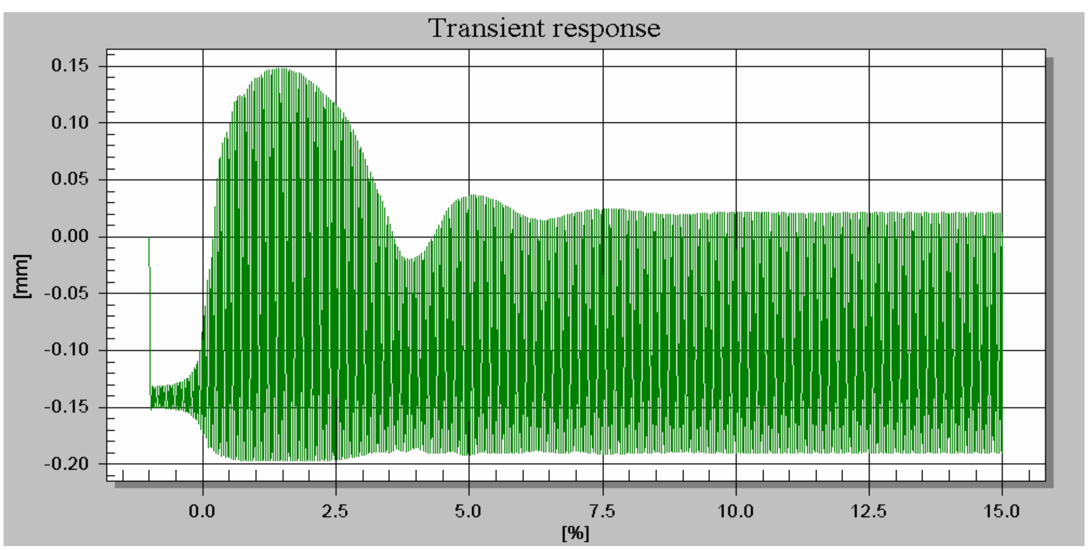


Fig. 15 Solution output, n = 1300 rpm (damper section)

