# Structural Analysis of the differential chassis for development of paddy weeder using finite element analysis


**ABSTRACT:**

**Aim:** Structural analysis of differential frame used for development of weeder using finitie element analysis interms of Von Misses stress, displacement, and safety factor
**Study Design:** Solid work simulation using finite element analysis
**Place and duration of study:** Dr NTR College of Agricultural Engineering, Bapatla. Duration of study was from June,2023 to Septmenr,2023
**Methodology:** SolidWorks 2018 software was used for the development of 3 D model for differential chassis. AISI 1010was the material utilized in the construction of the differential chassis of the weeder in this study. Based on the mentioned description of the analysis, the goal of this study was to use SolidWorks 2018 software and the finite element analysis method to examine the differential chassis frame construction. The minimum value of the safety factor was one of the references used as a gauge of a design's safety. Engineers frequently utilize an object's safety factor as a reference metric when determining how much stress it can withstand. This study's results include Von Mises stress, displacement, and safety factor for determining the material's capacity to sustain dynamic loads and shock loads.
**Results & Discussions:**The rated load of 2943N applied on differential chassis as per design calculation, lowest value of von Mises stress 0.112 $N/m^2$ was observed at the Centre of differential where drive chain attached portion and highest von misses stress of $3.12x10^6$ $N/m^2$ was observed at brake drum edges where axle sprocket attached. Max deformation of 0.0647mm was observed at Centre of differential and minimum deformation of $1x10^{-3}$mm was observed at edges of brake drum. When rated load of 2943N applied, the factor of safety was observed as 3 which suited for carrying dynamic loads.
**Conclusion:** The differential chassis selected was suitable for development of axle system up to 2000 N dynamic load.



*Key words: Differential chassis, paddy weeder, Stress analysis, Finite element analysis*


## 1. INTRODUCTION:

"Rice (*Oryzasativa*L.)is India's prominent crop, and is the staple food for most of the Indians. India has the world's largest area under rice cultivation and is one of the largest producers of white rice, accounting for 20 per cent of global production. Even though many improved technologies have been introduced in paddy cultivation, still management of weed is a major concern in paddy cultivation which competes for sunlight, space and nutrients with the main crop and directly responsible for reduction in crop yields due to 10 to 25% weeds and 35 to 45% in direct sowing paddy" (Yaduraju 2012). The common type of weeds which affects yield is *Cyperusdifformis*, *Marseliaquadrifoli, Echinochloacrusgalli etc.,* (Yaduraju,2012). Different manufactures, industries and scientists have developed different types of weeders for both dry and wet land paddy conditions using improved equipment like hand hoe, finger &conoweeders, animal, power tiller and self-propelled weeders for weeding in paddy fields. Major constraints in using above weeders are Chocking of mud, High risk of manoeuvrability, high cost of operation and tedious operation.to overcome above problems and identified research gap, a remote controlled paddy weeder was developed at Dr NTR College of Agricultural Engineering, Bapatla using differential chassis, triangular track wheels, drive system and operating system. The structure of differential chassis analysed with solid work analysis for stress analysis as all the parts of weeder was mounted on this chassis only. Based on the design considerations, 900 mm differential which has load bearing capacity of 4905 N was selected for attaching developed triangular track wheels with following specifications.

- Gear type: Cross gear
- Gear ratio: 1:10
- Max speed: ≤ 30km/h
- Shaft: EN45 Grade
- Brake diameter: 160 mm
- Brake type: Drum
- Nut type: Close nut
- Wheel rim: 4*M14
- Weight: 16.8 kg

"Prior to manufacture the machine, a design must be created using computer design technology (CAD/CAM). This technology can reduce major expenses associated with design flaws" (Chirende, Li, and Vheremu 2019; Cekus et al., 2019). "Design optimization can reduce manufacturing errors and can lengthen the product's service life" (Vegad and Yadav, 2018). "Technology-based design optimization has been used by cutting-edge businesses working in mechanics and other types of structures". (Gheorghe et al., 2018). Software like SolidWorks and ANSYS (AlShammari and Al-Waily, 2018; AlShammari and Abdullah, 2018) uses "finite element analysis techniques as an efficient tool to discover solutions to challenging problems and can solve many engineering difficulties effectively" (AlShammari et al., 2020).

