

STUDY OF DEFECTS FOR A RECTANGULAR PLATE FREELY SUPPORTED ON CONTOUR

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ABSTRACT: *In present paper we have conducted a study for locating and evaluating plate damage based on the determination of geometrical percentage deviation. Study of defects is of great importance because by a proper identification we are able to prevent loss part of component characteristics and endurance. We considered rectangular thin plates of various dimensions, under the influence of temperature. Impact of considered factor decreases with thickness of plate and in this scenario geometrical imperfections measured as deviations from ideal plate surface play a fundamental role in predicting the non-linear response.*

Keywords: plate, deviation, defect, contour

1. INTRODUCTION

Plates are found in various engineering fields such as naval, mechanical, aeronautics, constructions. In general, a plate is defined by shape and dimensions of median surface and in every point of it we can consider a normal to the surface on which we can define thickness, h , on one side and the other of median surface by values of $h/2$ [1-8].

There is a tendency of using structures even after deterioration occurs, the impossibility of proper and in time intervention placing study of defects in the first rows. This can improve finding efficient methods for structural health monitoring and even predicting defect appearance.

A defect has a significant impact upon dynamic and static behaviour of structures, affecting various characteristics such as natural frequencies, Eigen modes, rigidity, flexibility or damping degree[9-15].

A defect is considered to be a change in the structure that has a negative impact on its performances. Can be defined as a phenomenon that leads to weakening of structure or as a deviation of its material or geometrical characteristics, conducting to unwanted stresses, displacements or vibrations[16-21].

Material imperfections are commonly higher on very thin plates, hence in plates studies must be taken into account geometrical deviation as well as temperature variation.

2. DEFINING CASE STUDIES FOR ANALYSIS

For analysis a rectangular plate of constant thickness of 20mm, supported on contour, with and without central defect and of various dimensions was considered.

Meshing of 3D model was made using

tetrahedral elements. Material used for modelling was chosen from SolidWorks database as a steel AISI1020 with following mechanical properties: yield point 351.57N/mm², tensile strength 420.507N/mm², density 7900kg/m³, elastic modulus 200000 N/mm², Poisson coefficient 0.29, thermal extension coefficient 0.0000150K⁻¹.

For study we have considered rectangular plate with dimensions of 500x1000 freely supported on contour and having longitudinal central defects of following dimensions: 50x20mm, 100x20mm and 200x20mm. In order to determine deviation values using below equation, we have subjected the plate to various temperatures[20-23].

$$\varepsilon = \frac{f_{FEM} - f_{FEM(d)}}{f_{FEM}} \quad (1)$$

Where ε is error or percentile deviation; f_{FEM} is value of Eigen frequency for a plate with no defect at various temperatures; $f_{FEM(d)}$ is value of Eigen frequency for a plate with longitudinal central defect at various temperatures.

Values for deviations obtained by

Table 1. Deviation values determined at -10° C

Mode	ε_1	ε_2	ε_3	Mode	ε_1	ε_2	ε_3
1	0.003441	0.019338	0.083165	16	0.002226	0.005244	0.032407
2	0.003919	0.010339	0.031018	17	0.003576	0.007103	0.041756
3	0.000259	0.004063	0.038118	18	0.004044	0.02798	0.118325
4	0.009943	0.04263	0.179282	19	0.007142	0.033398	0.054544
5	0.004771	0.011074	0.024533	20	0.003337	0.01594	0.027494
6	0.000286	0.001345	0.011758	21	0.008732	0.018298	0.025145
7	0.008299	0.026297	0.06265	22	0.000531	0.001705	0.03146
8	0.000144	0.002741	0.031473	23	0.005545	0.009816	0.040673
9	0.001002	0.002494	0.083131	24	0.007957	0.024177	0.041772
10	0.005478	0.033133	0.118532	25	0.003399	0.007418	0.039905
11	0.004207	0.008394	0.101953	26	0.000266	0.003819	0.044814
12	0.007187	0.020167	0.048722	27	0.002136	0.004964	0.047556
13	0.00106	0.002468	0.014902	28	0.004155	0.011112	0.062251
14	0.004614	0.017933	0.076149	29	0.008765	0.027185	0.085532
15	0.000153	0.003242	0.095022	30	0.005858	0.009755	0.078941

simulations are centralized in tables and frequency deviation for a plate with no defect compared to a plate with defect, subjected to various temperatures are graphically represented[20,22].

3. EXPERIMENTAL TESTS FOR CONSIDERED CASE STUDY

We have considered for study following temperature values, used for all presented cases: -10° C, - 5° C, 0° C, 22° C, 24.85° C, 28° C, 29° C, 30° C, 31° C, 35° C, 40° C.

