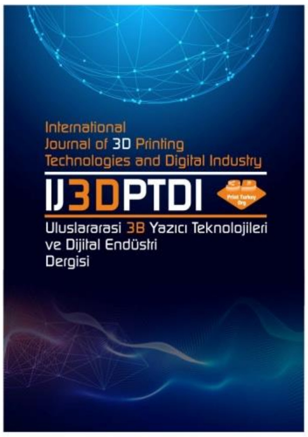

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DESIGN AND ANALYSIS OF COST-EFFECTIVE COMPACT DISC HARROW

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ABSTRACT

It is well-known that during tillage operations suprising items may appear below the soil surface in agricultural lands. Sometimes a stone/rock or solid root can cause major damage to the tillage equipments. These rocks and solid roots can cause major impacts on tillage equipment. In order to eliminate or minimize the impact of these forces, shock absorbing equipment is used which provides the connection between the disc harrow and the chassis. The most commonly used material for these shock absorbers is a rubber-based polymer known as vulkollan (polyurethane), which has a wide are of use in industry. Vulkollans are used to absorb the impact and wear out over time because of the sun, climate and impacts. Therefore, in this experimental study, steel springs are used since they are much more durable. Modal analysis was conducted in order to investigate the mechanical properties of steel springs. When spring and vulkollan are replaced, 20% improvement is achieved in terms of engineering. Because compact disc harrow becomes much lighter, more staible and flexible in hard fields. In this case, it ensures a long life of the disc harrow.

Keywords: Agriculture, Disc, Disc Harrow, Spring, Steel Spring, Vulkollan, Wear.

1. INTRODUCTION

Tillage is signifficant for the plant. It is the first step to prepare the appropriate environment for the germination and development of seeds. It is also defined as the physical processing of the soil clod size break up, kill the weeds and increase the infiltration capacity of the soil [1]. Increasing mechanization in agriculture is very important in terms of product quality. Effective use of agricultural machinery shortens the time required for any operations. Because today, depending on population growth, the need for food has increased the importance of agriculture even more. For this reason, large machines have started to be used in modern agriculture. These machines give the soil a much heavier load, much more pressure and the oppurtunity to reach more area [2].

The variety in soil tillage machines is very wide. Nowadays, disc harrow models is one of the most popular of these machines. Although it does not work as deep as a plow but it can be used for the same task in some fields. Tillage operations in traditional farming systems that require the use of tractors and harrows are costly. Improvements are made to increase sustainability and reduce costs. Fuel and time saving are achived by improvements. The study here is that the vulkollans, which function as a suspension between the disc and the chassis, wear out due to impacts and sun rays over time. As a result of wear, the disc harrow has problems in absorbing the impacts from the field and this reduces the performance of our system working fully [3].

In order to achieve tillage operations tractors are used.The most tractors uses fossil fuels. Tractor engines give emissions to the enviroment, the gases harm the nature and it is aimed to be reduced. If the soil is cultivated efficiently and quickly, less fuel is required and this has positive effects on both the enviroment and field [4].

In agriculture, tractors and tillage have become more modern with many technological developments over time. Hovewer, since the tractors are insufficient in suspension due to technical reasons, vibration cannot be completely avoided. For this reason, it is very important to reduce vibration in tillage. So shock absorbing equipment is used for this reaoson. The reason why the springs are chosen as suspension in the disc harrow is similar to the use in the automotive industry. Suspension is used to protect the machine body from field shocks and vibrations otherwise it directly effects system and driver. Because at any moment, it may encounter a stone or a solid root. The springs absorb the damages that may come from the shocks and vibrations [5].

The aim of this experimental study is to investigate the suitability of springs with different types of materials and improve the disc harrow efficiency.

2. MATERIAL AND METHOD

2.1. Compact Disc Harrow (Vulkollan Model)

Disc harrow is one of the most popular of tillage tools in industry. It is used to prepare the ground for the seed before the planting, to destroy the stubble after the planting and to cut the unnecesessary weeds in the field. It is designed to be used in stony fields with its wide disc spaces and connected design.

