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Probability and Sensitivity Analysis of Machine Foundation and Soil Interaction

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Abstract

This paper deals with the possibility of the sensitivity and probabilistic analysis of the reliability of the machine foundation depending on variability of the soil stiffness, structure geometry and compressor operation. The requirements to design of the foundation under rotating machines increased due to development of calculation method and computer tools. During the structural design process, an engineer has to consider problems of the soil-foundation and foundation-machine interaction from the safety, reliability and durability of structure point of view. The advantages and disadvantages of the deterministic and probabilistic analysis of the machine foundation resistance are discussed. The sensitivity of the machine foundation to the uncertainties of the soil properties due to longtime rotating movement of machine is not negligible for design engineers. On the example of compressor foundation and turbine fy. SIEMENS AG the affectivity of the probabilistic design methodology was presented. The Latin Hypercube Sampling (LHS) simulation method for the analysis of the compressor foundation reliability was used on program ANSYS. The 200 simulations for five load cases were calculated in the real time on PC. The probabilistic analysis gives us more complex information about the soil-foundation-machine interaction as the deterministic analysis.

Keywords: probability, sensitivity, dynamics, compressor, foundation, LHS, SSI, ANSYS

1. Introduction

The requirements to design of the foundation under rotating machines increased due to development of calculation method and computer tools. The Eurocodes and national standard define much of these requirements [3, 5, 8]. During the structural design process, an engineer has to consider problems of the soil-foundation and foundation-machine interaction in the point of view of the safety, reliability and durability of the structures.

Behavior of soil and structures depends on character and intensity of dynamic load. Material characteristic of soil and structures depends on velocity of strain and stress intensity. Randomness in the loading and the environmental effects, the variability of the material and geometric characteristics of structures and many other ”uncertainties” affecting errors in the computing model lead to a situation where the actual behavior of a structure is different from the modeled one [6, 8, 9, 11, 14, 17].

During the structural design process, an engineer has to consider problems of the safety, reliability and durability of machine foundations from the point of view of its planned life cycle. Recent advances and the general accessibility of information technologies and computing techniques give rise to assumptions concerning the wider use of the probabilistic assessment of

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the reliability of structures through the use of simulation methods [5, 6, 8, 9, 10, 11, 12, 14, 16, 17]. Much attention should be paid to using the probabilistic approach in an analysis of the reliability of structures [3, 5, 14, 17].

Most problems concerning the reliability of building structures are defined today as a comparison of two stochastic values, loading effects E and the resistance R, depending on the variable material and geometric characteristics of the structural element. The variability of those parameters is characterized by the corresponding functions of the probability density $f_R(r)$ and $f_E(e)$, see fig. 1.

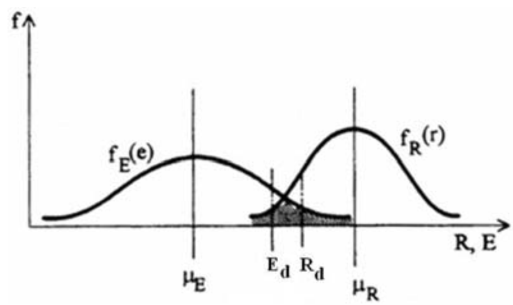

Fig. 1. Functions of the probability density $f_R(r)$ and $f_E(e)$

In the case of a deterministic approach to a design, the deterministic (nominal) attributes of those parameters R_d and E_d are compared.

The deterministic definition of the reliability condition has the form

$$R_d \geq E_d \tag{1}$$

and in the case of the probabilistic approach, it has the form

$$RF = R - E \geq 0, \tag{2}$$

where RF is the reliability function, which can be expressed generally as a function of the stochastic parameters X_1, X_2 to X_n, used in the calculation of R and E,

$$RF = g(X_1, X_2, \ldots, X_n). \tag{3}$$

The failure function $g(\boldsymbol{X})$ represents the condition (reserve) of the reliability, which can either be an explicit or implicit function of the stochastic parameters and can be single (defined on one cross-section) or complex (defined on several cross-sections, e.g., on a complex finite element model).