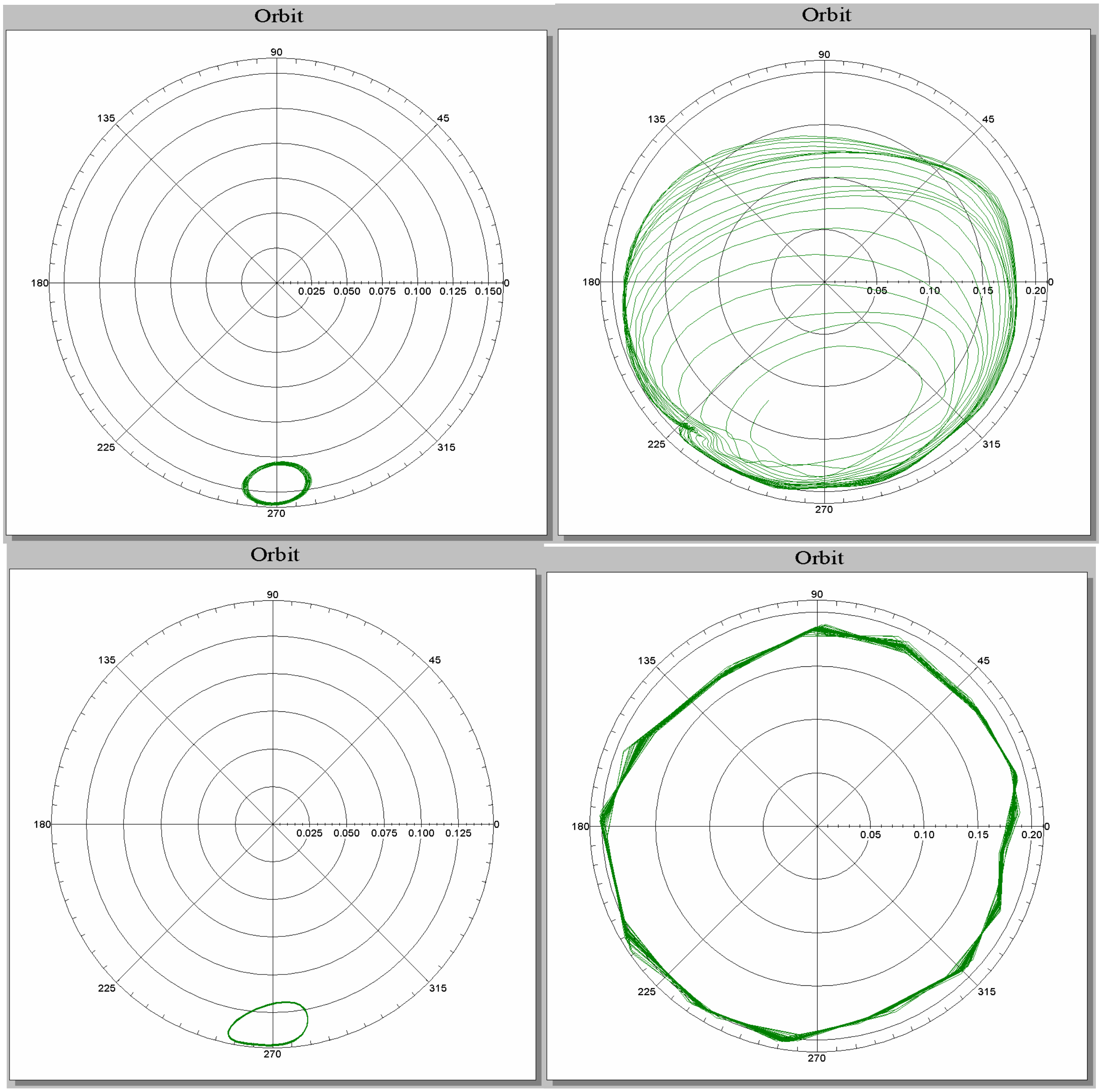


Fig. 16 Rotor orbits for different rotation speeds n= 1000, 1300, 2000, 4000 rpm