In table 1 are centralised data obtained from simulations for case in which the temperature value is -10° C and graphical representation for this study is shown in figure 1.

We can observe that the maximum deviation appears in the vibration mode number 4 but significant deviations also occur in the modes number 10,15,18 and 29 in the case of the plate with longitudinal central defect 200x20mm, but also in the case of the plate with longitudinal central defect 100x20mm. In the case of the plate with 50x20mm longitudinal central defect, the deviation is very small, approaching 0.

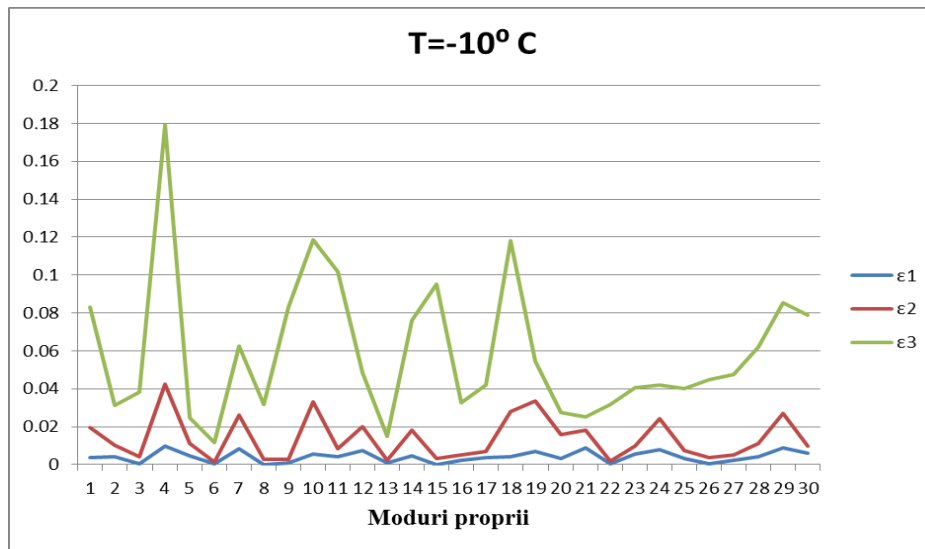


Figure 1. Deviation variation determined at -10°C

In table 2 are centralised data obtained from simulations for case in which the temperature value is 0°C and graphical representation for this study is shown in figure 2.

We can observe that the maximum deviation appears in the vibration mode number 4 but significant deviations also

occur in the modes number 10,15,18 and 29 in the case of the plate with longitudinal central defect $200\times 20\text{mm}$, but also in the case of the plate with longitudinal central defect $100\times 20\text{mm}$. In the case of the plate with $50\times 20\text{mm}$ longitudinal central defect, the deviation is very small, approaching 0.

Table 2. Deviation values determined at 0°C

Mode	ϵ_1	ϵ_2	ϵ_3	Mode	ϵ_1	ϵ_2	ϵ_3
1	0.00337	0.018982	0.081912	16	0.002767	0.00559	0.030869
2	0.003832	0.010017	0.030051	17	0.003785	0.00692	0.045937
3	0.000256	0.003972	0.023705	18	0.00446	0.020087	0.120335
4	0.009368	0.039858	0.182511	19	0.007119	0.03224	0.050522
5	0.004644	0.010643	0.023455	20	0.003032	0.012127	0.024335
6	0.00036	0.001343	0.011003	21	0.007687	0.022581	0.028554
7	0.007992	0.025225	0.061726	22	0.000606	0.001677	0.025908
8	0.000193	0.00264	0.023266	23	0.005925	0.009759	0.034675
9	0.001316	0.002734	0.068759	24	0.007413	0.023703	0.040231
10	0.005372	0.031574	0.122587	25	0.004012	0.007738	0.037456
11	0.003982	0.007873	0.077979	26	0.000168	0.003327	0.02051
12	0.007142	0.019432	0.051592	27	0.00254	0.005121	0.030671
13	0.001109	0.002371	0.01342	28	0.004783	0.011111	0.059466
14	0.004745	0.017641	0.069873	29	0.008531	0.026829	0.086766
15	0.00021	0.003042	0.092346	30	0.00625	0.00994	0.073393