The most general form of the probabilistic reliability condition is given as follows:

$$p_f = P(R - E < 0) \equiv P(RF < 0) < p_d, \tag{4}$$

where p_d is the so-called design ("allowed" or "acceptable") value of the probability of failure. From the analytic formulation of the probability density by the functions $f_R(r)$ and $f_E(e)$ and the corresponding distribution functions $\Phi_R(x)$ and $\Phi_E(x)$, the probability of failure can be defined in the general form:

$$p_f = \int_{-\infty}^{\infty} \mathrm{d}p_f = \int_{-\infty}^{\infty} f_E(x)\Phi_R(x)\,\mathrm{d}x = \int_{-\infty}^{\infty} \Phi_E(x) f_R(x)\,\mathrm{d}x. \tag{5}$$

Except of p_f the target reliability index β is used as the measure of reliability, which is defined on assumption of linear failure function $g(\boldsymbol{X})$. In the case of normal (or lognormal) histograms of this function, we have

$$\beta = \frac{\mu_{RF}}{\sigma_{RF}}, \tag{6}$$

where μ_{RF} and σ_{RF} are mean values and standard deviation of reliability function defined in the form

$$\mu_{RF} = \mu_R - \mu_E, \qquad \sigma^2_{RF} = \sigma^2_R + \sigma^2_E. \tag{7}$$

The integral in the formulation (5) can be solved analytically only for simple cases (6); in a general case it should be solved using numerical integration methods after discretization.

The reliability criteria are defined in the Eurocode in dependency on reliability index β, what is adequate to target level of failure probability (table 1).

Table 1. Target reliability index β and probability of failure by Eurocode 1990

Limit state	Target reliability index β_d	
	50 years	1 year
Últimate	3.8 ($p_f \approx 10^{-4}$)	4.7 ($p_f \approx 10^{-6}$)
Fatigue	1.5–3.8$^{*)}$ ($p_f \approx 10^{-1} \div 10^{-4}$)	–
Serviceability	1.5 ($p_f \approx 10^{-1}$)	3.0 ($p_f \approx 10^{-3}$)

In the case of the stochastic approach, various forms of analyses (statistical analysis, sensitivity analysis, probabilistic analysis) can be performed. Considering the probabilistic procedures, Eurocode 1 (Fig. 2) recommends a 3-level reliability analysis.

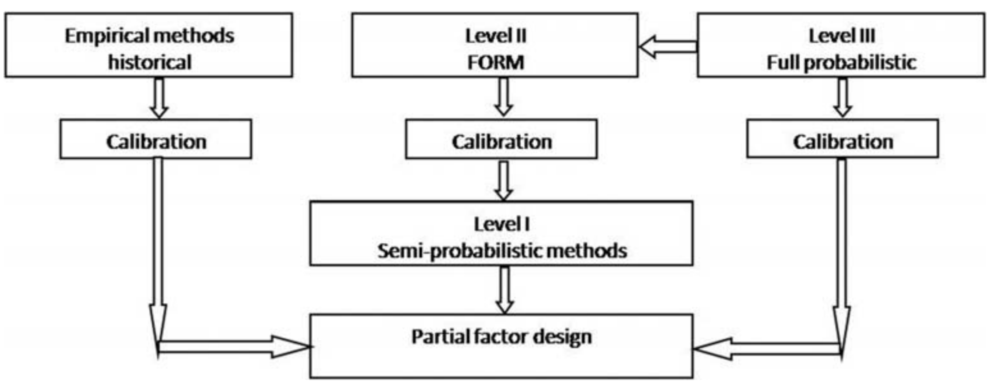

Fig. 2. Overview of reliability methods

The reliability assessment criteria according to the reliability index are defined here. Most well-known is the modified Monte Carlo method and Latin Hypercube Sampling (LHS) simulations. The simulation methods on the base of Monte Carlo method are more advantageous for the estimation of the failure probability. The probability of failure is calculated as best estimation of the statistical parameters and theoretical model of the probability distribution of the reliability function $Z = g(X)$.

The probability of failure is defined as best estimation of the numerical simulations in the form

$$p_f = \frac{1}{N}\sum_{i=1}^{N} I[g(X_i) \leq 0], \tag{8}$$

where N is the simulation number, $g(\cdot)$ is the failure function, $I[\cdot]$ is the function with value 1, if the condition in the square bracket is fulfilled, otherwise is equal to 0.

The variation of this failure estimation can be described by Melcher in the form

$$s_{pf}^2 = \frac{1}{(N-1)}\left\{\frac{1}{N}\left[\sum_{i=1}^{N} I^2[g(X_i \leq 0)]\right] - \left[\frac{1}{N}\sum_{i=1}^{N} I[g(X_i \leq 0)]\right]^2\right\}. \tag{9}$$

Monte Carlo method is demanding a lot of simulations and for that reason the simplified methods as IS (Importance sampling) or LHS (Latin Hypercube Sampling) are favored in the robustness problems in FEM.

Latin hypercube sampling (LHS), a stratified-random procedure, provides an efficient way of sampling variables from their distributions (Iman and Conover, 1980). The LHS involves sampling N values from the prescribed distribution of each of k variables $X_1, X_2, \ldots X_k$. The cumulative distribution for each variable is divided into N equiprobable intervals. A value is selected randomly from each interval. The N values obtained for each variable are paired randomly with the other variables. Unlike simple random sampling, this method ensures a full coverage of the range of each variable by maximally stratifying each marginal distribution.