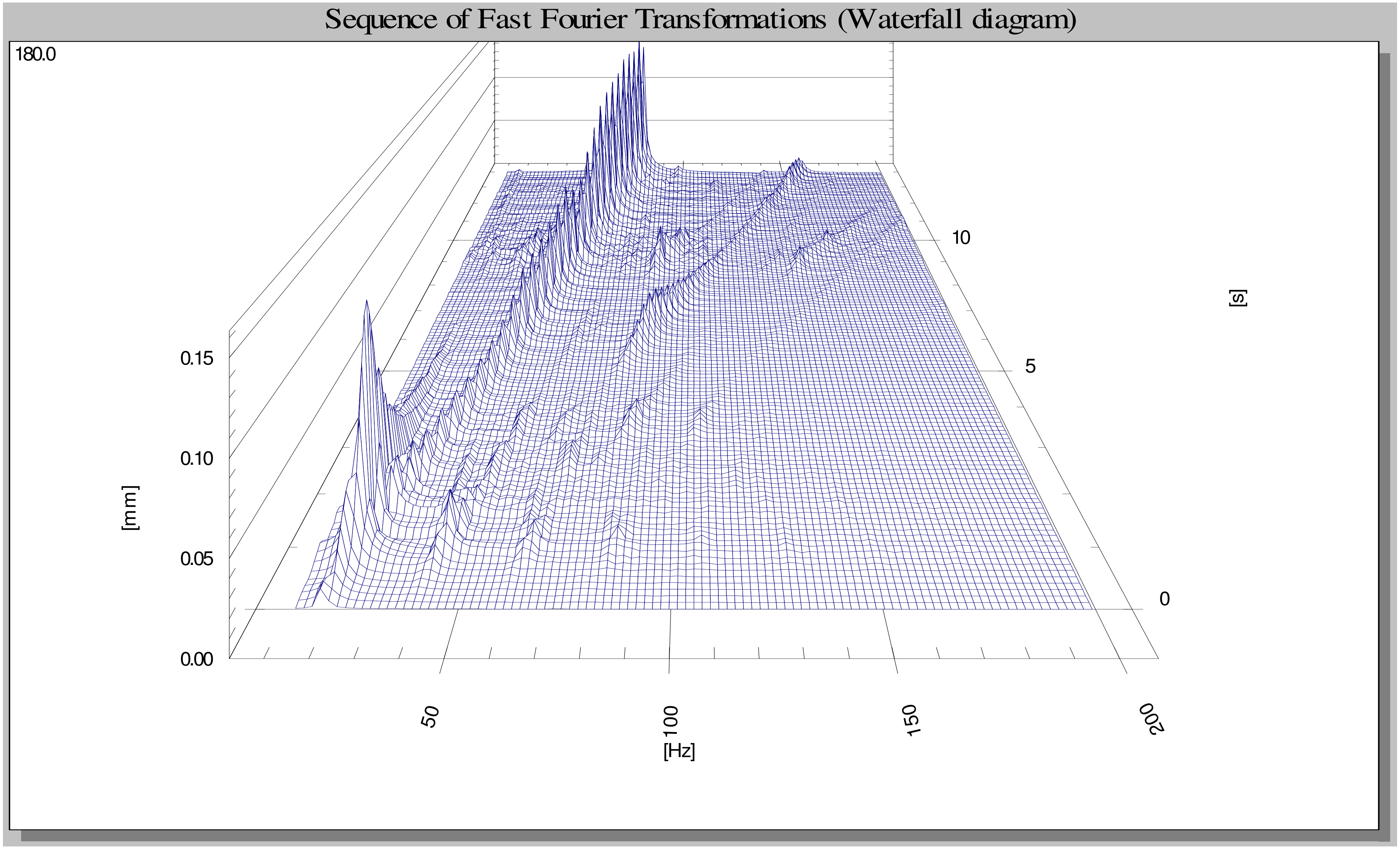


Fig. 17 Cascade spectra plot for rotor with two squeeze film-dampers

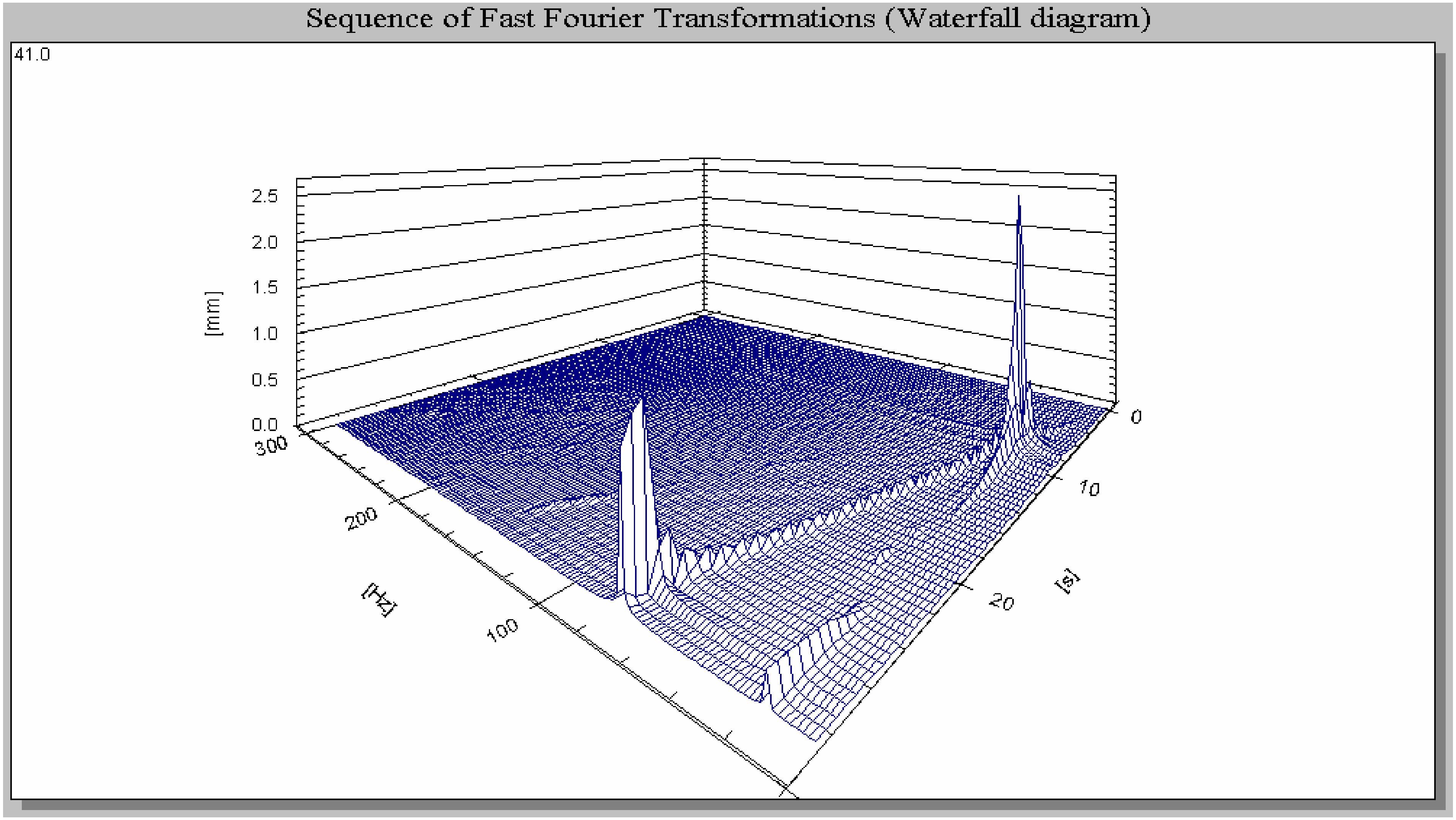