The tillage depth of the disc harrow increases in direct proportion to the disc direction angle and the tractor's forward speed, but it decreases as the position angle decreases. In the experiments, it is observed that the working depth of the machine varied between 81.2 and 224.4 mm. The immersion depth of the 560 mm diameter disc used in the compact disc harrow is determined as 150 mm. It has 24 discs with diameter of 560 mm (details in Figure 1).

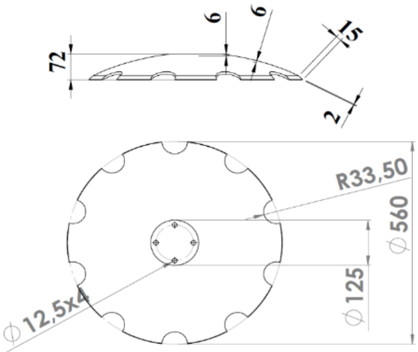

Figure 1. Dimensions of Disc (mm).

The attaching of discs on the chassis is made through cylindrical vulkollans (polyurethane) which is used for suspension duty. Compact disc harrow has lubrication and maintenance free bearing and consists of special alloy, long-lasting and notched discs (Figure 2).

Figure 2. Compact Disc Harrow (Vulkollan Model).

2.1.1 Vulkollans

It is a rubber-based technical plastic product that has a wide range of uses in the industrial sectors thanks to its properties (Figure 3). It has adhesion to the metal surface, works silently and is resistant to tearing and breaking.

Therefore they are used as they are resistant to wear, but it is observed that they wear out due to impact and climate change over time.

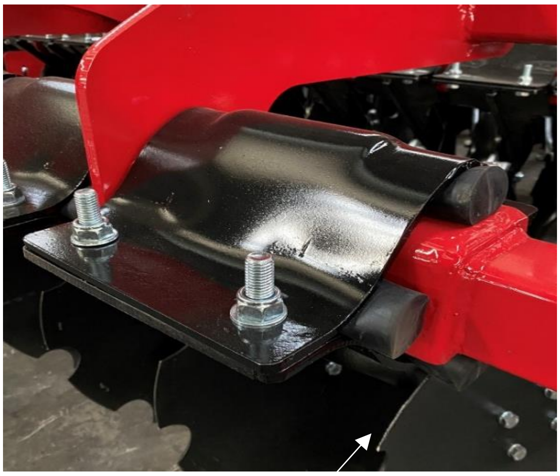

Figure 3. Vulkollan (Polyurethane).

2.1.2 Mechanical Spring

Mechanical springs are systems that can be defined as elastic and flexible, their main task is to store energy by bending under load and regain the original shape when the load is removed. In addition to creating a flexible working area, the load on the machine is reduced [6, 7].

Mechanical springs are widely used in automobile industries. And the reason for their use is similar to agricultural machinery. While processing the soil, many factors that may damage the machine may occur and the impacts must be damped. Helical springs are used for this task (Figure 4). It is designed and assembled to determine the range of movement of the disc. In addition to providing more comfortable driving, they are much more durable than vulkollan and do not wear in long-term use.

Figure 4. Helical Spring.

Lots of mechanical springs are available according to usage. For this study, helical springs were replaced with vulkollans for suspension. According to the selected mechanical spring type, the discs become adjustable according to the desired working depth. For compact disc harrow the working depth is 150 mm.

2.1.2.1 Selection of Steel Spring

Material properties have a direct effect on overall performance. Spring steels show different properties according to the chemical elements they contain. For this reason, the first issue is the criteria according to which spring selection will be made. The element that provides the necessary mechanical proporties to be a spring is silicon [8].

For compact disc harrow, 54SiCr6 grade steel spring is used (Table 1) [9,10].

Table 1. Chemical Composition of 54SiCr6.