The LHS can be summarized as:

- divide the cumulative distribution of each variable into N equiprobable invervals;
- from each interval select a value randomly, for the i^{th} interval, the sampled cumulative probability can be written as (Wyss and Jorgensen, 1998):
  $\text{Prob}_i = (1/N)\cdot r_u + (i-1)/N$, where r_u is uniformly distributed random number ranging from 0 to 1;
- transform the probability values sampled into the value Xusing the inverse of the distribution function $F^{-1} : X = F^{-1}(\text{Prob})$;
- the N values obtained for each variable X are paired randomly (equally likely combinations) with the n_s values of the other variables.

The method is based on the assumption that the variables are independent of each other, but in reality most of the input variables are correlated to some extent. Random pairing of correlated variables could result in impossible combinations, furthermore independent variables tend to bias the uncertainty.

The ANSYS Program belongs among the complex programs for solving potential problems [18]. It contains a postprocessor, which enables the execution of the probabilistic analysis of structures. In Fig. 3, the procedural diagram sequence is presented from the structure of the model through the calculations, up to an evaluation of the probability of structural failure. The postprocessor for the probabilistic design of structures enables the definition of random variables using standard distribution functions (normal, lognormal, exponential, beta, gamma, weibull, etc.), or externally (user-defined sampling) using other statistical programs like

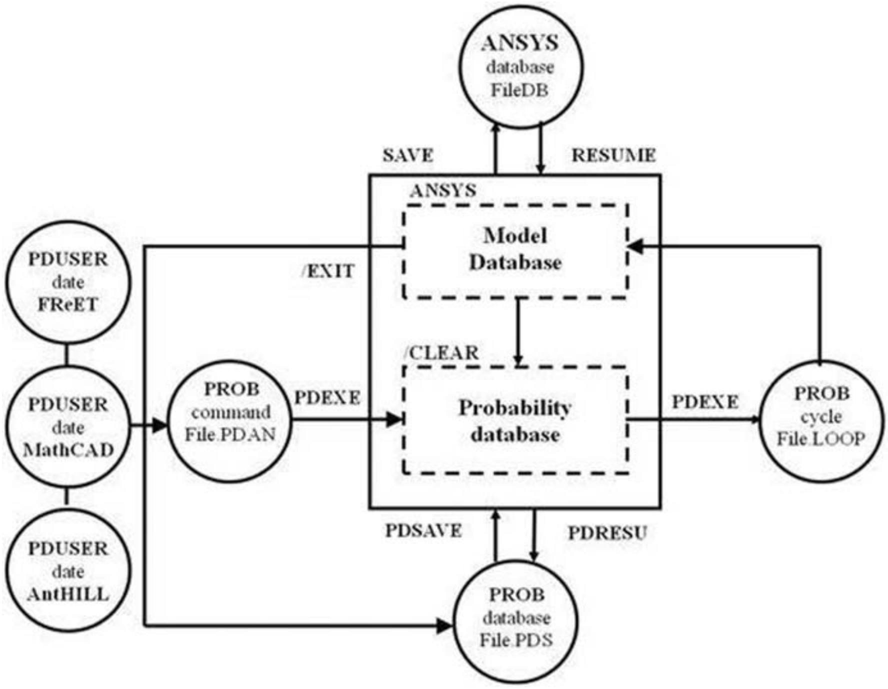

Fig. 3. Procedural diagram of probabilistic calculations using the ANSYS software system

AntHILL or FReET. The probabilistic calculation procedures are based on Monte Carlo simulations (DS, LHS, user-defined sampling) and "Response Surface Analysis Methods (RSM)" (CCD, BBM, user-defined sampling). The statistical postprocessor compiles the results numerically and graphically in the form of histograms and cumulative distributional functions. The sensibility postprocessor processes the data numerically and graphically and provides information about the sensitivity of the variables and about the correlation matrices.

2. Soil-foundation interaction

The dynamic response is other in the case of stiff and soft soil [1, 2, 4, 7, 8, 9, 11, 13, 15] due to soil-foundation interaction effects. There are following aspects:

- Soil move can affect the rotation of foundation about its horizontal axis,
- First period of foundation under soft soil will be longer as in the case of stiff soil,
- Eigenvalues and a participation factors will be different in the case of soft and stiff soil,
- Nonproportional damping is depend on the radial and reflex damping of soil under foundation and different damping of foundation structure.

The consideration of SSI effects is very important. The influence of stiffness and damping characteristic of the soil to the structure are not negligible.

3. Optimal design of the machine foundation

From the point of view of Eurocode the engineer-designer has take into account following influences:

- Impact of machine vibration to structures.
- Impact of machine vibration to the people and operation (mechanic, acoustic, optic).
- Impact of machine vibration to the technology (requirements of manufacturer).

