International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. XIV, No. 3 / 2022
https://doi.org/ 10.54684/ijmmt.2022.14.3.219

STUDY OF THE BEHAVIOUR FOR THE WORK EQUIPMENT OF A FORKLIFT DURING THE WORKING PROCESS USING FINITE ELEMENT ANALYSIS

Maria Aurora Potirniche, Gigel Florin Capatana

"Dunarea de Jos" University of Galati, Engineering and Agronomy Faculty of Braila, Research Center for Mechanics of the Machines and Technological Equipments, Calea Calarasilor 29, 810017 Braila, Romania

Corresponding author: Maria Aurora Potirniche, aurora.potirniche@ugal.ro

Abstract: Industrial manipulators and robots play a very important role in the current process of advanced industrialization. The use of industrial robots has led to increased labor productivity, human replacement in hazardous work situations, increased product quality, rapid recovery of investment. Supple automation, the highest level of programmable automation, is organized into computer-driven production cells and serviced by one or more industrial robots. The transformation of production systems from the human-machine system to the human-robot-machine system has replaced the human in the process of performing dangerous or uncomfortable works. The diversity of definitions given to industrial robots and the lack of consensus on the notion of "industrial robot" is a premise for opening new horizons in trying to bring the machine closer to human perfection. The present paper aims to conduct a study of the behavior for the work equipment of a forklift during the work process. The tool used to conduct the study was finite element analysis using specialized Solid Edge software. A 3D model of the forklift's work equipment was introduced in Solid Edge and a dynamic analysis was performed, which led to the equipment's eigenmodes and eigenfrequencies. The displacement of the nodes of the structure in the first 10 eigenmodes of vibration and the potential deformation energy accumulated by the system were chosen for visualization, suggestive results and especially important for the specialists in the domain of construction equipments.

Key words: industrial manipulators and robots, advanced industrialization, behavior for the work equipment of a forklift, specialized Solid Edge software, dynamic analysis, eigenmodes and eigenfrequencies.

1. INTRODUCTION

At present, an advanced industrialization of productive processes is taking place worldwide. This process is correlated with the automation phenomenon, which is achieved with the help of industrial robots and manipulators [1, 2].

Industrial robots are versatile and their use leads to a number of economic and social benefits.

With the introduction of industrial manipulators and robots, the human-machine production system has been transformed into a human-robot-machine system. Through this transformation, the workers were exempted from performing dangerous or uncomfortable work [3, 4].

Robots participate in the processes of handling, storage and transport of materials.

Warehousing is an activity that involves storing goods in covered or uncovered warehouses [1, 2, 4].

The technological engineering of transport, handling and storage leads to the finding of efficient technical-economic solutions, through which the following is achieved:

- increase the speed of circulation of handling equipment and means of transport;
- reduction of time on the manipulated area;
- efficient use of storage spaces;
- maintaining the quality and integrity of goods throughout the transport process;
- reduction or elimination of manual activities through the widespread introduction of automation, robotics and cybernetics in the activity of economic units [5, 6].

2. THEORETICAL CONSIDERATIONS ABOUT FORKLIFTS

The forklift is a small industrial vehicle that has a platform in front of it with a hydraulic fork attached. The platform can be raised or lowered for handling loads.

Forklifts have the advantage that they can be handled in tight spaces, where larger vehicles do not have access [4, 5].

Forklifts are commonly used in several industries:

✓ construction - industrial forklifts can be used on construction sites when unloading brick pallets, construction materials, steel beams. It is important to

note that forklifts used in construction must be forklifts adapted to rough terrain, with large wheels, to help them move on different types of terrain (Figure 1) [7];

Fig. 1. Forklifts for constructions [7]

✓ warehouses - they are mainly used for loading or unloading trucks, for transporting goods and for arranging pallets on storage racks (Figure 2) [8];

Fig. 2. Forklifts for warehouses [8]

✓recycling - are used for recycling operations, unloading trucks or unloading recycling containers and transporting them in sorting compartments (Figure 3) [9];
✓shipyards - forklifts are used in ports, helping to unload or load ships, to transport containers (Figure 4) [10];
✓other uses - with the help of a forklift and a snow plow attached, a snow space can be cleaned (Figure 5) [11, 12].