"The finite element approach used to tackle a variety of issues, including issues with structural analysis, buckling (buckling), and vibration analysis" (Popa*et al*., 2021). Structural analysis was the finite element analysis technique that was most widely employed. The term "structure" in this context refers to mechanical, aeronautical, and naval structures as well as buildings and bridges. "The static structural analysis ignores the effects of inertia and damping while accounting for displacements, stresses, strains, and forces on the structure as a result of loading. Solid models of the differential chasis , frame for mounting all components were prepared in solid work software. Each of these part assembly models wereanalyzed for maximum stress and deformation using a FEA software in solid work analysis module" (Popa et al., 2021)

"The material choice and frame design must be based on the maximum value of working stress, analysis of the stresses occurring on a structure is crucial. Based on the findings of the uniaxial tensile test, the von Mises stress is utilized to forecast the yield of materials subjected to complicate loading" (Suprapto and Wibawa, 2021). In general, deformation in blades mostly end up wear of the component at limited stress application. But where the stress received in high magnitude results in breakage of the chassis. Therefore, the dimension and strength of the differential chassis selected in such a way that even at ultimate stress, the chassis was expected to withstand and perform well. To prevent a failure and establish operability of the tool design, considering safety factor is necessary.

## 2. MATERIALS & METHODS:

SolidWorks 2018 software was used for thedevelopment of 3 D model for differential chassis. AISI 1010was the material utilized in the construction of the differential chassis of the weeder in this study. It was chosen because it was heat and corrosion-resistant (Rakesh *et. al.*,2018&Kelly, 2015). The overview of the parameters used in the simulation is shown in Table 1. For analysis, the data in the table will be entered into the solid work analysis module.

**Table 1 Simulation parameters of materials**

| Description Value | Name |
|---|---|
| Material | Steel for weeder |
| | MS iron for triangular track and frame |
| Model type | Isotropic |
| Yield strength | 1.7 x 108 $Nm^{-2}$ |
| Tensile strength | 4.85 x 108 $Nm^{-2}$ |
| Elastic modulus | 2x1011 $Nm^{-2}$ |
| Poison's ratio | 0.265 |
| Mass density | 8.027 $kgm^{-2}$ |
| Shear modulus | 8.2 x 1010 $Nm^{-2}$ |
| Thermal expansion | 1.65 x $10^{-5}$ /Kelvin |
| Load machine | 2452 N |
| Load on triangular track | 569 N |
| Load on rotary weeder | 176 N |

### 2.1. Mesh simulation

Mesh has an impact on computational modelling utilizing the Finite Element Analysis (FEA) technique. In a simulation, mesh was a process that has a high level of complexity (Srigiri*et. al.*, 2016

&Sosnowski*et al.,* 2018). Mesh results have a significant impact on the simulation's convergence outcomes. The simulation may fail as a result of an error made during creating the mesh, which means that mesh generation process must be reperformed, which was time-consuming. The findings are more accurate with smaller meshes, but the simulation procedure takes longer.

**Table 2 Mesh distribution information**

| | |
|---|---|
| Mesh type | Tetrahedral |
| Mesher used | Curvature |
| Maximum element | 2.69609 cm |
| Minimum element | 0.539218 cm |
| Mesh quality | Draft |
| Total nodes | 7808 |
| Total elements | 25599 |
| Maximum aspect ratio | 2.558,3 |
| Percentage aspect ratio<3 | 91.6% |
| Percentage aspect ratio>10 | 0.43% |

Hexahedral mesh, polyhedral mesh, and tetrahedral mesh are some of the mesh types utilized in computational fluid dynamics (CFD) simulation. The tetrahedral mesh was employed in this study because it was more effective for simulating stress distributions and CFD simulations are frequently used in irregular geometries (Chen *et al.,* 2021).

The information on the mesh distribution used in this investigation is shown in Table 2. Calculations utilizing the finite element approach must be performed using a computer due to many equations involved. This approach was cost and time efficient while also ensuring the accuracy of the results. The fundamental idea behind the finite element approach was to discretize an item into a finite number of parts. This section takes the shape of a triangle, with each element being a linear quadrilateral connected by a node (node) as shown in Fig.1.

