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Structural Design and Vibration Analysis of Soil Loader For Seedling

LI Linmei[1, 3]，YU Xiangmei[2]，ZENG Xianren[2*]
1. School of Civil Engineering and Architecture，NanchangHangkongUniversity，Nanchang，Jiangxi330063，China
2. School of Mechanical and Intelligent Manufacturing，JiujiangUniversity，Jiujiang，Jiangxi332005，China
3. School of Architectural Engineering and Planning，JiujiangUniversity，Jiujiang，Jiangxi 332005，China

Abstract: *With the vigorous development of seedling container of crops, the automatic production technology of device for raising seedling has been continuously improved, and the automatic technology and equipment of soil loading for raising seedling are also imminent. In this paper, a soil loading device for seedling cultivation is innovatively designed to realize the function of automatic soil loading and compaction at the same time. The natural frequency and vibration characteristics of the soil loader for seedling are further studied.The relationship between the natural frequency and them of beam spacing, side beam length and leg spacing of the soil loader for seedling are also studied. The results show that the lowest natural frequency of the soil loader for seedling is about 39.4Hz. Under the unit excitation, the maximum displacement of the soil loader for seedling in the x direction is 0.00075 mm. The natural frequency of soil loader for seedling has nothing to do with the beam spacing, but increases with the increasing of the length of side beams and decreases with the increasing of the leg spacing. The results of this study have certain guiding significance for the structural design of soil loader for seedling.*

Key words: *soil loader for seedling, planting barrel,structural design, natural frequency, vibration response*

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I. INTRODUCTION

With the vigorous development of soil container seedling[1], European countries began to research and develop compressed soil container seedling in the middle of the twentieth century, and successfully developed a semi-automatic pot-making machine. Subsequently, the mechanization level of vegetable cultivation in the former Soviet Union was ahead of the scale of artificial cultivation in China. By the end of 1980s, the scale of agricultural mechanization of crop cultivation had expanded a large number, which was well adapted to the local agricultural production demand. At present, the compression of crops into pots and the matching automatic seedling raising device have achieved a high level of production and have been applied in practical production[2].

At present, the most common types of seedling containers are: orifice plate, paper container, film container, plastic bag, hard plastic cup and so on. Most nursery utensils are made of plastic products, because of their low cost, strong durability and convenient transportation[3]. In seedling cultivation, there are common two types of bowls with hard and soft in the market (as shown in Figure 1).

The main material of hard bowl is polyethylene, which is characterized by light weight, high reuse rate, strong water permeability, promoting the growth of single seedling and high productivity rate of soil and fertilizer. Soft bowl is generally made of polyethylene, which is thinner than hard bowl, lower in use cost and has the same characteristics of hard bowl, so the software is more recognized by farmers.

In order to improve the effective utilization rate of vegetable planting space, the cultivation of vegetables was expanded from plane to space by filling the nutrient soil which is the standard mixture of animal excretion and soil in the planting barrel and by planting vegetables on the side wall of the planting barrel. As shown in figure 2. The top planting barrel is used for direct irrigation. In order to maximize the plant cultivation area per unit area, each planting barrel column is formed by stacking 5 planting barrels. The watering, illumination and mechanized harvesting of plants after maturity are all carried out in the unit of planting barrels. The new vegetable cultivation mode is show in figure 3.

However, in the process of seedling cultivation, there is still a lack of automatic machines that can be used for loading the nutrient soil into the planting barrel and there is relatively little research on related agricultural machinery. Therefore, it is of great practical significance to design a special soil loader for seedling cultivation, which can provide reference for the design of similar models in the future.

II. STRUCTURAL DESIGN OF SOIL LOADER FOR SEEDLING

1) Design of hopper

A circular hopper is adopted, and hopper support structures are arranged on the left and right sides. The hopper bracket is made of hollow rectangular steel, with four columns and square brackets. The center of the hopper is set with a cylinder, which can control the pressing action of the pressing plate on the planting barrel, so as to fill the planting barrel with soil and vibrate and tamp it[4]. Figure 4 shows the whole structure of hopper assembly.