Fig. 3. Forklifts for recycling [9]

Fig. 4. Forklifts for shipyards [10]

3. CASE STUDY

In a first stage, the 3D modeling of the work equipment of the forklift was made and for this a functional forklift was used as a model within a company that operates in a cash & carry system with a form of self-service wholesale trade. For the chosen forklift model, the forks and their support were measured (Figure 6).
The execution of the 3D model of the lifting arms, called forks, as well as their fastening system was done in Autodesk Mechanical Desktop, software specialized in 3D mechanical engineering, design and simulation.

Fig. 5. Forklifts for various uses [11, 12]

With the help of these component parts was made the work equipment assembly of the forklift, shown in Figure 7.

In a second stage, the work equipment assembly was imported into the Solid Edge software, where an analysis in frequency was performed, following which the first 10 vibration eigenmodes of the forklift work equipment were highlighted.

Fig. 6. The real equipment used as a model

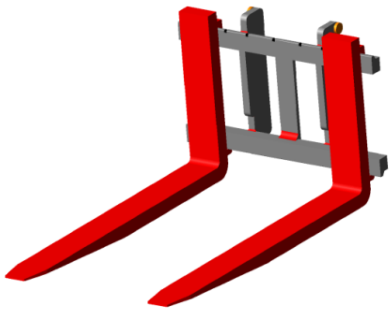


Fig. 7. Realization of the assembly between the fork and the fastening system

The assembly has been embedded on the 4 cylindrical surfaces that are practiced on the fork clamping system, surfaces that ensure the displacement of the work equipment along the mast.

Within the type of modal analysis, Solid Edge provides the user with various results, following which he will choose what he considers suggestive for the analyzed case.

In Figure 8 are shown the values of the eigenfrequencies for the working equipment of the forklift and their variation mode for the first 10 eigenmodes of vibration.

Eigenmode	Frequency value, [Hz]
1	28.91
2	29.23
3	32.94
4	32.99
5	144.0
6	145.7
7	195.5
8	198.3
9	230.2
10	261.5