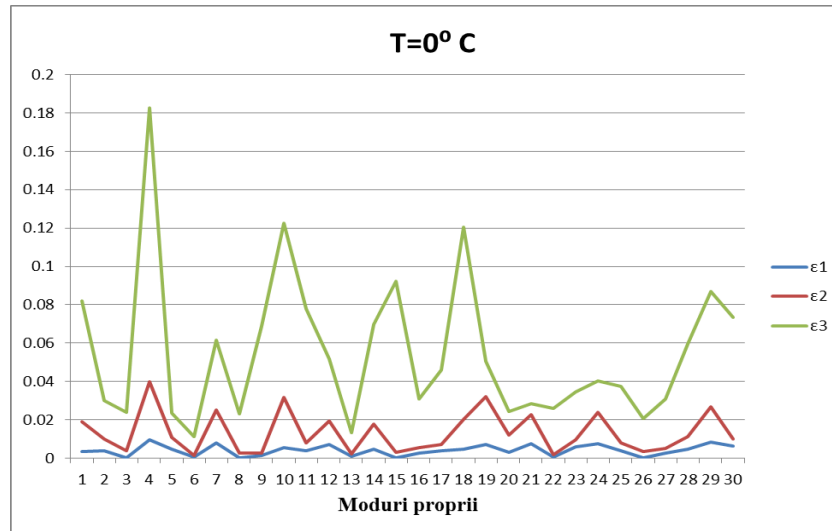


Figure 2. Deviation variation determined at -10° C

In table 3 are centralised data obtained from simulations for case in which the temperature value is 22° C and graphical representation for this study is shown in figure 3.

We can observe that the maximum deviation appears in the vibration mode number 18 but significant deviations also occur in the modes number 4,7,10,12,21

and 29 in the case of the plate with longitudinal central defect 200x20mm and in the case of the plate with longitudinal central defect 100x20mm the maximum deviation appears in the module of vibration number 29. In the case of the plate with 50x20mm longitudinal central defect, the deviation is a very small one, approaching 0.

Table 3. Deviation values determined at 22° C

Mode	ϵ_1	ϵ_2	ϵ_3	Mode	ϵ_1	ϵ_2	ϵ_3
1	0.002571	0.015809	0.068319	16	0.006758	0.00855	0.034406
2	0.002785	0.006406	0.017768	17	0.005394	0.00658	0.058716
3	0.001213	0.00494	0.018894	18	0.007101	0.012742	0.136502
4	0.003955	0.016744	0.102835	19	0.005308	0.014457	0.030014
5	0.00304	0.00595	0.012287	20	0.003806	0.005196	0.006904
6	0.00137	0.002383	0.00685	21	0.002199	0.01827	0.046528
7	0.005028	0.014418	0.057058	22	0.001078	0.001797	0.00941
8	0.001424	0.003241	0.010902	23	0.00812	0.009817	0.031276
9	0.00464	0.006058	0.015681	24	0.00417	0.017396	0.032687
10	0.002135	0.004003	0.059283	25	0.007759	0.009862	0.027729
11	0.005314	0.023361	0.038714	26	8.05E-05	0.001127	0.004509
12	0.006649	0.014151	0.069618	27	0.004762	0.006273	0.020192
13	0.001496	0.002191	0.006921	28	0.008069	0.011471	0.025824
14	0.005838	0.015452	0.030112	29	0.007321	0.024718	0.069186
15	0.000937	0.002177	0.018324	30	0.008291	0.010652	0.012031

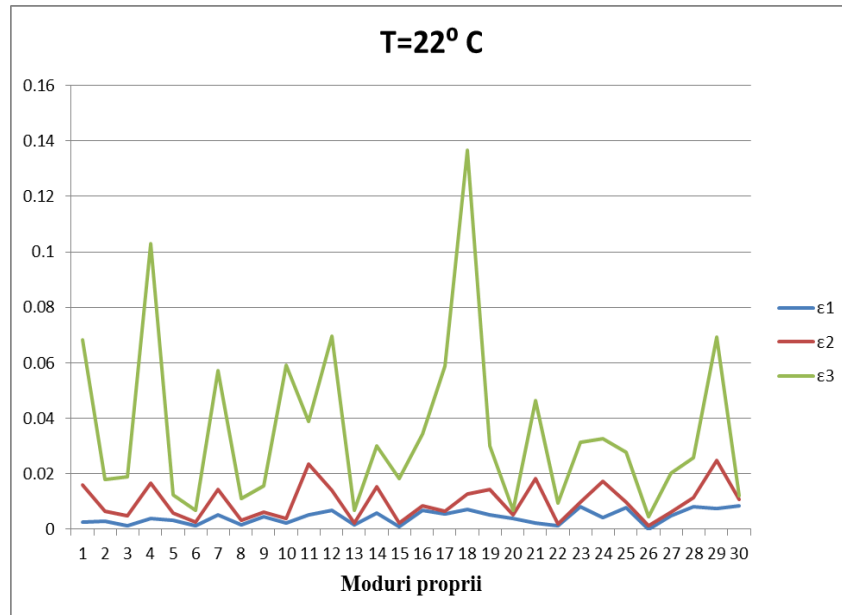


Figure 3. Deviation variation determined at 22° C

In table 4 are centralised data obtained from simulations for case in which the temperature value is 40° C and graphical representation for this study is shown in figure 4.

