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The influence of stiffness on the dynamic behavior of a PCB enclosure

Razvan-George Olingheru*, Adrian-Bogdan Olariu, Zeno-Iosif Praisach

Abstract. *The paper presents the modification of the first 6 natural frequencies for a PCB case where the material quality was modified from Ultradur B4300 G6 material in AlSi12Cu1 aluminum alloy. Following the change in the quality of the materials, the natural frequency of the 1st vibration mode changed from 164 Hz to 378 Hz, as a consequence of the change in the modulus of elasticity, respectively the stiffness.*

***Keywords**: natural frequencies, moment of inertia, longitudinal modulus of elasticity, ultradur B4300 G6, AlSi12Cu1*

1. Introduction

The work appeared as a result of the competition [1] organized by the Continental company in which the goal was to modify the spectrum of natural frequencies so that for mode I vibration, the resulting natural frequency is higher than 300 Hz.

The Continental company provided the 3D model of the PCB case and the initial materials of the assembly, and the research theme was to modify the frequency spectrum only by increasing the stiffness.

In fig. 1 shows the sectional view of the PCB case, and figure 2 shows the materials that make up the case.

In the work, it was aimed to increase the rigidity of the casing on the one hand by modeling internal and external ribs, respectively by increasing the moment of inertia, on the other hand by changing the quality of the material from Ultradur B4300 G6 to AlSi12Cu1. For each stage, the obtained results are presented.

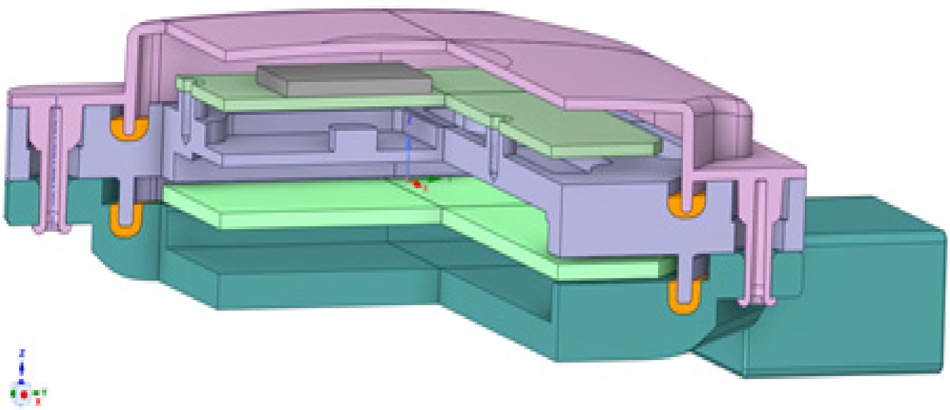

Figure 1. PCB housing detail

Part	Material	Young's Modulus [MPa]	Poission's ratio [-]	Density [g/cm3]	Yield strength [MPa]	Strain limit [μstrain] / [-]
Cover, Housing	B4300 G6	8500	0.35	1.35	70	/
Screws	Steel	200000	0.3	7.85	250	/
PCBs	FR-4	X:20400 / Y:18400 / Z:15000	XY: 0.11 YZ:0.09 XZ:0.14	1.84	/	700 μstrain / 0.0007
Chip	Chip encapsulant	25000	0.35	1.7	/	/
Seallings	Glue	10	0.45	1.35	/	/
Carrier	AlSi12Cu1	73000	0.33	2.65	140	/

Figure 2. Material list

2. Increasing stiffness by changing the moment of inertia.

In the first step, for increasing of the natural frequencies, especially for the first vibration mode, we considered that by introducing additional ribs [2], [3] in the PCB case we will obtain the minimum of 300 Hz for the vibration module.

The introduction of additional ribs leads to an increase in the moment of inertia or stiffness [4].

The adopted solutions are presented in figures 3 and 4.