2) Design of conveying device for planting barrel

The conveying bracket of the conveying device adopts a stair structure with two side beams and a plurality of cross beams. A power transmission mechanism and a driving motor are installed at both ends of the head and tail.The power transmission mode adopts a chain transmission mode with auxiliary plate.A support plate can be installed on auxiliary plate of the chain to support the planting barrel. Legs are equally spaced to support the conveying bracket and are fixed to the ground with expansion bolts[5]. The figure 5 is shown in details.

III. VIBRATION ANALYSIS OF SOIL LOADER FOR SEEDLING

Because the soil loading process is to load the soil in the funnel into the planting barrel, and because the soil falls freely into the planting barrel. Therefore, the loaded soil is not tight, and it needs to be vibrated in the process of loading soil to ensure that the nutrient soil in the soil loading bucket is relatively dense. In the structural design, a vibration exciter is designed and installed at the pressure plate to provide vibration source for the loader. In order to ensure that its vibration intensity is appropriate without serious damage to the soil loader, it is necessary to analyze the vibration of the soil loader.

3.1 finite element modeling of soil loader for seedling

In order to establish the finite element model of the soil loader for seedling, firstly, three-dimensional modeling of the loader is carried out, and the tiny structural features that do not affect the vibration analysis results, such as screws and small bosses, are ignored. Three-dimensional modeling of soil loader for seedling is carried out by ZW3D software, as shown in the following figure 6.

After the three-dimensional model of the loader is built, the grid is divided. The simulation module of ZW3D is adopted, and its internal automatic grid division tool is used. The grid cell size is set to 26.8mm, and tetrahedral grid division is adopted with medium grid density. The division is completed and the finite element model of the loader is established as the following figure 7.

3.2 Modal analysis

Because the support legs of the loader are fixed on the ground with expansion bolts, the support legs of the loader are fixed and restrained. The modal and natural frequency under the constraint of fixed leg are solved[6]. Table 1 shows the first 10 natural frequencies of the loader. Fig. 8 shows the first 10 vibration modes of the loader.

It can be seen from the figure above that the first vibration mode is translational deformation in Y direction. The second vibration mode is rotational deformation in Y axis. The third vibration mode is rotational deformation in Z axis. The fourth vibration mode is bending deformation in YZ plane. The fifth vibration mode is bending deformation in Y axis. The sixth vibration mode is combined bending deformation in YZ plane. The seventh vibration mode is twisted deformation in Z axis. The eighth vibration mode is warping deformation in Z direction. The ninth and tenth vibration modes are both bending deformation in Y axis.

3.3 Harmonic Response Analysis

In order to understand the vibration response of the loader under a certain excitation, the unit sine excitation (1N) with the frequency of 50Hz was applied to the motor mounting surface, and the maximum vibration response displacement was studied in three directions, namely, X, Y and Z[7]. Figs. 9-11 show the vibration response displacement of unit excitation in the x, y and z directions respectively.

From the vibration response nephogram, it can be seen that the displacement of the loader excited in the X direction is the largest, followed by the Y direction. The vibration in the Z direction is the smallest. And the maximum displacement in X direction is 0.0075mm under the action of unit excitation with frequency of 50Hz.

IV. STUDY ON NATURAL FREQUENCY OF SOIL LOADER FOR SEEDLING

Because the frequency of excitation motor is limited by the frequency of power supply, in order to improve the vibration effect of loader, it is necessary to adjust the natural frequency of loader structure.

4.1 Influence of beam spacing on natural frequency of loader structure

The beam spacing of the conveying bracket of the loader is designed as 200mm, 500mm, 800mm, 1100mm, 1400mm, 1700mm and 2000mm respectively. The natural frequencies of the structure are calculated respectively. Table 2 shows the first eight natural frequencies of the loader with different beam spacing.