Chemical composition % of 54SiCr6					
C	Si	Mn	P	S	Cr
0.54	1.40	0.64	0.005	0.009	0.63

After selection, it needs to be calculated for desired working depth. For working depth, the spring stroke should be calculated. All dimensions are selected for this spring stroke (Figure 5).

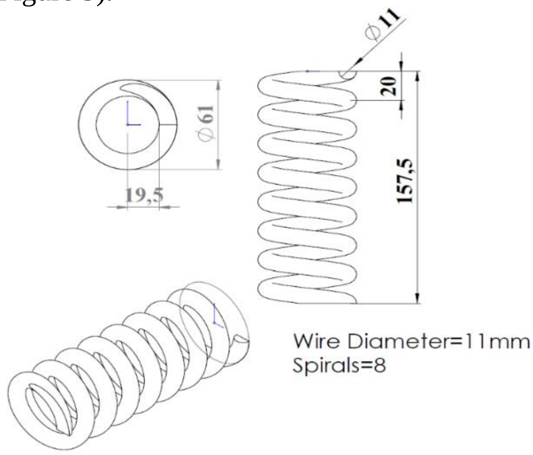

Figure 5. Dimensions of Spring.

Spring Stroke = Free Length of Spring – (Number of Spiral x Wire Diameter)

Spring Stroke= 157.5 mm – (8 x 11 mm) = 69.5 mm

So, for the 150 mm working depth, it needs 69.5 mm spring stroke.

The spring coefficient "k" value also needs to be calculated:

N_e= Effective Spirals of Spring = 6.5
d= Wire Diameter= 11mm
D= Spring Mean Diameter = 50mm
G = Young's Modulus of Spring = 200GPa

$$k = \frac{d^4 \times G}{8 \times N_e \times D^3}$$

Therefore, k value becomes 450.492.

2.1.2.2 Static Analysis of Spring

While choosing the spring, its inner diameter, free length and quality are important, but it needs to measure how much stress it can withstand when the load comes. These analyzes should be performed to predict when the spring will be deformed and damaged by the forces it is subjected to [11].

The spring is modeled in Computer Aided Design Software. Springs dimensions are as given (Figure 5). After design is ready, Computer Aided Engineering Simulation Software is used for static analysis and vibration analysis. All the necessary features and material for the spring should be defined (Table 2) [9,10].

Table 2. Mechanical Proporties of 54SiCr6.

Density (x1000 kg/m^3)	7.7-8.03
Elastic Modulus (GPa)	190-210
Tensile Strength (Mpa)	1158
Yield Strength (Mpa)	1034
Hardness (HB)	335

For the analysis, the required model and material are added to the program as defined. According to the content of this material, analyses are calculated automatically, and its maximum and minimum values are calculated. In other words, no value is entered, only fix and displacement locations are specified, and the program calculates according to these inputs.

When working the soil, high force may occur, so analysis should be made. Total deformation, stress and vibration analysis are performed for the spring. Analyses setup can be seen in Figures 6 and 7 as fixed support and displacement components.

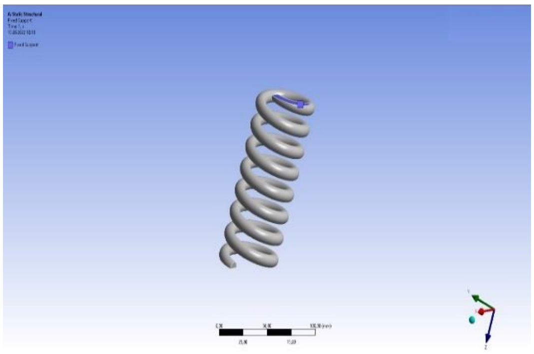

Figure 6. Fixed support.

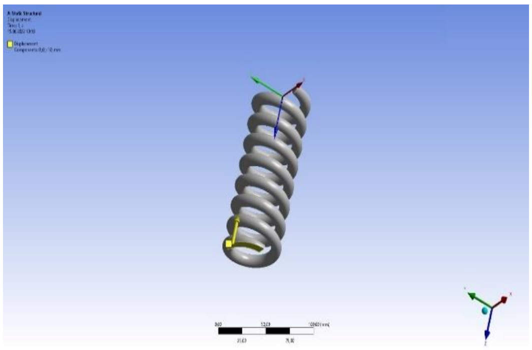

Figure 7. Displacement components.