Fig. 18 Cascade spectra plot for rotor with two squeeze film-damper

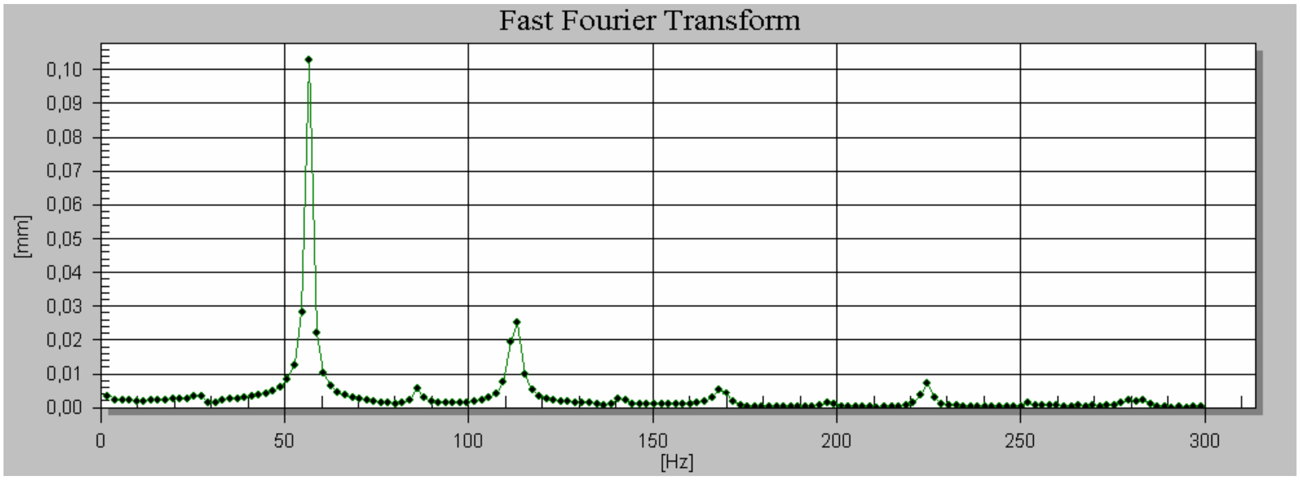


Fig.19. FFT spectrum plot