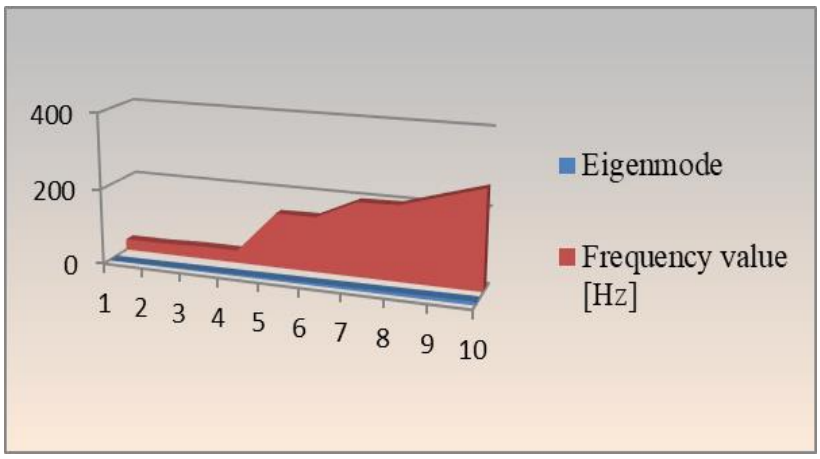
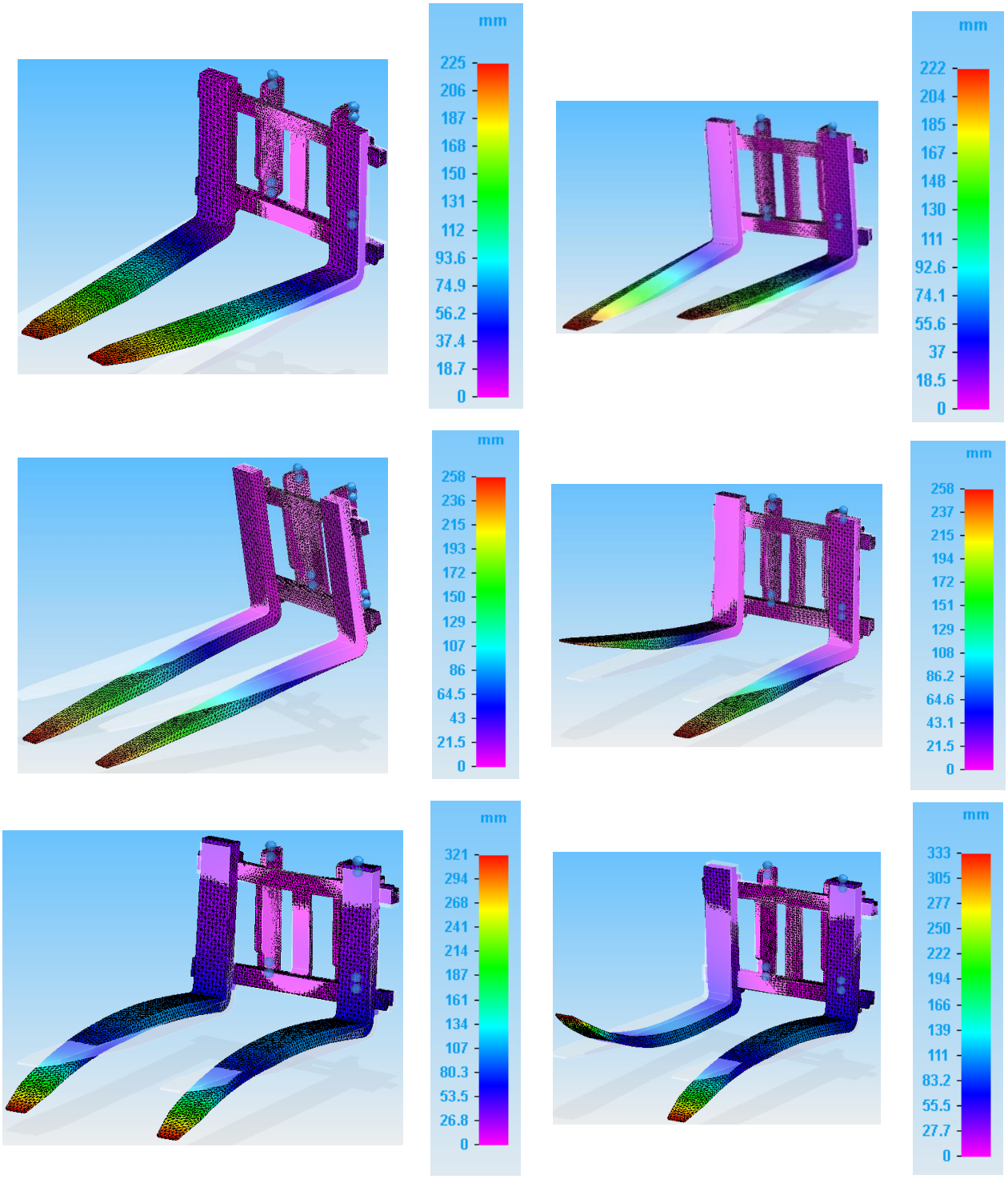


Fig. 8. The values of the eigenfrequencies and their variation mode for the first 10 eigenmodes of vibration

The results were taken from the Solid Edge software and, based on the values of the eigenfrequencies for the forklift equipment, a variation graph of them was drawn up in the first 10 eigenmodes.

For the present paper, it was interesting to visualize the behavior for the work equipment of the forklift when the frequency response is a displacement. Displacement is an important kinematic parameter of the movement of any mechanical system and if this parameter acquires extremely high values, the system fails due to the occurrence of the resonance phenomenon [13]. That is why it is important to know the displacements values.

The displacements of the structure in the first 10 eigenmodes of vibration and their values are shown in Figure 9.