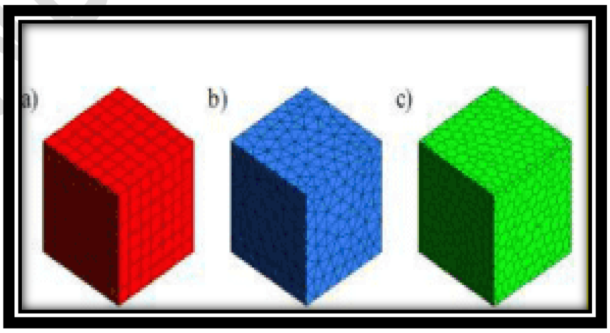


**Fig. 1** a) Hexahedral mesh b) tetrahedral mesh and c) polyhedral mesh on finite element method.

Based on the mentioned description of the analysis, the goal of this study was to use SolidWorks 2018 software and the finite element analysis method to examine the differential chassisframe construction. The minimum value of the safety factor was one of the references used as a gauge of a design's safety. Engineers frequently utilize an object's safety factor as a reference metric when determining how much stress it can withstand (Wang *et al.,* 2019). This study's results include Von Mises stress, displacement, and safety factor for determining the material's capacity to sustain dynamic loads and shock loads.

Von Misses stress, displacement, and safety factor are among the simulation outcome parameters. The following equation was used to calculate theoretically the value of strain and stress and equation 1 was used for estimating factor of safety value.

$$\begin{cases}\sigma_{xx}\\ \sigma_{yy}\\ \sigma_{zz}\end{cases} = \frac{E}{(1+v)(1-2v)}\begin{cases}(1+v)\varepsilon_x + v\varepsilon_y + v\varepsilon_z\\ v\varepsilon_x + (1-v)\varepsilon_y + v\varepsilon_z\\ v\varepsilon_x + v\varepsilon_y + (1-v)\varepsilon_z\end{cases} \quad \ldots\ldots\ldots\ldots\ldots 1$$

Where σ is stress, ε is strain, **v** is poison ratio and E is modulus young of material. The following equation can be used to calculate the safety factor's value,

$$\mathrm{SF} = \frac{\sigma_{\max}}{\sigma_{\max\ \text{material}}} \quad \ldots\ldots\ldots\ldots\ldots 2$$

Where,

SF is a safety factor, $\sigma_{max}$is allowable material stress and $\sigma_{max\ material}$ is stress on the material

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## 3. RESULTS AND DISCUSSION:

The structural and stress analysis of developed differential chassis was conducted using finite element analysis to understand the stress zones, elongation and safety of factor for improving the performance of weeder.

The differential chassis which was supported by triangular track wheels, supporting frame for engine, gearboxes and weeding system. In order to understand the suitability to loading conditions, von mises stress, deformation and factor of safety were analyzed using Finite element analysis on 3 D diagram of differential chassis with meshed diagram as shown in Fig 2.