On the base of the evaluation of all influences it is necessary to check following assessment:

- criterion of limit state design of structures,
- physiological criterion,
- functionality criterion.

The design forces and displacements are calculated using the harmonic response analysis of the structures for normal and extreme operation. The maximum displacements and velocities must be checked to the criterion of standard:

- Machine frequencies $< 10\,\text{Hz}$
  Maximum displacement amplitude – for normal operation $u_{\max} \leq 63\,\mu\text{m}$
  – for initial state (n =0) $u_{\max} \leq 23\,\mu\text{m}$
- Machine frequencies $> 10\,\text{Hz}$
  Maximum velocity amplitude – for normal operation $v_{\max} \leq 2.8\,\text{mm/s}$
  – for initial state ($n = 0$) $v_{\max} \leq 1.0\,\text{mm/s}$

4. Model of compressor foundation

The analysis of the soil-foundation-machine interaction was realized on the case of compressor foundation type 13K401 fy. DEMAG DELAVAL using in the building RAYTHEON Slovnaft Bratislava.

Compressor 13K401 (with total masses 5.8 t) and turbine GK 22/28 fy. SIEMENS AG (with total masses 7.5 t and pipe system 22 t) are put on the reinforced concrete foundation

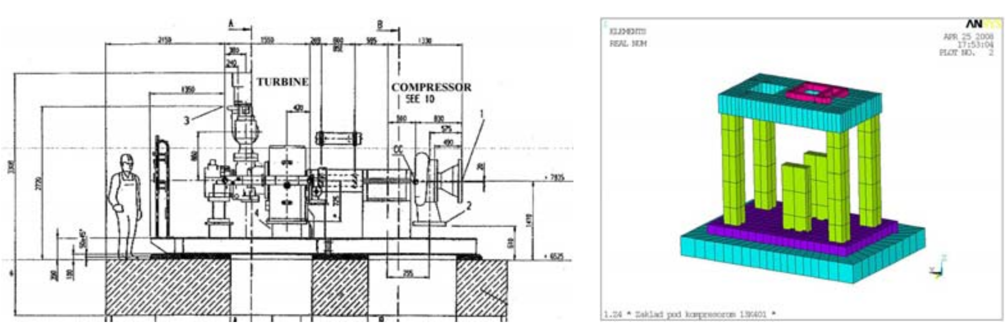

Fig. 4. Scheme of compressor 13K401 and foundation FEM model

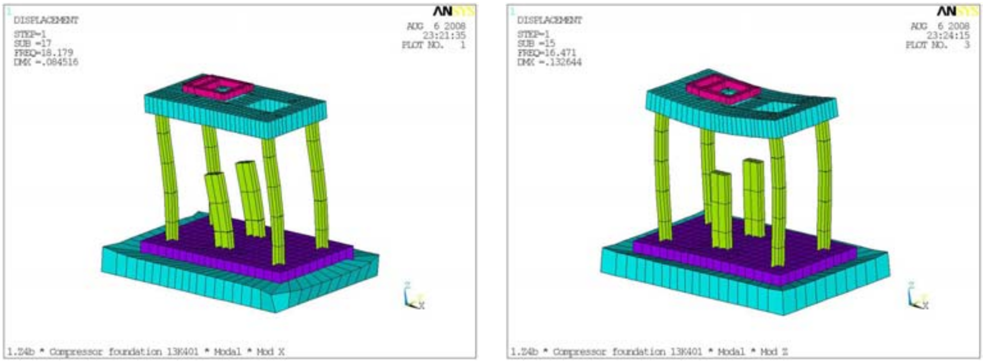

Fig. 5. Dominant horizontal and vertical modes of compressor foundation 13K401

in the form of invert table on the level $+6.52$ m. This structure consists the foundation plate (with dimension $5\,000 \times 8\,250 \times 1\,000$ mm) on level -1.45 m, four columns (with dimension $300 \times 300 \times 5\,875$ mm and alternately $400 \times 400 \times 5\,875$ mm) and horizontal reinforced concrete frame, resp. plate (with dimension $3\,050 \times 7\,250 \times 800$ mm) on level $+6.52$ m. The mass of foundation frame is 192.44 t. The subsoil consist the gravel. The material properties were taken from the geophysical test in this locality. We considered two FEM models Z4a (with column section 300×300) and Z4b (with column section 400×400). FEM model consist 888 elements (shell, solid, beam) and 1001 nodes.

The comparison of the dynamic characteristics of the subsoil and published values is presented in the table 2. On the base of meassured data three soil models — low, medium and high were incorporated in the FEM model (table 3). The stiffness of soil has the considerable influence to the modal characteristic and eigenvalues of entire structure.