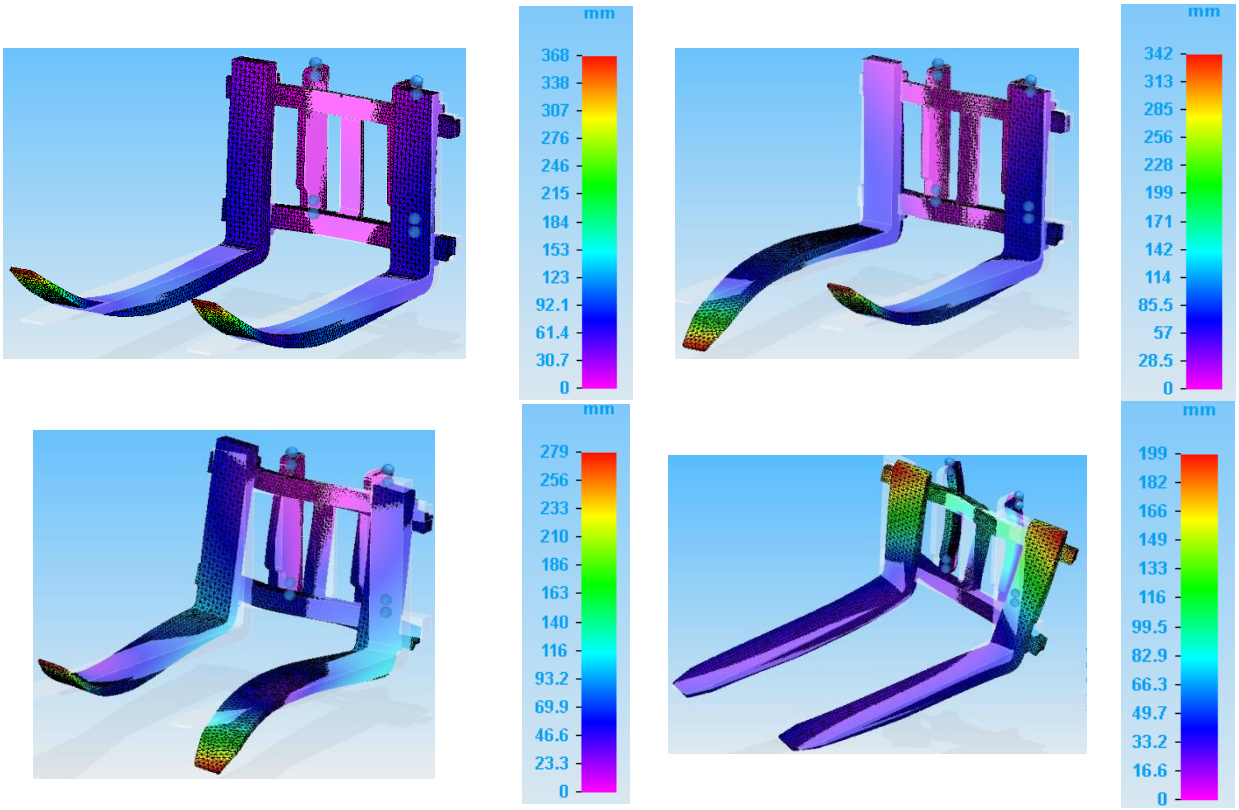


Fig. 9. The displacements of the structure nodes and their values corresponding to the first 10 eigenmodes of vibration

Figure 10 shows the variation mode of the displacements of the structure nodes for each of the first 10 eigenmodes of vibration. The variation of the displacements is relatively close in values, but the maximum value of the displacements appears for the eigenmode with the number 7.

It was also of interest to visualize the potential strain energy accumulated by the system in each of the 10 eigenmodes of vibration for which the analysis was performed, shown in Figure 11. The visualization of the potential strain energy stored by the system following its solicitation and the values of this energy leads to obtaining valuable information for specialists in the domain [14].

Figure 12 shows the variation mode of the potential strain energy for each of the first 10 eigenmodes of vibration. There is a very similar variation, up to overlap, of the potential deformation energy accumulated by the equipment in the first 4 eigenmodes, then close variation, but increasing in maximum values, for modes 5 with 6, 7 with 8, 9 with 10.