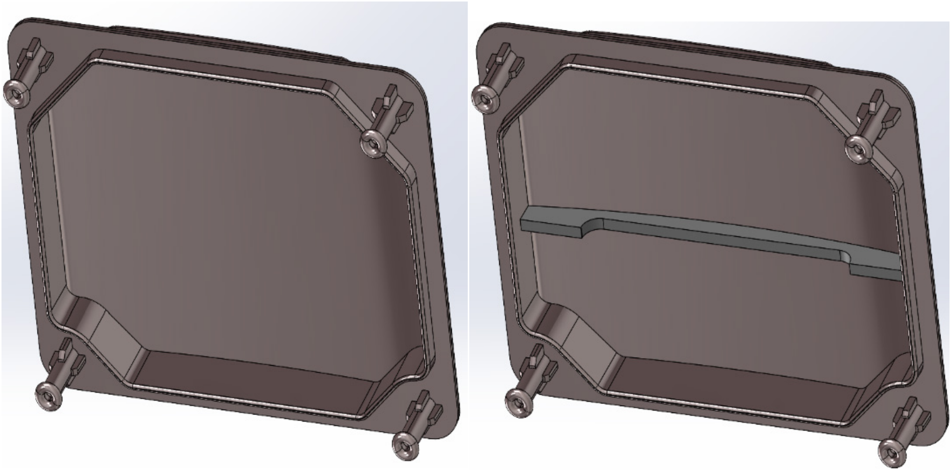

Figure 3. The constructive solution without a rib (left) and the constructive solution with an internal rib (right)

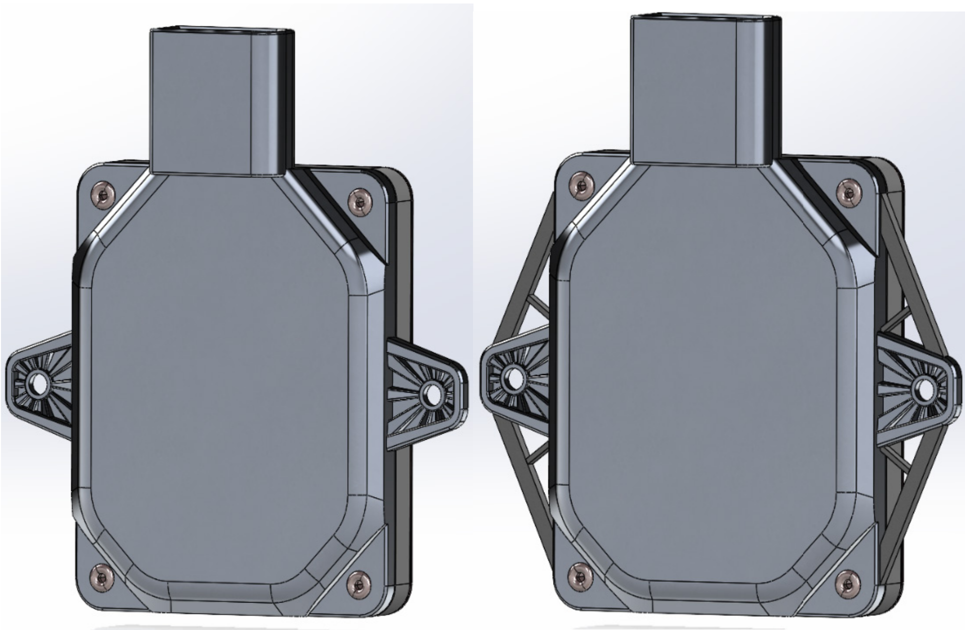

Figure 4. The constructive solution without a rib (left) and the constructive solution with an external rib (right

3. Increasing stiffness by changing the longitudinal modulus of elasticity

In order to increase our own frequencies, we considered that by changing the quality of the material [5], [6], respectively the longitudinal modulus of elasticity, we will reach the threshold of 300 Hz required in fear.

Property	Value	Units
Elastic Modulus	73000	N/mm^2
Poisson's Ratio	0.33	N/A
Shear Modulus		N/mm^2
Mass Density	2650	kg/m^3
Tensile Strength		N/mm^2
Compressive Strength		N/mm^2
Yield Strength	140	N/mm^2
Thermal Expansion Coefficient		/K
Thermal Conductivity		W/(m·K)
Specific Heat		J/(kg·K)
Material Damping Ratio		N/A

Figure 5. AlSi12Cu1 alloy properties

The initially provided Ultradur B4300 G6 material was replaced by an AlSi12Cu1 aluminum alloy. The Ultrahard material B4300 G6 according to figure 2 has the Modulus of elasticity E= 8500 MPa, and the proposed material has the modulus of elasticity E= 73000 MPa.