In this study, ground supports and loads suitable for use in damping air conditioning evaluated as static were used. Computer engineering simulations were used in the study. The number of nodes are 5389 and the number of elements are 2337.

Displacement analysis was performed and the boundary displacement value was calculated. This value is 10.013 mm for the spring (Figure 8). This does not indicate the maximum displacement the spring can achieve without deforming.

It is necessary to determine the region where alloys such as steel lose their elasticity and undergo plastic deformation as a result of tests. It must be designed within this elastic limit to be safe. In the test performed here, the maximum yield strength of the spring is determined. In this study, after Von-mises stress analysis, it was observed that the maximum stress it could withstand was 357.05 MPa (Figure 9).

Modal analysis is the study of dynamic properties of systems in frequency. This analysis informs the design engineer how it will respond to different dynamic loads. In this study, modal analysis was performed with reference to static structural analysis and the values displayed at different frequencies were simulated (Figures 10-15). The maximum values corresponding to the frequency are extracted from the table (Table 3). This analysis allows us to determine the response of materials to vibrations that are random by nature. For example, the vibrations that may come from a terrain will be different with each pass. For this reason, random vibration analysis is performed and statistically average value is determined from their history. This analysis makes the machines more reliable.

The directional deformation is the regular results given by the vibration analysis program, the default is the sigma value or the standard deviation value. This test is performed with reference to the modal analysis in the analysis program (Ansys) [11]. And a table is created with the maximum values according to the axes (Table 4). As seen in the figures, the maximum directional deformations are listed as z, x, and y, from largest to smallest, respectively (Figures 16-19).

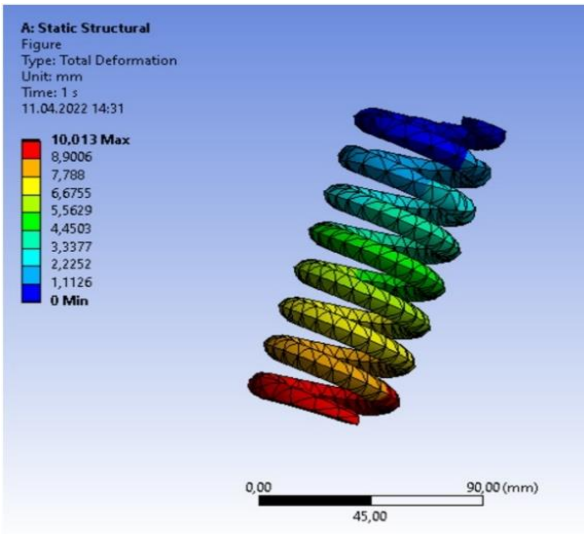

Figure 8. Static Structural, Total Deformation.

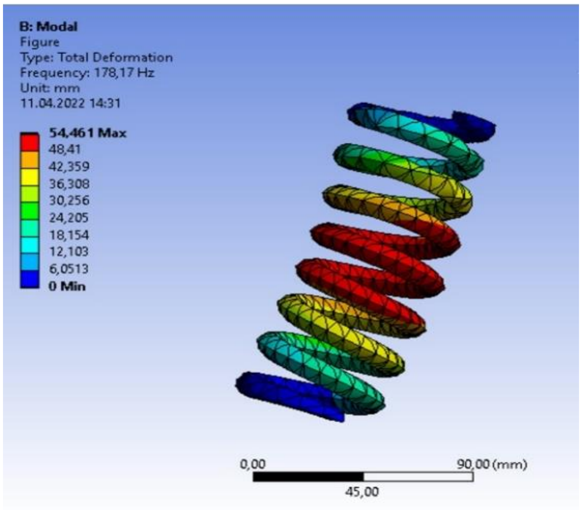

Figure 11. Modal Analysis, Total Deformation 2, 178.17 Hz.

