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RESEARCHES CONCERNING THE PREVENTION OF THE RESONANT FREQUENCY APPEARANCE BY USING REINFORCED PLASTICS

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Abstract: *The paper presents the possibility of replacing plastics (PC and PA66), commonly used in automotive, by composite materials (PC + GF and PA66 + GF with different degrees of reinforcement) to reduce the risk of resonance frequency. Thereby, it was pursued for the substituted material to have similar or superior mechanical and thermal properties as the considered plastic. After simulation were identified natural frequencies for higher components values in the composite materials case, so they are higher than frequencies that could be encountered in the vehicle operation, the final purpose being the elimination of resonance risk. In order to perform the simulation, a housing mounted on a metal support frame was used (the parts were made in Creo 2.0 software) and the modal analysis was realized with Ansys software.*

Key words: *resonant frequency, modal analysis, polyamide, polycarbonate, reinforcement, glass fiber*

1. INTRODUCTION

According to technical literature, it can be said that plastics used in vehicles manufacturing represent 7-10% of the total mass.

Thus, a problem encountered for these materials is the high amplitude vibration, which occurs, depending on the component, at different frequencies, called natural frequencies.

Any physical structure is characterized by one or more natural frequencies that can be determined through an energy application and identification of the vibration frequencies appearance.

In the case of the forced vibrations, the resonant frequency is obtained when the transmitted vibration to the considered system is characterized by a frequency, which is equal to the natural frequency of the system.

Specifically to resonant frequency is the tendency of the mechanical system to absorb more energy than if the excitation frequency is different from the natural. This phenomenon may lead to destructive vibrations which influence the functional role of the mechanical system.

Among the causes that lead to vibration's appearance, can be included: internal combustion engine, condition of rolling track, technological tolerances, contacts type between subassemblies and unbalanced parts in rotation moving.

Thereby, low intensity vibrations that seem to generate no problems will determine other mechanical parts excitation in the structure, for which vibration and noise will be amplified.

3. MATERIALS AND METHODS

In order to avoid destructive resonant frequency appearance for the mechanical systems, in the article it is studied the possibility of replacing plastics, polycarbonate (PC) or polyamide (PA66) with the same material reinforced with glass fiber (whiskers) in different ratios. The composite materials are obtained through extrusion with different degree of reinforcement according to the specialized literature.

For simulation the following parameters are considered, as presented in table 1: the density of the material, the Young's modulus for each material and each temperature used in the analysis (extracted from characteristic curves [4]) and the Poisson ratio with a constant value of 0.38.

Therefore, it was intended for the replacement material to satisfy mechanical and thermal requirements at ambient temperature 23^{o}C and also at temperatures of -40°C, respectively 80°C.

Table 1

The properties of the materials used

Material	Tempe rature [^{o}C]	Density [kg/m³]	Young's Modulus
PC	23	1200	2200
PC+ 20%GF	23	1340	5500
PC+30%GF	23	1410	8400
PA66	-40	1130	3426
	23		3342
	80		595
PA66+ 15%GF	-40	1230	6144
	23		4731
	80		1976
PA66+30% GF	-40	1360	7992
	23		7784
	80		3592
PA66+35% GF	-40	1410	8980
	23		8199
	80		4257
PA66+50% GF	-40	1560	13182
	23		13023
	80		6721

Using the finite element analysis, the simulation for the behavior of a housing, made of plastic or composite material as shown in Table 1, was performed. The part is considered to be fixed in four mounting areas on a metal support, positioned on the vehicle structure, as shown in Figure 1.

Fig. 1. Analyzed assembly meshing

4. RESULTS OF THE MODAL ANALYSIS

According to the obtained simulation results, presented in Table 2 and the graphics interpretation presented in Figures 2-5, it is observed that reinforcing plastics with glass fiber leads to natural frequencies of the studied component of higher values than if it was made of unreinforced material. Also, progressive increasing of fiberglass reinforcement degree, generates increased frequency values. (Figures 2 and 3).

Therefore, depending on the natural frequency value that is intended to be obtained, certain amount of fiberglass reinforcement needs to be chosen.

Whereas now, in the vehicle case the components could be at certain times at different temperatures, for polyamide the behavior has been studied at extreme temperatures of -40°C, respectively 80° C. Thus, the same increasing trend was obtained, namely higher values for natural frequencies in case of increasing glass fiber reinforcement degree, as can be seen in the diagrams in Figure 4 and Figure 5.