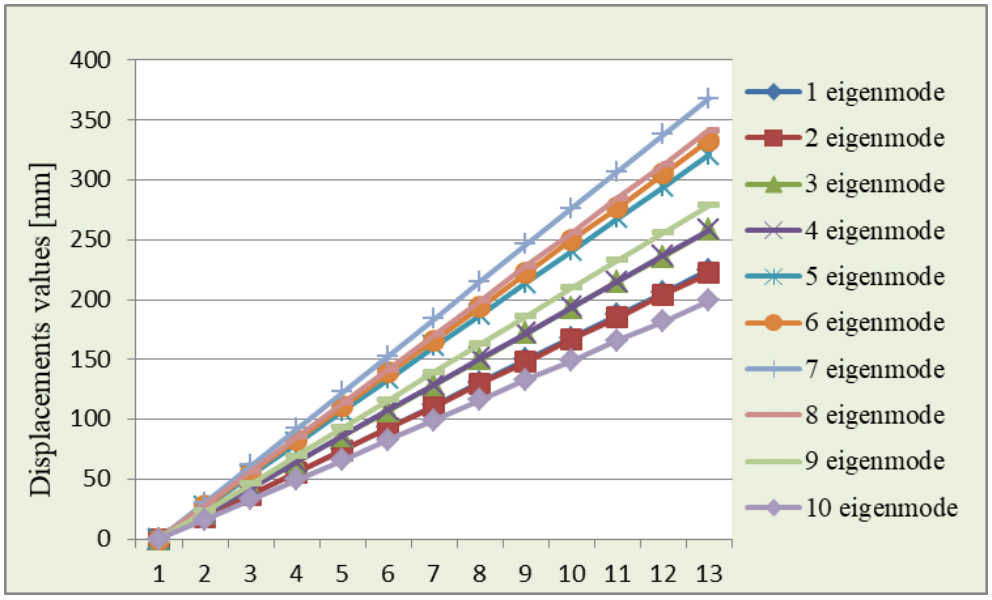
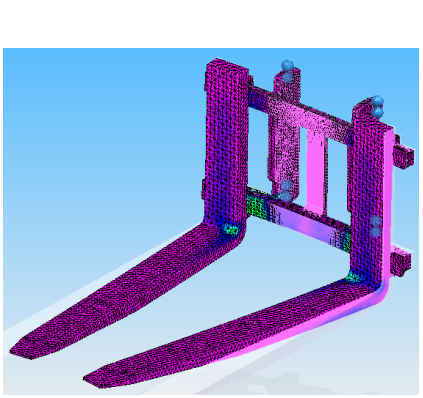
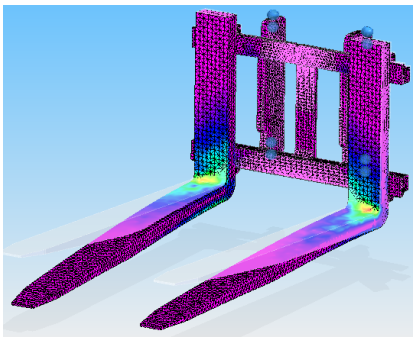
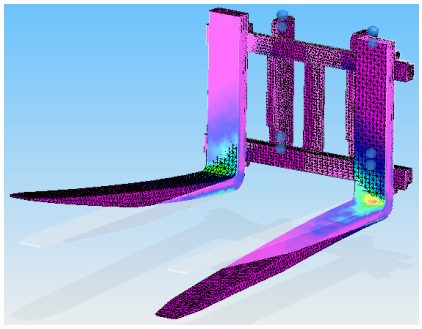


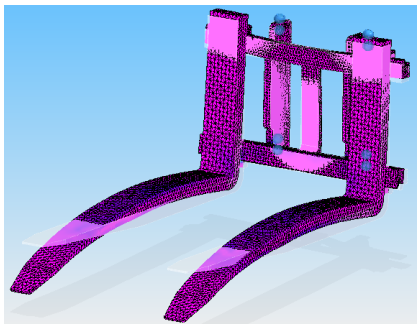
Fig. 10. The variation mode of the displacements of the structure nodes for each of the first 10 eigenmodes of vibration