We can observe that the maximum deviation appears in the vibration mode number 20 but significant deviations also

occur in the vibration modes number 11-17 in the case of the longitudinal central defect plate 200x20mm and in the case of the longitudinal central defect plate 100x20mm and in the case of the longitudinal central defect plate 50x20mm the maximum deviation appears in vibration mode number 19 in the remainder it tends to 0.

Table 4. Deviation values determined at 40° C

Mode	ε1	ε2	ε3	Mode	ε1	ε2	ε3
1	0.015285	0.012906	0.039376	16	0.009755	0.021299	0.170575
2	0.012781	0.025664	0.046257	17	0.010267	0.049684	0.262934
3	0.022681	0.032779	0.003456	18	0.146357	0.209236	0.014094
4	0.020755	0.033003	0.024115	19	0.791574	0.516056	0.572662
5	0.004289	0.001637	0.007732	20	0.327584	0.124017	1.296442
6	0.001073	0.006774	0.017161	21	0.082962	0.177654	0.296147
7	0.000911	0.00148	0.012179	22	0.006949	0.000486	0.062748
8	0.000917	0.002293	0.019831	23	0.038211	0.017739	0.103234
9	0.000402	0.017356	0.027069	24	0.020179	0.002625	0.075905
10	0.001631	0.006466	0.055685	25	0.016905	0.002791	0.065042
11	0.031195	0.075505	0.19538	26	0.011864	0.08927	0.101503
12	0.013589	0.059777	0.230239	27	0.020532	0.013577	0.051494
13	0.041089	0.024439	0.227812	28	0.030663	0.014729	0.007082
14	0.012102	0.069525	0.216887	29	0.017337	0.021987	0.064134
15	0.010147	0.002322	0.156393	30	0.002588	0.00891	0.03194

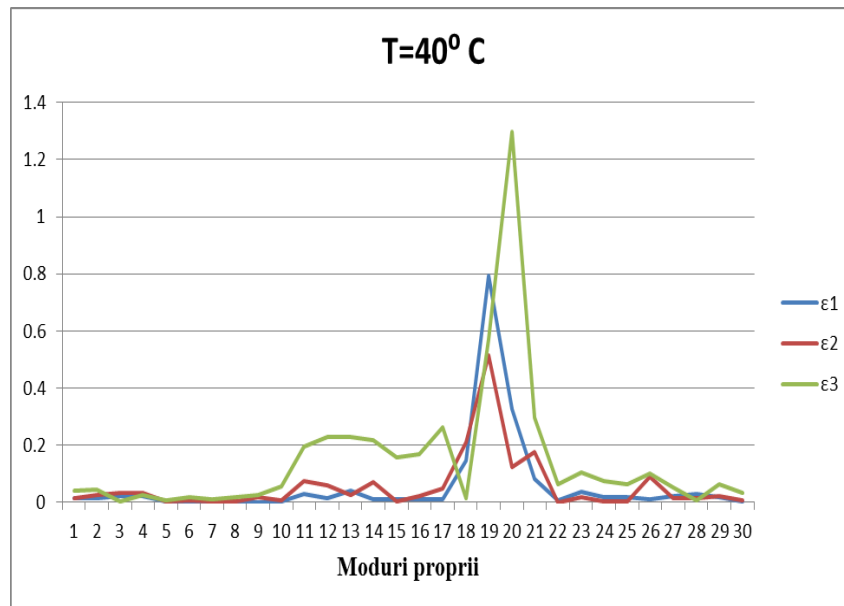


Figure 4. Deviation variation determined at 40° C

Analyzing entire data it can be observed that the standard deviation increases with defect regardless of temperature because, since the defect is of the through type, the contour of the plate where the defect is located behaves like a free plate.

4. CONCLUSIONS

For temperatures lower or equal to the ambient temperature with value of 24.85° C it is observed that the percentage deviations of frequencies according to vibration modes are pronounced.

We can conclude that the standard deviation shows a proportional increase with defect increase, presenting no real dependency upon temperature, main reason being the defect positioning which causes contour of plate where the defect is located to act like a free plate. For further analysis it would be of interest to study plate behaviour for other nature of defects.

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