Table 2. Material properties of soil

Author	Soil type	v_s [m/s]	v_p [m/s]	G_d [MPa]	E_d [MPa]
Meassured	G2-GP	280–300	580–600	156.8–180	672.8–720
Lorenz&Klein	G2-GP	180–550	500–1 000	64.8–605	500–2 000
AFPS 90	G2-GP	150–400	500–800	45–320	500–1 280
Cieselski	G2-GP	250	480	125	460

Table 3. Comparison of foundation principal frequencies

Model		Direction X		Direction Y		Direction Z	
Foundation	Soil	Frequency [Hz]	Prop. ratio [%]	Frequency [Hz]	Prop. ratio [%]	Frequency [Hz]	Prop. ratio [%]
13K401a	Low	15.02	48.9	12.06	53.9	14.66	65.8
13K401b	Medium	18.18	51.7	14.69	55.1	16.47	54.8
13K401c	High	22.04	52.5	17.91	55.4	17.78	41.8

The dynamic loads were defined by intensity of forces in the point of anchor and rotation velocity. In the case of normal operation the velocity of turbine (resp. compressor) rotor is equal to 12 500 r.p.m (resp. 10 998 r.p.m) and for extreme condition the velocity of turbine (resp. compressor) rotor were defined by manufacturer as 4 700 r.p.m (resp. 17 200 r.p.m).

5. Harmonic response analysis

The harmonic response analysis solves the time-dependent equations of motion for linear structures undergoing steady-state vibration. The equation of motion for a structural system is defined in the following form

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{C}\dot{\mathbf{u}} + \mathbf{K}\mathbf{u} = \mathbf{F}, \tag{10}$$

where $\mathbf{M}, \mathbf{C}$ and $\mathbf{K}$ are the structural mass, damping and stiffness matrices, $\ddot{\mathbf{u}}, \dot{\mathbf{u}}$ and $\mathbf{u}$ are the nodal acceleration, velocity and displacement vectors, $\mathbf{F}$ is applied load vector.

The displacement and applied force vector may be defined in the form

$$\begin{aligned} \mathbf{u} &= \{u_{\max} e^{i\Phi}\} e^{i\Omega t} = \{u_{\max}\}(\cos\Phi + i\sin\Phi) e^{i\Omega t} \quad \text{and} \\ \mathbf{F} &= \{F_{\max} e^{i\psi}\} e^{i\Omega t} = \{F_{\max}\}(\cos\psi + i\sin\psi) e^{i\Omega t}, \end{aligned} \tag{11}$$

where u_{max} and F_{max} are the maximum displacement and force, i – square root of -1, Ω – imposed circular frequency $(2\pi f)$, f – imposed frequency, t – time, Φ – displacement phase shift, ψ – force phase shift.

Substituting relations (11) into (10) gives

$$[\mathbf{K} - \Omega^2\mathbf{M} + i\Omega\mathbf{C}](\cos\Phi + i\sin\Phi)\{u_{\max}\} = (\cos\psi + i\sin\psi)\{F_{\max}\}, \tag{12}$$

where time term $e^{i\Omega t}$ is removed from the left and right side of the equation. The equation may be solved directly as the complex system of the equations

$$\mathbf{K}_c\mathbf{u}_c = \mathbf{F}_c, \tag{13}$$

where $\mathbf{K}_c$ is the complex stiffness matrix, $\mathbf{u}_c$ is the complex displacement vector and $\mathbf{F}_c$ is the complex force vector (applied forces, damping and inertial forces). N-numerical simulations are used in the case of probabilistic analysis.

6. Uncertainties of input variables

The effect of soil-structure interaction can be investigated in the case of probabilistic assessment by sensitivity analysis of the influence of variable properties of soil. A soil stiffness variability in the vertical direction is defined by the characteristic stiffness value k_z from the geological measurement and the variable factor $k_{z.var}$. The random distribution of the soil stiffness under foundation plate is approximated with bilinear function on the slab plane in dependency on three parameters $k_{z.var}, k_{xx.var}, k_{yy.var}$

$$k(x,y) = \left\{ k_{z.var} + 2\frac{(x - x_o)}{L_x} k_{yy.var} + 2\frac{(y - y_o)}{L_y} k_{xx.var} \right\} k_{z,k}, \tag{14}$$

where $k_{z.k}$ is characteristic value of soil stiffness, x_o, y_o are coordinates of foundation structure gravity centre, L_x and L_y are the plane dimensions of the slabs in directions x and y.

The variability of geometric characteristics is defined with $h_{.var}$ (column dimension), $d_{1.var}$ (foundation plate thickness), $d_{2.var}$ (compressor plate thickness).

The stiffness of the structure is determined with the characteristic value of Young's modulus E_k and variable factor e_{var}. A load is taken with characteristic values $G_k, F_k, F_{r.k}$ and variable factors g_{var}, f_{var} and $f_{r.var}$.