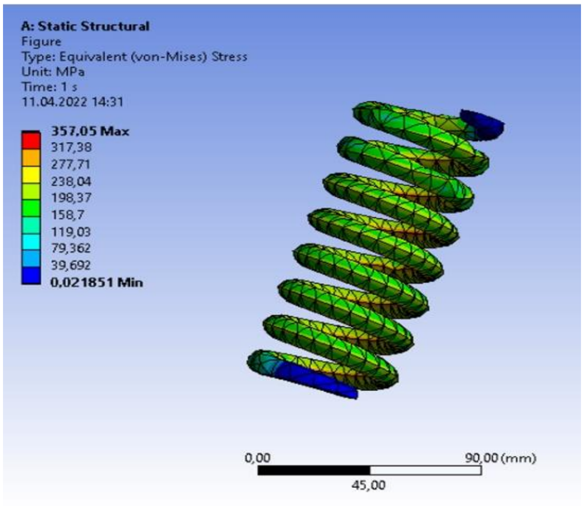

Figure 9. Static Structural, Stress Analysis (von Mises).

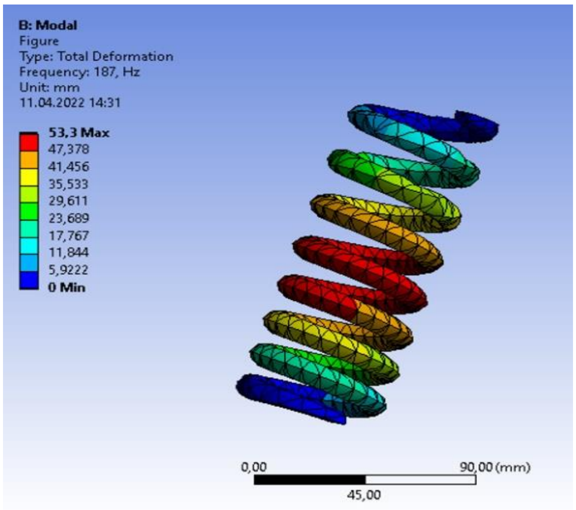

Figure 12. Modal Analysis, Total Deformation 3, 187 Hz.

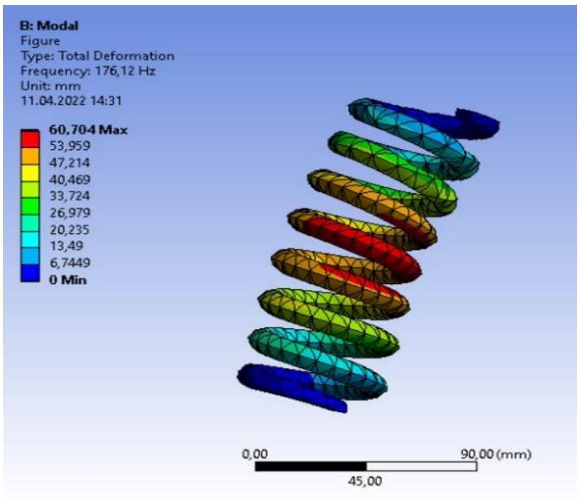

Figure 10. Modal Analysis, Total Deformation 1, 176.12 Hz.

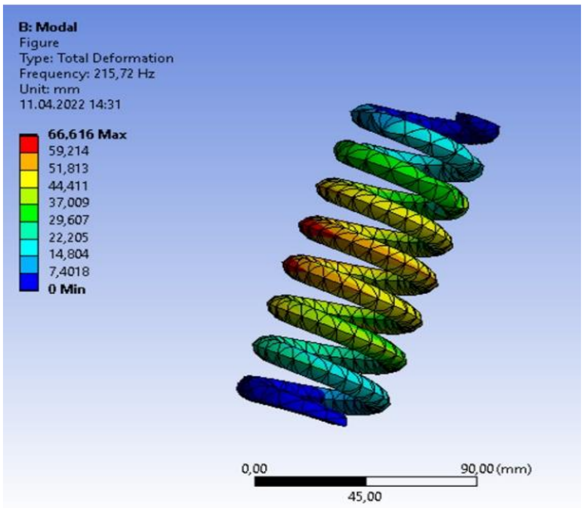

Figure 13. Modal Analysis, Total Deformation 4, 215.72 Hz.