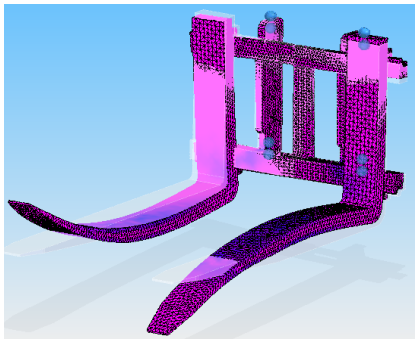

J
3.78
3.48
3.18
2.88
2.58
2.27
1.97
1.67
1.37
1.07
0.767
0.466
0.165

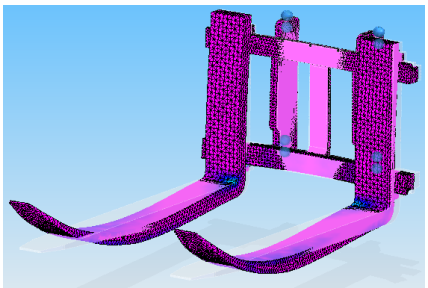
J
3.9
3.59
3.28
2.97
2.66
2.35
2.04
1.72
1.41
1.1
0.791
0.48
0.168

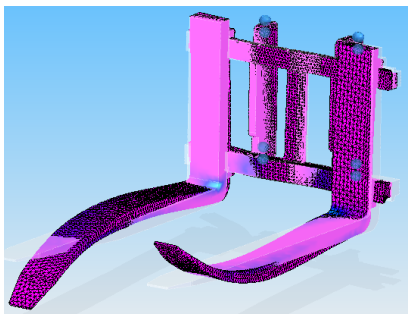

J
5.4
4.96
4.53
4.1
3.67
3.24
2.8
2.37
1.94
1.51
1.08
0.646
0.214


J
5.82
5.35
4.88
4.42
3.95
3.48
3.02
2.55
2.08
1.62
1.15
0.682
0.215


J
209
192
175
158
141
124
107
89.5
72.4
55.3
38.3
21.2
4.09


J
176
162
147
133
119
104
90.1
75.8
61.5
47.2
32.8
18.5
4.18


J
350
321
293
264
236
207
179
150
122
93.1
64.6
36.1
7.53


J
389
358
326
294
262
230
199
167
135
103
71.3
39.5
7.75

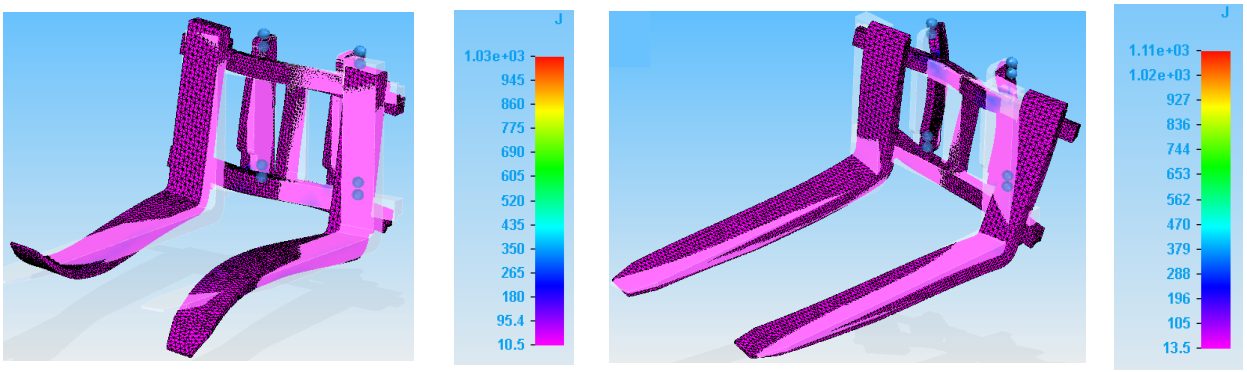


Fig. 11. The potential strain energy accumulated by the system and its values in each of the 10 eigenmodes of vibration