As can be seen from the data in the above table, the first eight natural frequencies of the loader fluctuate slightly when the beam spacing increases from 200mm to 2000mm, and remain basically unchanged as a whole. It shows that the beam spacing has no great influence on the natural frequency of the loader.

4.2 Influence of the length of the side beam on natural frequency of loader structure

The distance between the beams of the conveying support of the loader are set to be 500mm The distance between the legs are set to be 1000 mm. The length of that convey bracket are designed to be 1m, 2m, 3m, 4m, 5m and 6m respectively. The natural frequencies of the structure are calculated respectively. Table 3 shows the first eight natural frequencies of the loader with different support lengths.

As can be seen from the data in the above table, when the length of the side beam is increased from 1m to 6m, the first eight natural frequencies of the loader change greatly. The value of natural frequency increases with the increase of the length of the side beam in the low-order natural frequency. However, the higher-order natural frequency tends to decrease with the increase of the length of the side beam. It shows that the length of the side beam has great influence on the natural frequency of the loader.

4.3 Influence of leg spacing on natural frequency of loader structure

The distance between the cross beams of the conveying support of the loader are set to be 500mm and the length of the side beams are set to be 3000 mm. Then the leg spacing of the conveying support is designed as 500mm, 800mm, 1100mm, 1400mm, 1700mm and 2000mm respectively. The natural frequencies of the structure are calculated respectively. Table 4 shows the first eight natural frequencies of the loader with different leg spacing.

As can be seen from the above table data, the first eight natural frequencies of the loader change greatly when the leg spacing increases from 500mm to 2000mm. In the whole frequency band, its natural frequency decreases with the increase of leg spacing. It shows that the leg spacing has a great influence on the natural frequency of the loader.

V. CONCLUSION

According to the function of the soil loader for seedling, the structural design of the loader is completed. The designed new loader consists of hopper, planting barrel, vibration motor, conveyor support frame and other components. The first 10 natural frequencies and vibration modes of soil loader for seedling are analyzed, and the vibration response of soil loader for seedling under unit excitation is studied by mode superposition method. The results show that the lowest natural frequency of the loader is 39.4Hz, and the maximum displacement in X direction is 0.00075mm under unit excitation. At the same time, the influence of the beam spacing, side beam length and leg spacing on the natural frequency distribution of the soil loader for seedling is further studied. The structure shows that the beam spacing has no correlation with the natural frequency of the loader. The increase of the length of the side beam makes the natural frequency of the soil loader for seedling increase, while the increase of the leg spacing will lead to the decrease of the natural frequency of the soil loader for seedling.