Table 4. Probabilistic model of input parameters

Name	Quantity	Charact. value	Variable paramet.	Histogram	Mean	Standard deviation	Min. value	Max. value
Soil	Stiffness	$k_{z,k}$	k_z_var	Uniform	1.085	0.240	0.67	1.5
		$k_{xx,k}$	k_{xx}_var	Uniform	0	0.580	-1	1
		$k_{yy,k}$	k_{yy}_var	Uniform	0	0.580	-1	1
Material	Young's modulus	E_k	e_var	Lognormal	1	0.050	0.868	1.149
Load	Dead	G_k	g_var	Normal	1	0.100	0.719	1.281
	Live – amplitude	F_k	f_var	Lognormal	1	0.100	0.752	1.317
	– frequency	Fr_k	fr_var	Normal	1	0.100	0.719	1.281
Geometric	Height	h_k	h_var	Normal	1	0.050	0.860	1.140
	Thickness	$d1_k$	d1_var	Normal	1	0.010	0.972	1.028
		$d2_k$	d2_var	Normal	1	0.010	0.972	1.028
Model	Model uncertainties	θ_E	Te_var	Normal	1	0.100	0.719	1.281
	Resistance uncert.	θ_R	Tr_var	Normal	1	0.100	0.719	1.281

The uncertainties of the calculation model are considered by variable model factor θ_R and variable load factor θ_E for Gauss's normal distribution.

The results of the probability analysis of the foundation model Z4a present that the principal frequencies are variable in the direction X (from 4.32 Hz to 6.37 Hz), Y (from 13.05 Hz to 17.61 Hz) and Z (from 16.84 Hz to 21.68 Hz). These frequency intervals have the important influence to response from the harmonic compressor excitation.

7. Reliability criteria for seismic resistance of structure

Reliability of the foundation structures is analyzed in accordance of national and Eurocode standard requirements [3, 5, 6, 7] for ultimate and serviceability limit state. Horizontal reinforced plane structures are designed on the bending and shear loads for ultimate limit state function (3) in the next form

$$g(M) = 1 - \frac{M_E}{M_R} \geq 0, \qquad g(V) = 1 - fracV_E V_R \geq 0, \tag{15}$$

where M_E, V_E are design bending moment and design shear force of the action and M_R, V_R are resistance bending moment and resistance shear force of the structure element.

Vertical plane reinforced concrete structures are designed to the tension or pressure and shear resistance for function of failure [3] in the form

$$g(N) = 1 - \frac{N_E}{N_R} \geq 0, \qquad g(V) = 1 - \frac{V_E}{V_R} \geq 0, \tag{16}$$

where N_E, V_E are normal and shear design forces of action and N_R, V_R are resistance normal and shear forces to unit length.

The serviceability of compressor foundation is limited by maximum displacement amplitude and velocity amplitude in dependency on operation frequency of compressor.

The failure function of the amplitude of horizontal displacement u and velocity v is defined in the form

$$g(u) = 1 - \frac{u_E}{u_R} \geq 0, \qquad g(v) = 1 - \frac{v_E}{v_R} \geq 0, \tag{17}$$

where u_E, v_E are maximum amplitude of displacement and velocity from action and u_R, v_R are limit displacement and velocity.