Also, it was found for the same material, regardless its composition, contains glass fiber or not, that the obtained resonance frequency values were higher at low temperatures and dropped with increasing temperature (Fig. 4 and 5), so for PA66 or PA66 30% GF at -40^{o}C were obtained values which were approximately 60%, respectively 67% higher for the first 7 vibration modes.

After simulations, it was found that the natural vibrations modes remain unchanged (Fig.7 and 8), although different natural frequency values are obtained by increasing the reinforcement degree by changing the material or temperature variation for the analyzed part. Thus, for the first vibration mode the affected zone is presented in figure 6, which is not very important for various reasons (does not collide with other components and also due to the presence of damping elements). If the side of the affected part in the 6th vibration mode is considered a critical zone, the issue can be solved with reinforcement or increasing the reinforcement degree in order to obtain higher values of natural frequencies, avoiding the risk of affecting the zone within a lower vibration mode. Otherwise, the addition of glass fiber would lead to increasing the value of natural frequencies but would not necessarily lead to improve the parts behavior.

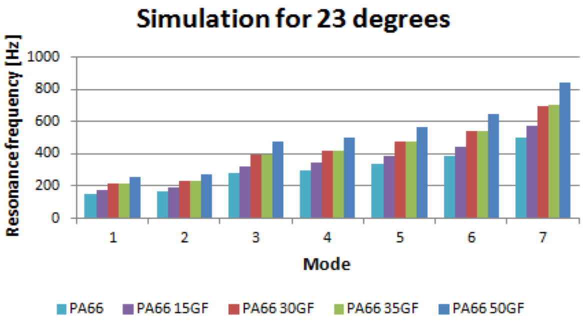

Fig.2. Resonant frequency for PA66 at 23^{o}C

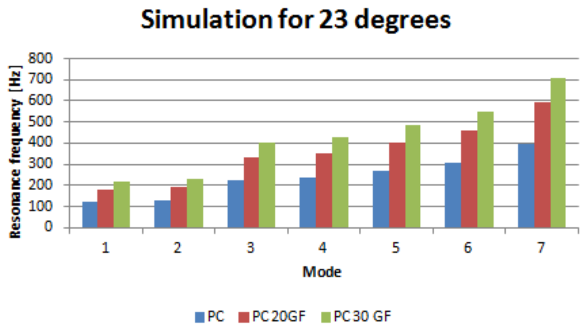

Fig.3. Resonant frequency for PC at 23^{o}C

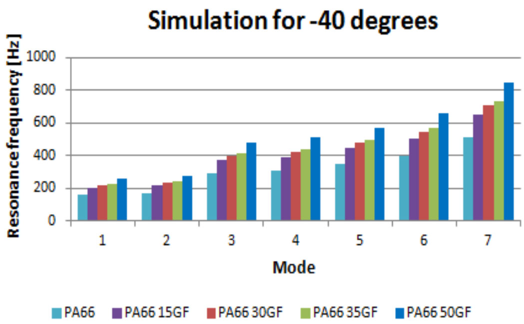

Fig.4. Resonant frequency for PA66 at -40^{o}C

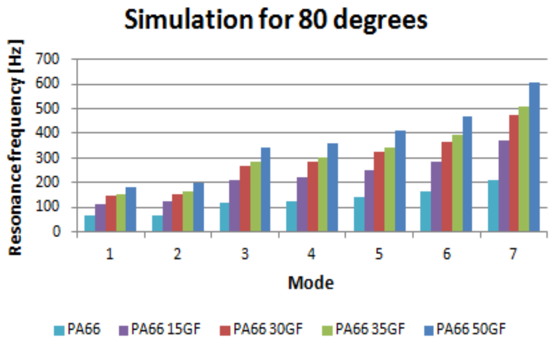

Fig.5. Resonant frequency for PA66 at 80^{o}C

Table 2

The simulation results from ANSYS software application

Material	Temperature [^{o}C]	Resonant frequency [Hz]						
		Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7
PC	23	121.53	130.86	223.23	236.81	269.33	305.52	394.66
PC+ 20%GF	23	180.58	194.11	333.78	354	401.5	456.9	589.96
PC+30%GF	23	216.32	232.17	401.89	426.17	482.22	550.22	710.2
PA66	-40	155.87	167.73	286.99	304.42	345.87	392.81	507.34
	23	153.98	165.7	283.46	300.67	341.63	387.97	501.09
	80	65.363	70.446	119.67	126.97	144.61	163.78	211.6
PA66+ 15% GF	-40	198.95	213.78	368.17	390.46	442.61	503.99	650.71
	23	175.09	188.28	323.16	342.76	389	442.35	571.23
	80	113.82	122.58	208.97	221.69	252.18	286	369.46
PA66+ 30% GF	-40	215.01	230.82	399.19	423.3	479.14	546.5	705.44
	23	212.28	227.91	393.97	417.78	472.97	539.36	696.23
	80	145.43	156.48	267.85	284.12	322.75	366.62	473.5
PA66+ 35% GF	-40	223.42	239.72	415.49	440.57	498.3	568.85	734.2