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FIGURE AND TABLE

a) the hard bowl

b) the soft bowl

Fig. 1 Plastic film seedling container

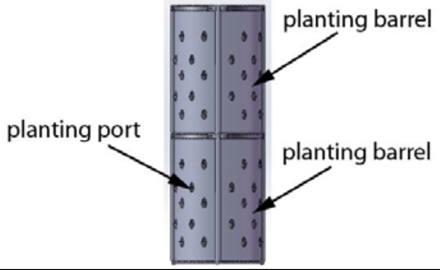


Fig. 2 planting barrel column

Fig. 3 the new vegetable cultivation mode

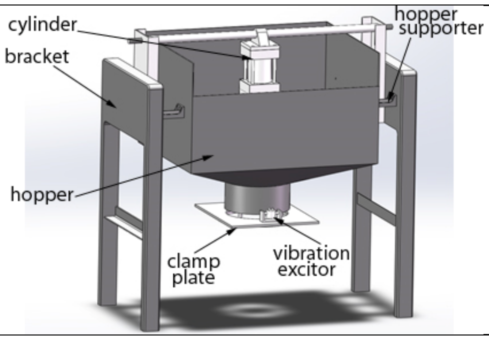


Fig. 4 Structure of hopper device

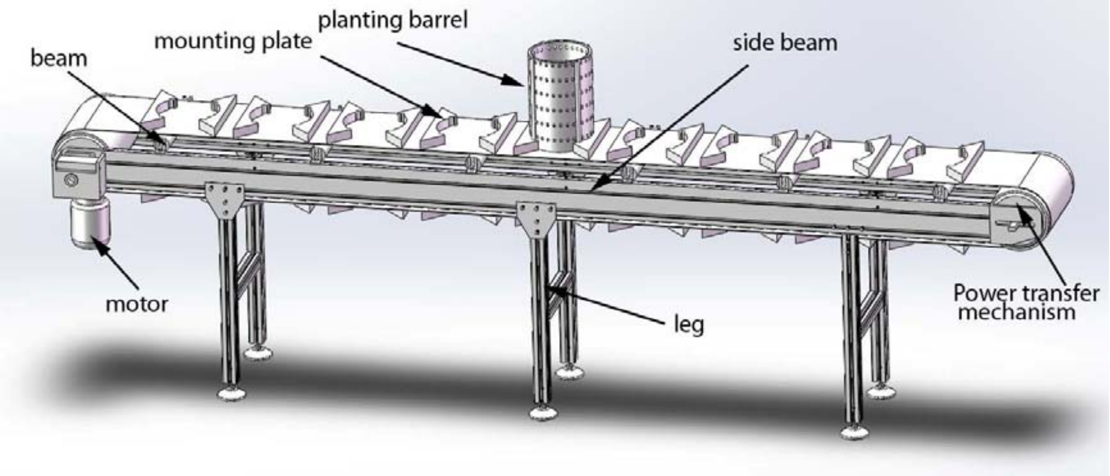
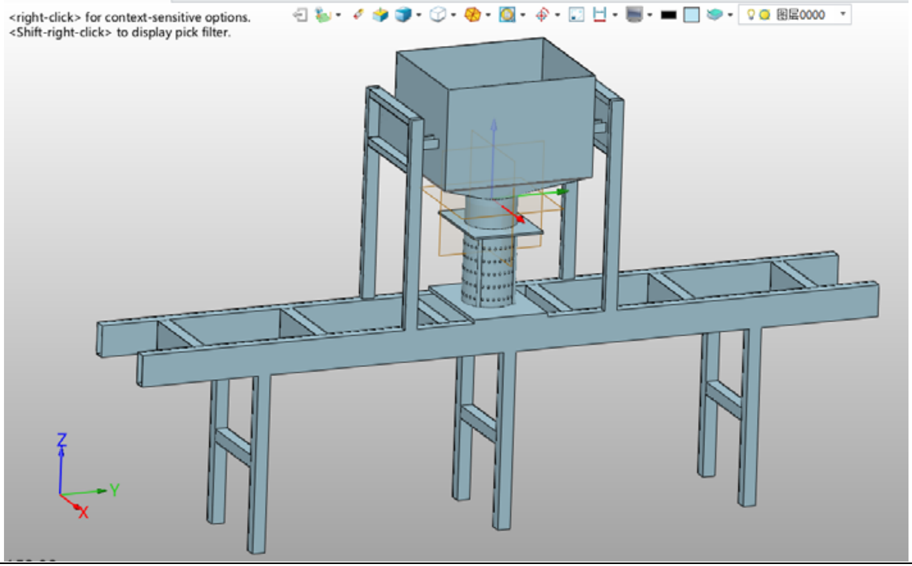
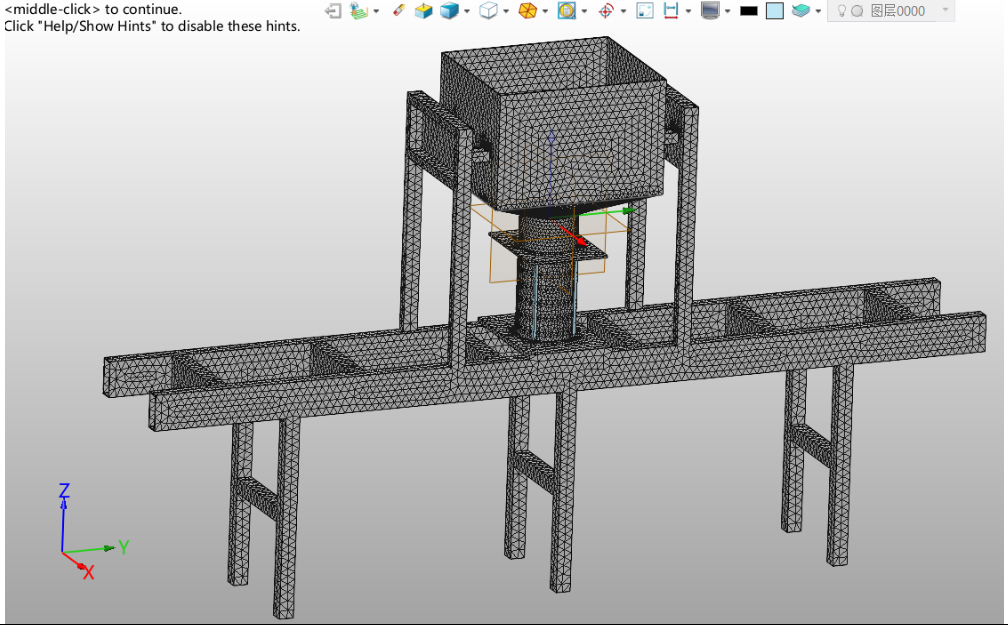