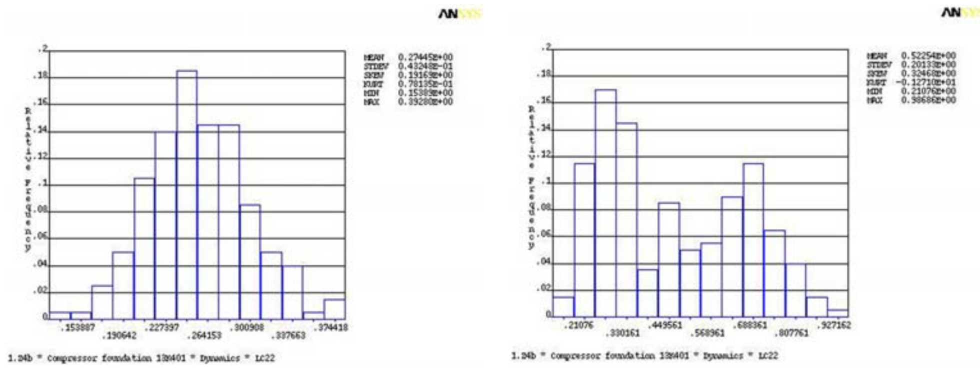

Fig. 6. Reliability density function of horizontal and vertical velocity

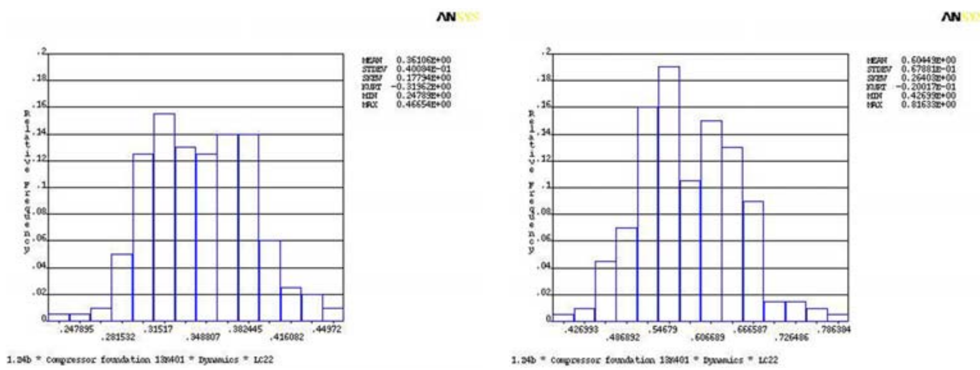

Fig. 7. Reliability density function of normal forces and bending moment

8. Sensitivity analysis

Sensitivity analysis of the influence of the variable input parameters to the reliability of the structures depends on the statistical independency between input and output parameters.

Matrix of correlation coefficients of the input and output parameters is defined by Spearman in the form

$$r_s = \frac{\sum_{i=1}^{n}(R_i\bar{R})(S_i\bar{S})}{\sqrt{\sum_{i=1}^{n}(R_i\bar{R})^2}\sqrt{\sum_{i=1}^{n}(S_i\bar{S})^2}}, \tag{18}$$

where R_i is rank of input parameters within the set of observations $[x_i]^T$, S_i is rank of output parameters within the set of observations $[y_i]^T$, $\bar{R}$, $\bar{S}$ are average ranks of the parameters R_i and S_i respectively.

The results of the sensitivity analysis of the vertical displacement of the compressor foundation are presented in the Fig. 8. The sensitivity of the normal forces and bending moments to the variability of input parameters are demonstrated in the Fig. 9.

Variability of three input quantities (velocity of the turbine rotor, load amplitudes, foundation mass) is important to the displacement of compressor foundation (Fig. 8) due to normal performance of rotor. In the case of extreme loads the variability of the five input quantities (velocity of the turbine rotor, soil stiffness, foundation mass, structure stiffness, load amplitudes) is important to the displacement of compressor foundation (Fig. 9). The frequency of

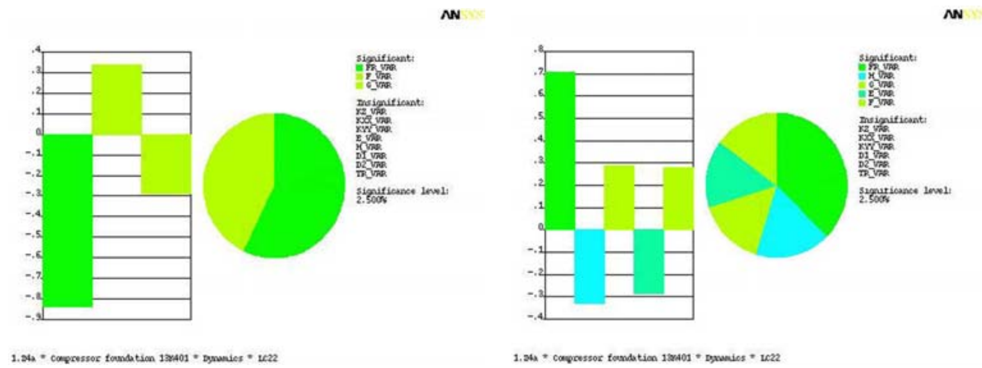

Fig. 8. Sensitivity analysis of the vertical displacement for normal and extreme compressor loads

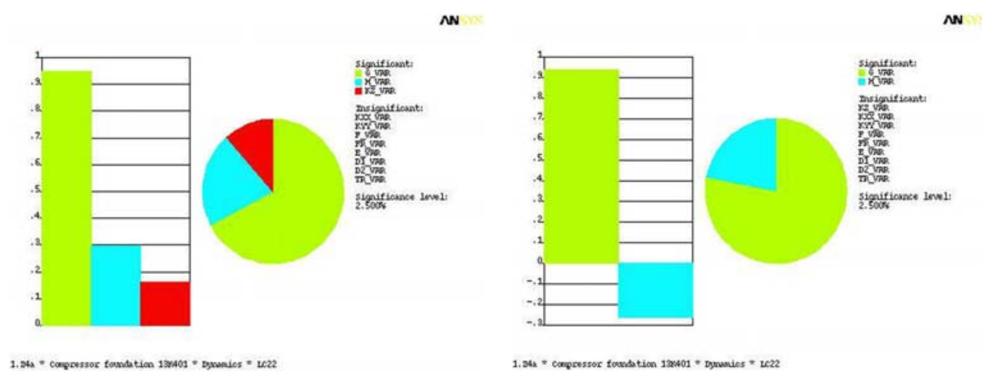

Fig. 9. Sensitivity analysis of the normal forces and moment of the compressor foundation