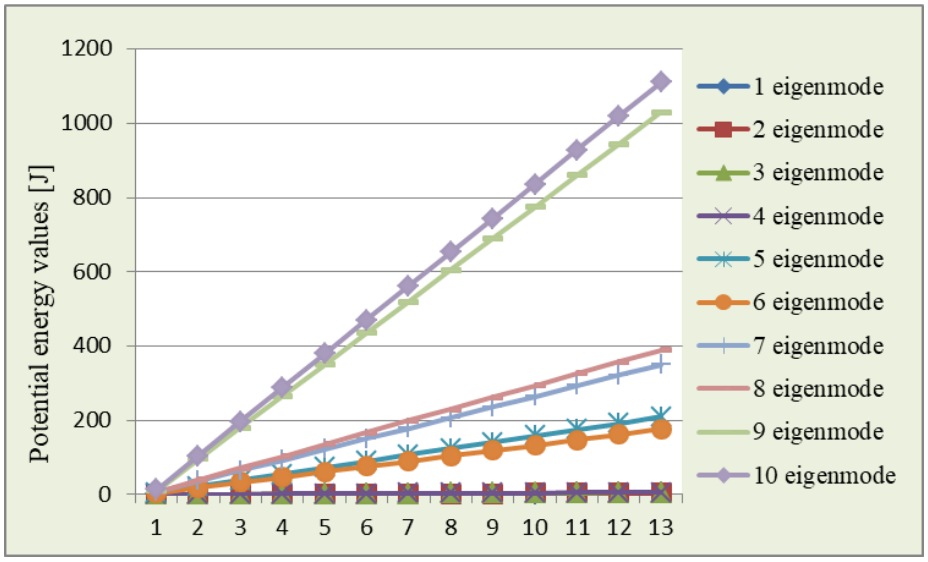


Fig. 12. The variation mode of the potential strain energy accumulated by the system

Next was made in Microsoft Excel a graph of variation of the maximum values of the displacements of the structure nodes according to the values of the eigenfrequencies of the working equipment of the forklift for the first 10 eigenmodes of vibration.

The graph in Figure 13 shows an increasing evolution of the maximum values of the displacements of the structure nodes directly proportional to the values of the eigenfrequencies from the eigenmode 1 to the eigenmode 7, then an increasing evolution of the maximum values of the displacements of the structure nodes inversely proportional to the values of the eigenfrequencies from the eigenmode 8 to the eigenmode 10.

Also, a graph of variation of the maximum values of the potential strain energy was made according to the values of the eigenfrequencies of the working equipment of the forklift for the first 10 eigenmodes of vibration.

The graph in Figure 14 shows an increasing evolution of the maximum values of the potential strain energy directly proportional to the values of the eigenfrequencies for all the 10 eigenmodes of vibration analyzed.

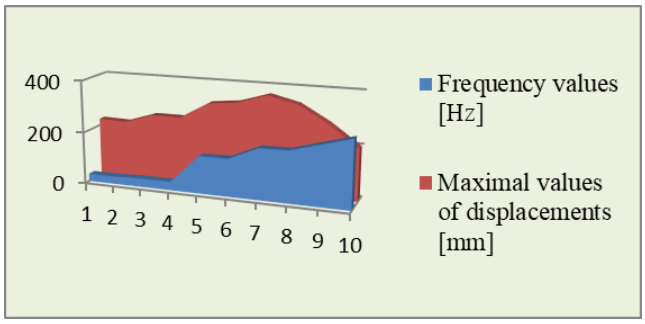


Fig. 13. The variation graph of frequency - maximum displacements of the structure nodes for the first 10 eigenmodes of vibration

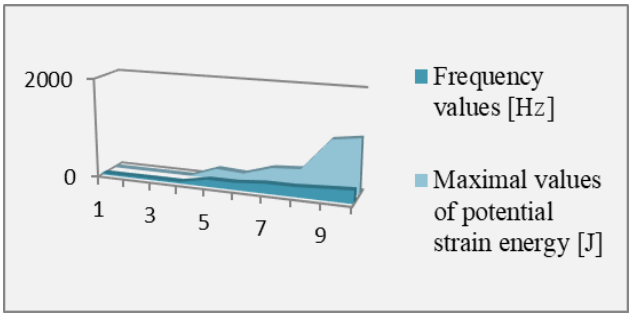


Fig. 14. The variation graph of frequency - maximum values of the potential strain energy for the first 10 eigenmodes of vibration

4. CONCLUSIONS

The analysis of the eigenmodes of vibration for the work equipment of the forklift was performed in order to make an estimate of the eigenfrequencies range of this constructive type of equipment. The information obtained from this analysis is useful because it highlights the possible occurrence of the resonance phenomenon.