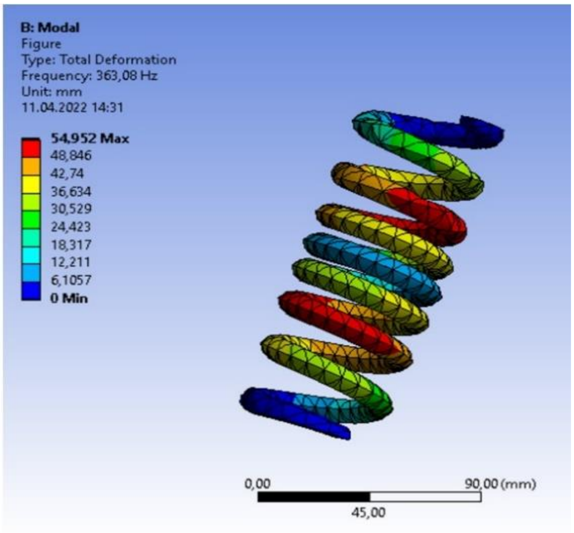

Figure 14. Modal Analysis, Total Deformation 5, 363.08 Hz.

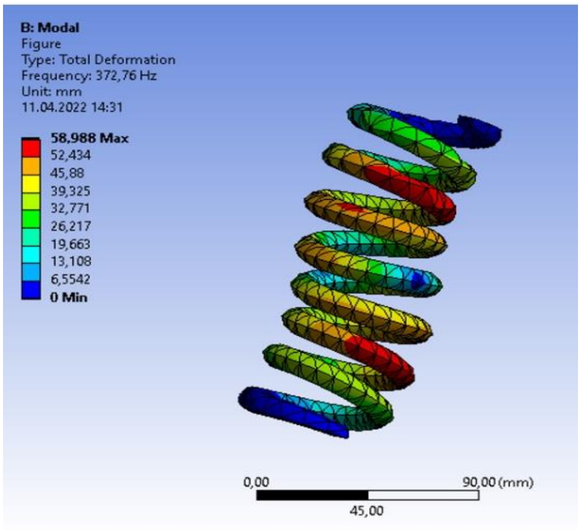

Figure 15. Modal Analysis, Total Deformation 6, 372.76 Hz.

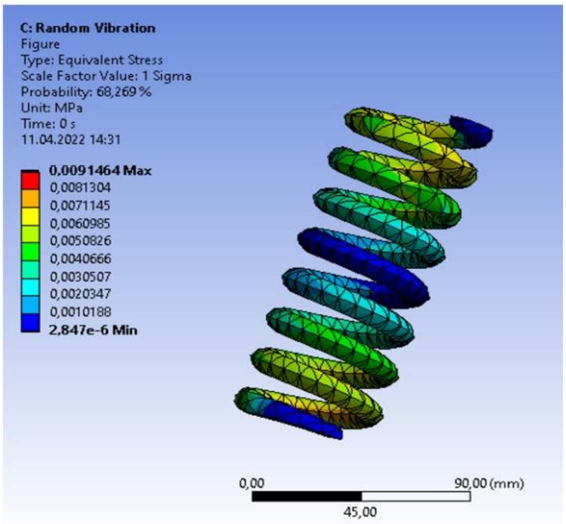

Figure 16. Random Vibration, Stress Analysis 176.12 Hz.