Fig. 5 Structure of conveying device for planting barrel



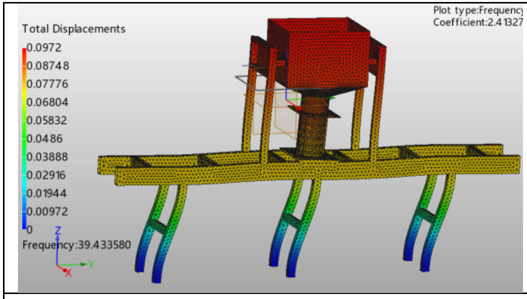
<right-click> for context-sensitive options.
<Shift-right-click> to display pick filter.

Figure 6 Three-dimensional model of loader

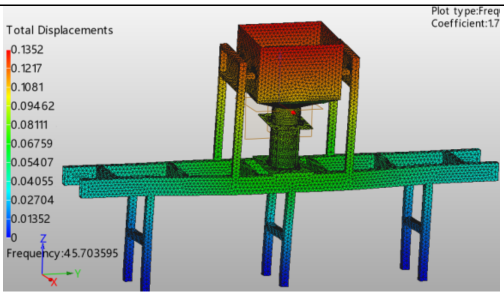


<middle-click> to continue.
Click "Help/Show Hints" to disable these hints.