The material was chosen from the SolidWorks library shown in figure 5, the program with which the modal analysis [7] was performed to determine the natural frequencies.

4. Results

The natural frequencies for the unmodified PCB housing are presented in table 1.

For the variants in the case of the modified PCB housing and following the modal analysis, the following natural frequencies for the first 6 vibration modes were obtained.

Table 1. Unmodified PCB housing natural frequencies

Vibration mode	Angular frequency ω [rad/sec]	Frequency f [Hz]	Period T [s]
1	1.030,5	164,01	0,006097
2	3.853,9	613,37	0,0016303
3	4.868,7	774,87	0,0012905
4	6.265,8	997,23	0,0010028
5	8.165,4	1.299,6	0,00076949
6	8.726,9	1.388,9	0,00071998

Table 2. PCB case natural frequencies with increasing moment of inertia

Vibration mode	Angular frequency ω [rad/sec]	Frequency f [Hz]	Period T [s]
1	1.169,6	186,15	0,0053721
2	3.527,2	561,37	0,0017814
3	4.585,9	729,87	0,0013701
4	6.579,5	1.047,2	0,00095496
5	8.680,6	1.381,6	0,00072382
6	10.151	1.615,6	0,00061897

For the case where we considered the increase of the moment of inertia by introducing internal and external ribs in the PCB case, the obtained natural frequencies are shown in table 2.

It can be seen from the results obtained that the natural frequency in the 1^{st} vibration mode increased from 164.01 Hz to 186.15 Hz. The results obtained are both for the version with internal ribs (Fig. 3) and with external ribs (Fig. 4).

The natural frequencies obtained for the variant with an increase in the longitudinal modulus of elasticity can be found in table 3.

Table 3. PCB case natural frequencies with increasing modulus of elasticity

Vibration mode	Angular frequency ω [rad/sec]	Frequency f [Hz]	Period T [s]
1	2.376,7	378,26	0,0026437
2	4.197,8	668,1	0,0014968
3	5.393,8	858,45	0,0011649
4	8.527,9	1.357,3	0,00073678
5	11.246	1.789,8	0,00055872
6	12.411	1.975,3	0,00050625

4. Conclusion

Following the numerical modal analyzes performed, we obtained the natural frequencies for the first 6 vibration modes for the initial version, the version with internal and external ribs and the version with material modification.

For the initial variant, the 1st natural frequency obtained from the numerical analysis has the value of 164.01 Hz, far below the value required in the research topic of 300 Hz.

By increasing the moment of inertia, i.e. adding inner and outer ribs, the 1st natural frequency increased by approximately 11%, i.e. to the value of 184.15 Hz. This value also did not meet the 300 Hz minimum threshold requirement.

The only acceptable solution to reach the minimum threshold of 300 Hz was to increase the longitudinal modulus of elasticity from 8500 MPa to 73000 MPa, respectively by replacing the Ultradur B4300 G6 material with the AlSi12Cu1 alloy. The natural frequency obtained in 1st vibration mode is 378.26 Hz, a value that exceeds the minimum threshold of 300 Hz.

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Addresses:

- Stud. Razvan-George Olingheru, Faculty of Engineering, Babeș-Bolyai University Cluj-Napoca, Romania, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa razvan.olingheru@stud.ubbcluj.ro
(*corresponding author*)

- Stud. Adrian-Bogdan Olariu, Faculty of Engineering, Babeş-Bolyai University Cluj-Napoca, Romania, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa
adrian.olariu@stud.ubbcluj.ro
- Lect. PhD. Habil. Zeno-Iosif Praisach, Department of Engineering Science, Faculty of Engineering, Babeş-Bolyai University Cluj-Napoca, Romania, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa
zeno.praisach@ubbcluj.ro