Mechanical resonance is the tendency of a mechanical system to absorb more energy when the oscillation frequency becomes identical to one of the eigenfrequencies of the system (resonant frequencies), as opposed to absorbing energy at other frequencies. This phenomenon can lead to disastrous vibrations for static or dynamic equipments and for structures, constructions or buildings.

Also, the visualization of the potential strain energy stored by the system following its solicitation and the values of this energy leads to obtaining valuable information for specialists in the domain.

A body solicitated within elastic limits by a system of external loads deforms, external loads displace and an energy work occurs, called external energy work. As the body deforms, under the action of a certain solicitation, the consumption of energy work leads to the accumulation in the body of a potential strain energy. This amount of energy is released when the body is unloaded or released, which determines the reversibility of the deformations, when is performed the condition that the stress does not exceed the limit of elasticity of the considered material.

The property of solid bodies for storing potential energy has many technical applications (clock springs, suspensions, elastic damping elements). The expressions of the strain energy are the basis of some general methods for calculating the bending deformations of elastic systems.

5. REFERENCES

1. Anghelache, G.D., Goanță, A.M., (2016). *Diging simulation of a narrow trench*, Book Series: IOP Conference Series - Materials Science and Engineering, 145, 042016.

2. Utilben, Most important things to know about forklifts, Available from: https://www.utilben.ro/article/cele-mai-importante-lucruri-de-stiut-despre-stivuitoare, Accessed on: 02/03/2022.

3. Muscă (Anghelache), G.D., (2018). *Static and dynamic stability for floating cranes*, Book Series: IOP Conference Series -Materials Science and Engineering, 400, 082015.

4. Muscă (Anghelache), G.D., Năstac, S., (2020). *Dynamic modelling of overhead crane*, IOP Conf. Ser.: Mater. Sci. Eng. 916, 012071.

5. Drăgan, N., (2009). *Studies on the Mechanical Elastic Systems Dynamics of the Rigid Body with Structural Symmetries. Modal Analysis. Transmitted Forces and Moments*, Proceedings of the 10th WSEAS International Conference on AUTOMATION & INFORMATION "ICAI'09", Prague, p 118.

6. Drăgan, N., (2008). *Theoretical studies regarding the dynamics of the rigid body with elastic bearings and structural symmetries, excited by harmonical forces and couples*, Annals of the Oradea University, Fascicle of Management and Technological Engineering vol. VII (XVII), Section Mechanics, p 217-224.

7. Construction motivators, Available from: https://www.google.com/search?q=motostivuitoare+pentru+constructii, Accessed on: 04/03/2022.

8. Forklift for deposits, Available from: https://www.google.com/search?q=stivuitoare+pentru+depozite, Accessed on: 04/03/2022.

9. Forklift for recycling, Available from: https://www.google.com/search?q=stivuitoare+pentru+reciclare, Accessed on: 05/03/2022.

10. Forklift naval sites, Available from: https://www.google.com/search?q=stivuitoare+pentru+santiere+navale, Accessed on: 06/03/2022.

11. Forklift with snow plow, Available from: https://www.google.com/search?q=stivuitoare+cu+plug+pentru+zapada, Accessed on: 10/03/2022.

12. Forklift with brush for cleaning, Available from: https://www.google.com/search?q=stivuitoare+cu+perie+pentru+curatat, Accessed on: 10/03/2022.

13. Resonance, Available from: http://www.mobilindustrial.ro/current_version/online_docs/COMPENDIU/rezonanta_2.htm, Accessed on: 10/03/2022.

14. Potential energy of deformation, Available from: https://www.creeaza.com/tehnologie/tehnica-mecanica/Energia-potentiala-de-deformat388.php, Accessed on: 11/03/2022.

Received: March 31, 2022 / Accepted: December 15, 2022 / Paper available online: December 20, 2022 © International Journal of Modern Manufacturing Technologies