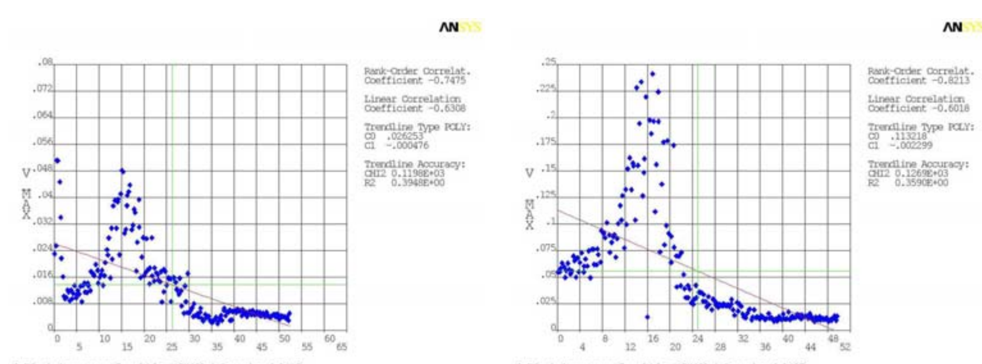

Fig. 10. Sensitivity analysis of the vertical displacement through frequency for normal and extreme performance

rotor movement is lower in the case of extreme performance than the normal performance. It is the reason of the higher sensitivity of foundation to the variability of material and geometry input parameters. The normal forces and bending moments in the columns are sensitive to the variability of the dead loads and soil stiffness. The sensitivity analysis gives the valuable information about the influence of uncertainties of input variables (load, material, model) to engineer for optimal design of the structures. The sensitivity of the vertical displacement over the compressor operation frequencies is demonstrated in the fig. 10a for normal performance and in the fig. 10b for the extreme performance. The horizontal displacements of the compressor foundation are higher for the lower frequency as 5Hz. In the case of vertical displacements their peaks are about the frequency 15Hz for both performance normal and extreme (fig. 10).

9. Comparison of deterministic and probabilistic analyses

The comparison of deterministic and probabilistic solution of the safety and reliability of the compressor foundation is documented in the table 5. The differences between deterministic and probabilistic results are equal about to 17–27 % (resp. 57–111 %) for mean (resp. maximum) displacement amplitude values. In the case of normal forces and bending moment these differences are lower.

Table 5. Comparison of deterministic and probabilistic analyses

Method	Model	Maximum displacement amplitude [mm]				Maximum velocity amplit. [mm/s]			
		Min	Max	Mean	St. dev	Min	Max	Mean	St. dev
Normal operation of turbine and compressor									
Deterministic	Z4a	0.012 43	0.014 59	0.012 72	–	2.277 8	2.673 6	2.277 8	–
Probabilistic		0.002 78	0.023 08	0.010 09	0.005 37	0.594 8	3.837 5	1.775 3	0.835 3
Deterministic	Z4b	0.006 75	0.007 90	0.007 03	–	1.237 2	1.448 4	1.288 1	–
Probabilistic		0.002 87	0.016 72	0.008 26	0.003 70	0.590 1	2.763 2	1.463 1	0.563 7
Extreme operation of turbine and compressor									
		Maximum normal force [kN]				Maximum bending moment[kNm]			
Deterministic	Z4a	203.01	203.76	203.15	–	264.97	265.98	265.17	–
Probabilistic		137.50	278.70	206.90	21.31	182.20	368.30	206.90	27.72
Deterministic	Z4b	212.66	213.11	212.75	–	255.30	255.85	255.41	–
Probabilistic		143.30	287.40	215.60	22.24	177.20	351.00	259.10	26.75

10. Conclusion

This paper deals with the possibility of the sensitivity and probabilistic analysis of the reliability of the compressor foundation depending on variability of the soil stiffness, structure geometry and machine operation. The sensitivity of the machine foundation to the uncertainties of the soil properties due to longtime rotating movement of machine is not negligible for design engineers. On the example of compressor foundation 13K401 and turbine GK22/28 fy. SIEMENS AG the affectivity of the probabilistic design methodology was presented. The simulation method LHS for the analysis of the compressor foundation reliability was used on program ANSYS. The 200 simulations for five load cases were calculated in the real time on PC (CPU = 1 292 sec). The probabilistic analysis gives us more complex information about the soil-foundation-machine interaction than the deterministic analysis.

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