	23	213.8	229.49	397.07	421.06	476.52	543.61	701.69
	80	155.27	167.01	286.34	303.71	344.82	391.94	506.16
PA66+ 50% GF	-40	255.39	273.46	478.21	506.96	571.58	654.87	844.78
	23	253.91	271.91	475.33	503.92	568.21	650.93	839.7
	80	184.56	198.26	341.88	362.57	410.81	468.02	604.23

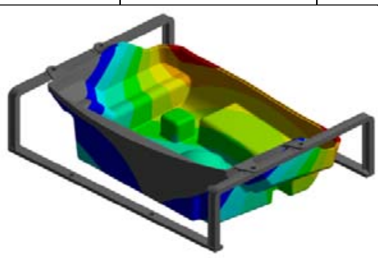

Fig. 6. Zone affected by vibration-mode 1

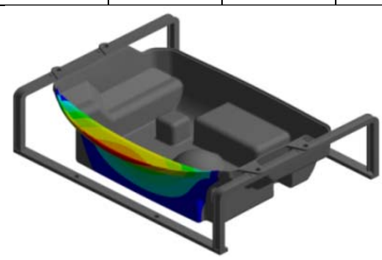

Fig.7. Zone affected by vibration-mode 6

(PA66 30% GF at 23^{o}C)

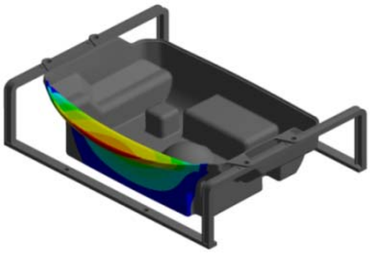

Fig.8. Zone affected by vibration-mode 6 (PA66 at -40 ^{o}C)

Thus, according to simulation and considering that increasing the density should decrease the natural frequency of the part, this being balanced by the increase of Young's modulus, which determines a higher behavior of composite materials.

5. CONCLUSION

According to simulation results it can be concluded that the use of composite materials for automotive parts is an efficient solution for increasing the value of the frequency when it is starting to resonate. Before this solution could be adopted, a series of analyzes regarding the parts behavior are necessary, even if it is already well known that adding glass fiber increases the rigidity of the part.

Therefore, the trend of increasing frequency when using PA66 or PC reinforced with glass fiber is significant as value, consequently the use of these materials in automotive field is justified.

6. REFERENCES

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Cercetari privind prevenirea riscului de apariție al fenomenului de rezonanță prin utilizarea materialelor plastice armate

Rezumat: Lucrarea prezintă posibilitatea înlocuirii materialelor plastice (PC şi PA66), utilizate frecvent în industria auto, cu materiale compozite (PC+GF şi PA66+GF cu diferite grade de armare), în vederea reducerii riscului de apariție al fenomenului de rezonanță. Astfel s-a urmărit ca materialul înlocuitor să dețină proprietăți mecanice, termice similare cu cele ale materialului plastic considerat. În urma simulării s-au identificat frecvențe proprii ale piesei de valori superioare în cazul materialelor compozite, astfel încât valorile acestora sunt mai mari decât frecvențele care ar putea fi întâlnite în exploatarea autovehiculului, scopul final fiind eliminarea riscului de apariție al rezonanței. Pentru realizarea simulărilor s-a utilizat o carcasă montată pe un suport metalic (piese modelate în softul Creo 2.0), iar analizele modale s-au realizat cu softul Ansys.

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