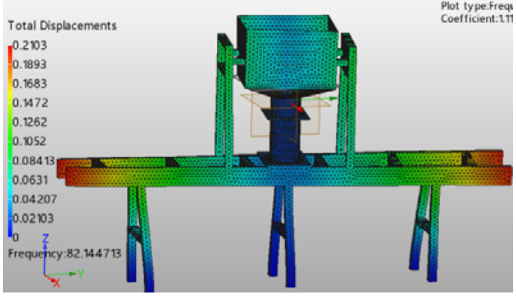
Fig. 7 Finite element model of loader



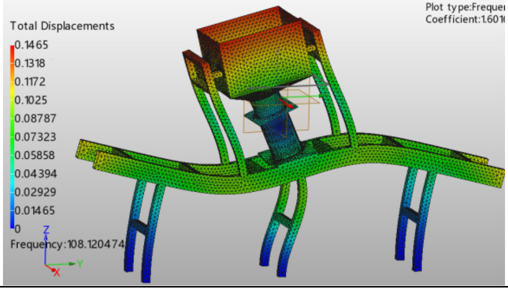
Mode shape : 1 ,Frequency : 39.4336



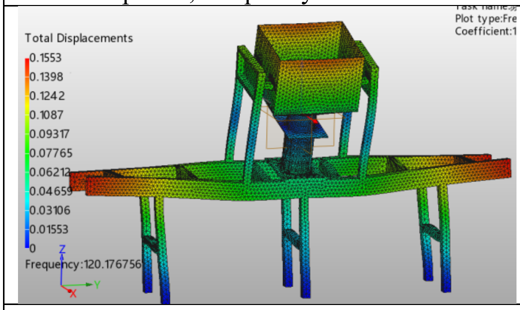
Mode shape : 2 ,Frequency : 45.7036



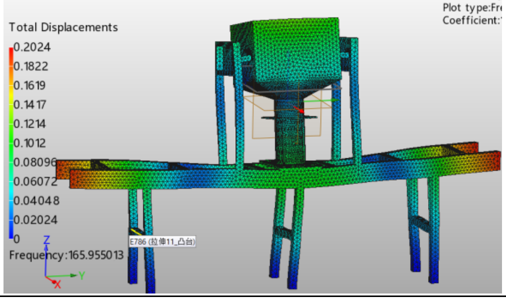
Mode shape : 3 , Frequency : 82.1447



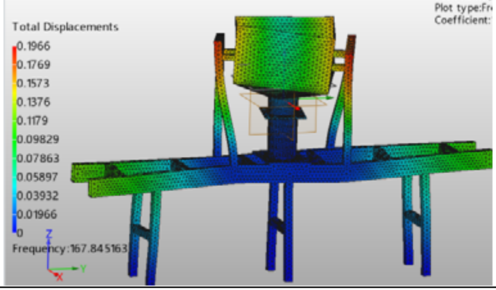
Mode shape : 4 , Frequency : 108.12



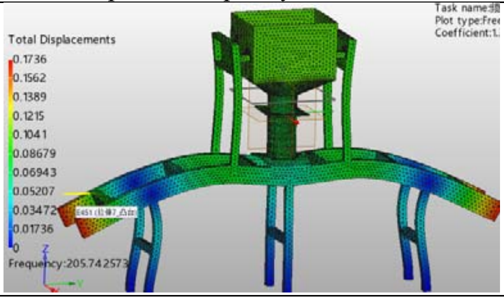
Mode shape : 5 ,Frequency : 120.177



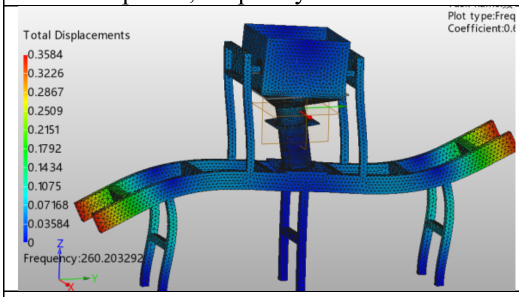
Mode shape : 6 ,Frequency : 165.955



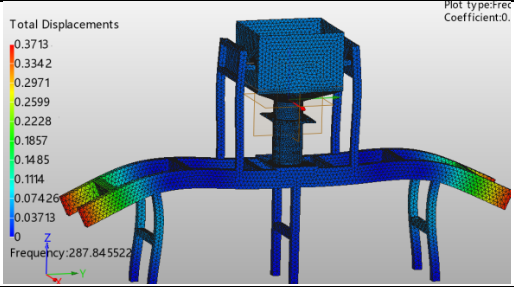
Mode shape : 7 ,Frequency : 167.845



Mode shape : 8 , Frequency : 205.743



Mode shape : 9 , Frequency : 260.203



Mode shape : 10 ,Frequency : 287.846

Fig. 8 the first 10 vibration modes of loader.