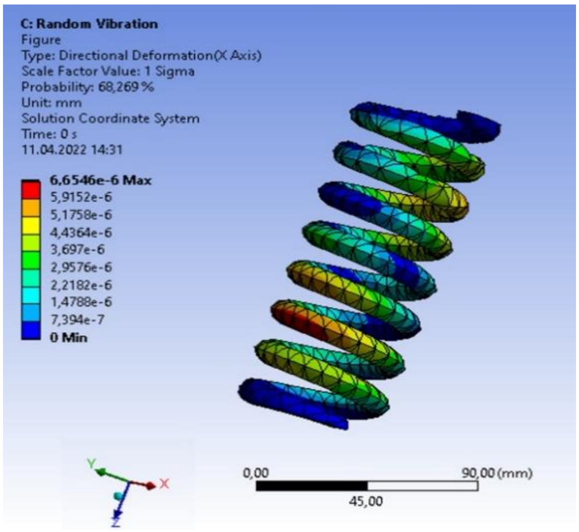

Figure 17. Random Vibration, Directional Deformation (X Axis).

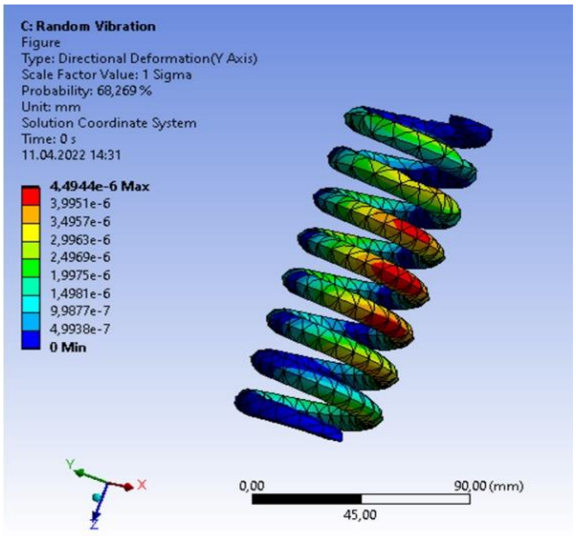

Figure 18. Random Vibration, Directional Deformation (Y Axis).

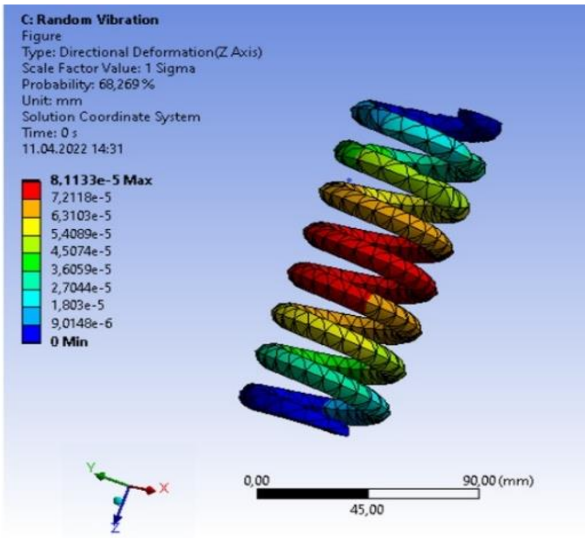

Figure 19. Random Vibration, Directional Deformation (Z Axis).

3. RESULTS AND DISCUSSION

Modal analysis is the study of dynamic properties of systems in frequency. This analysis informs the design engineer how it will respond to different dynamic loads. In this study, modal analysis was performed with reference to static structural analysis. Stress and vibration analysis are performed by Computer Aided Engineering Simulation Software. The values show helical spring's strength against load. It is important because designer should know that how strong is the material.

The analyses show that what is the maximum yield strength and deformation informations. The force applied to the material causes permanent deformation by removing the material from its elastic state after a point. That point is much larger than vulkollans.

Vibrations can cause undesirable situations such as waste of energy, sound and noise. It even causes machines to become unusable. This can lead to increased costs, unwanted downtime, spare parts costs, and even scrapping the puchased equipment costing lots of money. In order to prevent this, necessary vibration analyses were made.