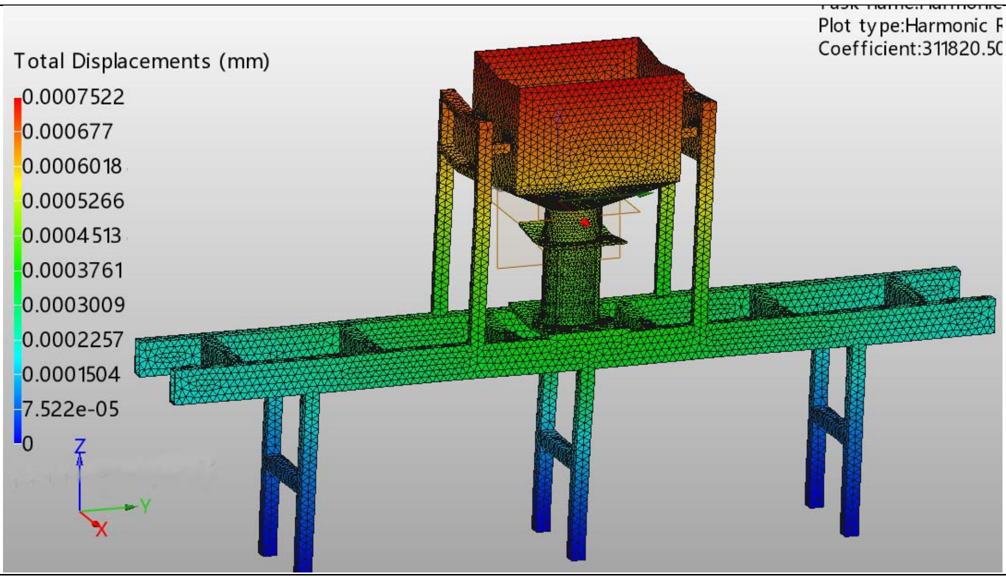


Fig. 9nephogram of displacement response of loader under unit excitation in X direction.

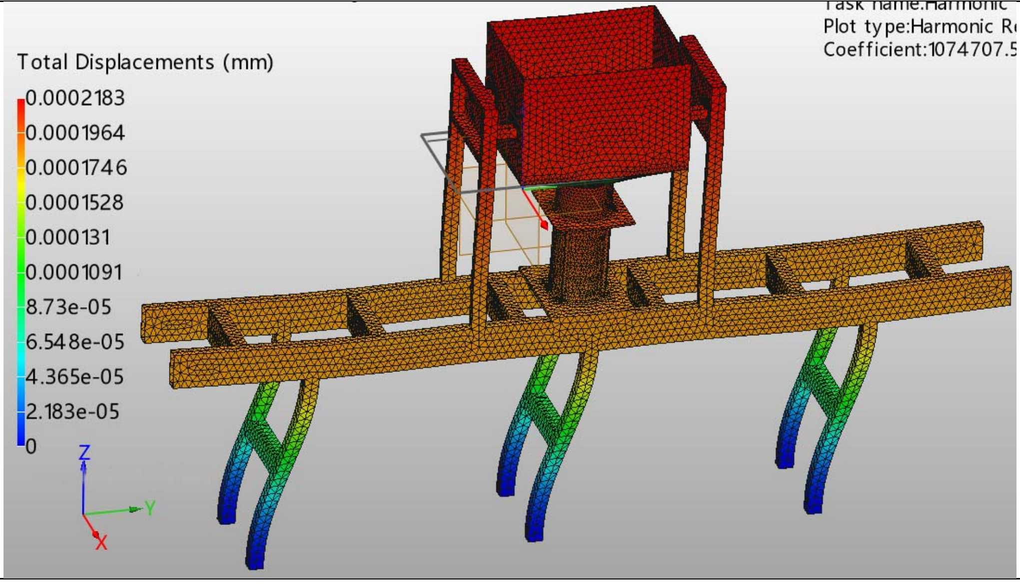


Fig. 10nephogram of displacement response of loader under unit excitation in Y direction.

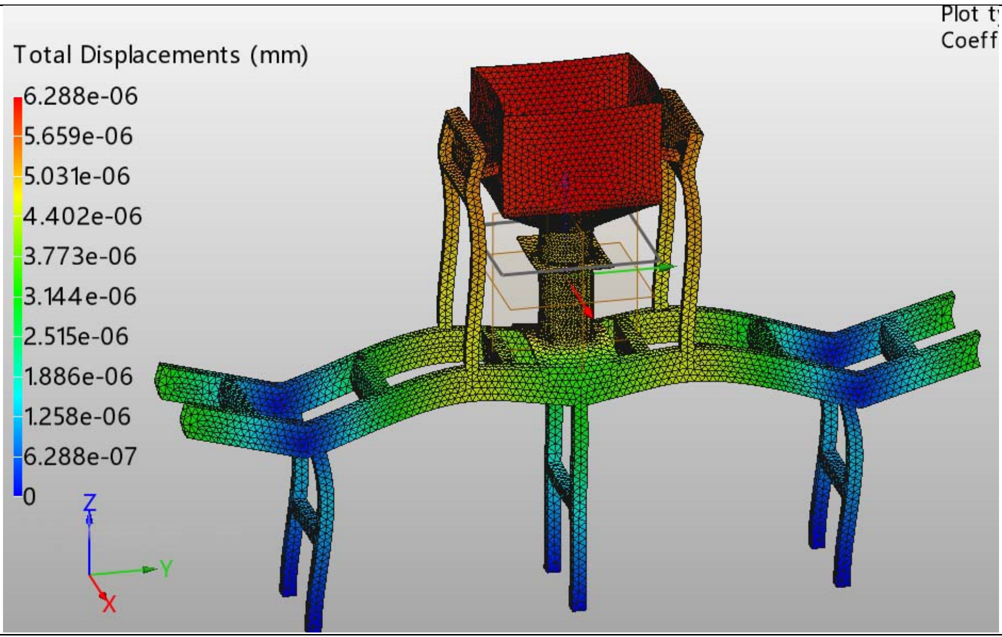


Fig. 11nephogram of displacement response of loader under unit excitation in Z direction.

Table 1 the first 10 natural frequencies of loader

order	1	2	3	4	5	6	7	8	9	10
Natural frequency (Hz)	39.4	45.7	82.1	108.1	120.2	165.9	167.8	205.7	260.2	287.8

Table 2 First 8 natural frequencies (Hz) of loader with different beam spacing

No. Beam spacing(mm)	1	2	3	4	5	6	7	8
200	41.1	50.7	81.8	112	127.3	180	198.6	204.6
500	39.4	45.7	82.1	108.1	120.2	165.9	167.8	205.7
800	40.2	43.8	81.4	108.9	118.5	149.9	157.2	206.1
1100	40.6	44.8	84.6	114.5	121.6	150.6	155.5	220.5
1400	40.7	42.86	76	109.3	113.6	142.4	142.8	208.8
1700	41.6	45	85.9	114.7	120.5	149.1	157.6	174.9
2000	41.1	44.8	85.2	113.1	118.3	146.7	154.8	211.2

Table 3 First 8 natural frequencies (Hz) of the loader with different side beam lengths

No. frame spacing(mm)	1	2	3	4	5	6	7	8
1000	36.4	41.4	87.4	129.8	164.8	177.7	248.2	303.7
2000	41	46.7	106	112.4	133.6	189.7	222.6	227.3
3000	47.3	47.6	113.6	130.8	156.6	170.6	177.4	198.4
4000	49	51.5	121	122	135	164.6	169.3	233.5
5000	50.5	52.7	117.5	126.6	149.5	154	166.2	203.4
6000	55.4	58.3	124.1	126.2	133	160	167.7	202.8

Table 4 First 8 natural frequencies (Hz) of loader with different leg spacing

No. Leg spacing(mm)	1	2	3	4	5	6	7	8
500	63.2	65.2	138.6	163.9	171.7	191.2	208.3	306.5
800	48.7	51.7	99.2	134.7	159	167.7	176.2	242.2
1100	39.7	47.4	88.7	106.4	125	165.6	166.3	210.3
1400	38.6	44.5	91.4	103.7	123.7	169.2	177.5	201.6
1700	33.3	34	68	70.8	88.6	108.1	139	163
2000	32.1	32.2	57.2	79.6	83.4	102.8	145.1	167.1