Table 3. Modal Analysis Results.

Frequency (Hz)	Total Deformation (mm)
176.12 (mod 1)	60.7
178.17 (mod 2)	54.46
187 (mod 3)	53.3
215.72 (mod 4)	66.6
363.08 (mod 5)	54.95
372.76 (mod 6)	58.98

Table 4. Random Vibration Analysis Results.

Coordinate	Directional Deformation (mm)
X Axis	6.65
Y Axis	4.49
Z Axis	8.11

3.1 Vulkollan Model Design versus Mechanial Spring Model Design

3.1.1 Compact Disc Harrow with Vulkollan

In the vulkollan model, the front and back rear chassis profiles are 100x100 mm, and the middle chassis profile is 100x200 mm dimensions. There is the details of the dimensions of the chassis on Computer Aided Design Software (Figure 20).

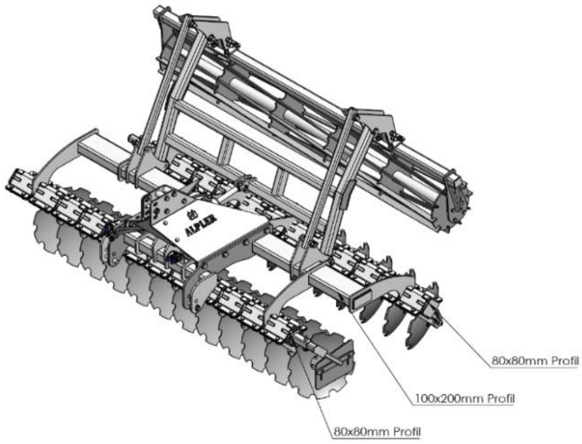

Figure 20. Compact Disc Harrow (Vulkollan Model).

3.1.2 Compact Disc Harrow with Helical Spring

For the spring model, the front and back rear chassis profile changed to 80x80 mm and the middle chassis profile changed to 100x100 mm dimensions (Figure 21).

The reason for using smaller profiles in the spring model is that the springs are much more successful in absorbing the impacts to the mechanism than the vulkollan. Accordingly, the use of a smaller and lighter chassis provides both weight reduction and cost reduction.

In short, the reason for its use is that the smaller profile is sufficient, as there is less impact on the body in the spring model. After these changes, the total weight of the spring leg model is 80 kg less than the total weight of the vulkollan leg model. The mechanical spring model, besides its long life, enables the farmer to save fuel and time due to the reduction in mass.

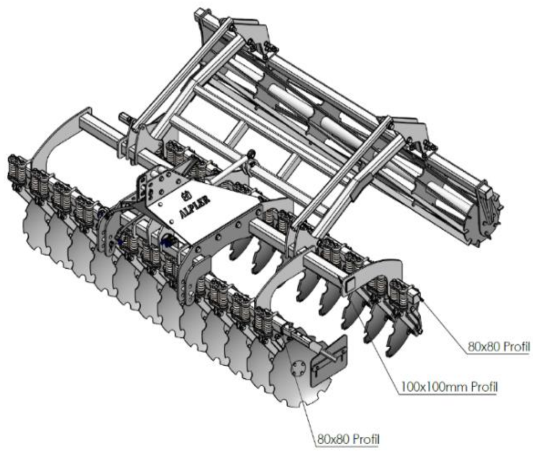

Figure 21. Compact Disc Harrow (Helical Spring Model).

4. CONCLUSION

The reason for this analysis is that it is not known what happens in the field while performing the tillage operations. A very solid root or rock may come out during cultivation with disc harrow. Vibration analysis was carried out to measure the response of our system during operations. When this information is obtained, some parts of the system can be modified and thus reduced the weight and the cost.

When spring and vulkollan are replaced, 20% improvement is achieved in terms of engineering. Because compact disc harrow becomes much lighter, more stable and flexible in hard fields. In this case, it ensures a long life of the disc harrow.

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