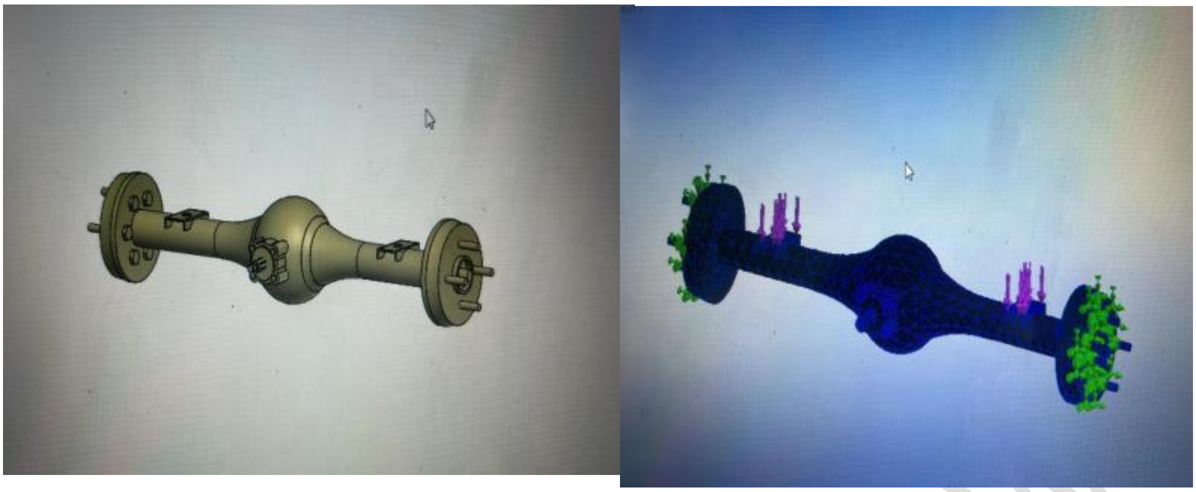

**Fig 2**. 3-D model of differential chassis with mesh generation

### 3.1. Von mises stress:

The material choice and frame design must be based on the maximum value of working stress, analysis of the stresses occurring on a structure is crucial. Based on the findings of the uniaxial tensile test, the von Mises stress is utilized to forecast the yield of materials subjected to complicated loading (Suprapto and Wibawa, 2021). The Von Mises stress determines whether a material will be safe or fail (Karmankar, 2017). If the stress value exceeds the material strength, von Mises can fail (Vutton D. V., 2003).

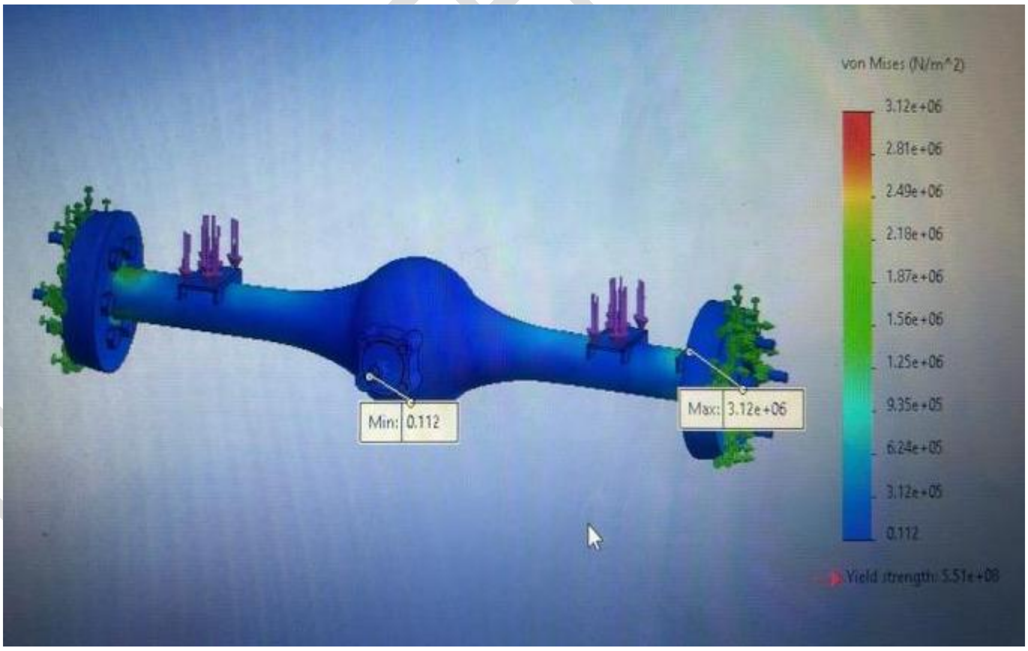


**Fig 3.** Von mises stress distribution over differential chassis

It was observed that, the red portion in the figures represents high levels of stress deformation, while the yellow and green represents moderate level and blue mark represent low level of stress deformation. It demonstrated how the stress is spread equally throughout the differential chassis. The rated load of 2943N applied on differential chassis as per design calculation, lowest value of von Mises stress 0.112 $N/m^2$ was observed at the Centre of differential where drive chain attached portion and highest von misses stress of $3.12x10^6$ $N/m^2$ was observed at brake drum edges where axle sprocket attached.

### 3.2. Deformation of differential chassis :

Deformation is a physical alteration to an object brought on by a load or force. Elastic deformation and plastic deformation are the two categories into which deformation is further separated (Juvinall, 2011). When an object undergoes elastic deformation, which is a physical change brought on by a force or load, it will revert to its original shape (Juvinall, 1967). Naturally, elastic deformation is used while developing tools since the maximum stress is constrained below the yield strength (K. Z. V. Dobrovolsky, 1973). The displacement over the differential chassis frame when applied rated load of 2943N load is shown in Fig.4.

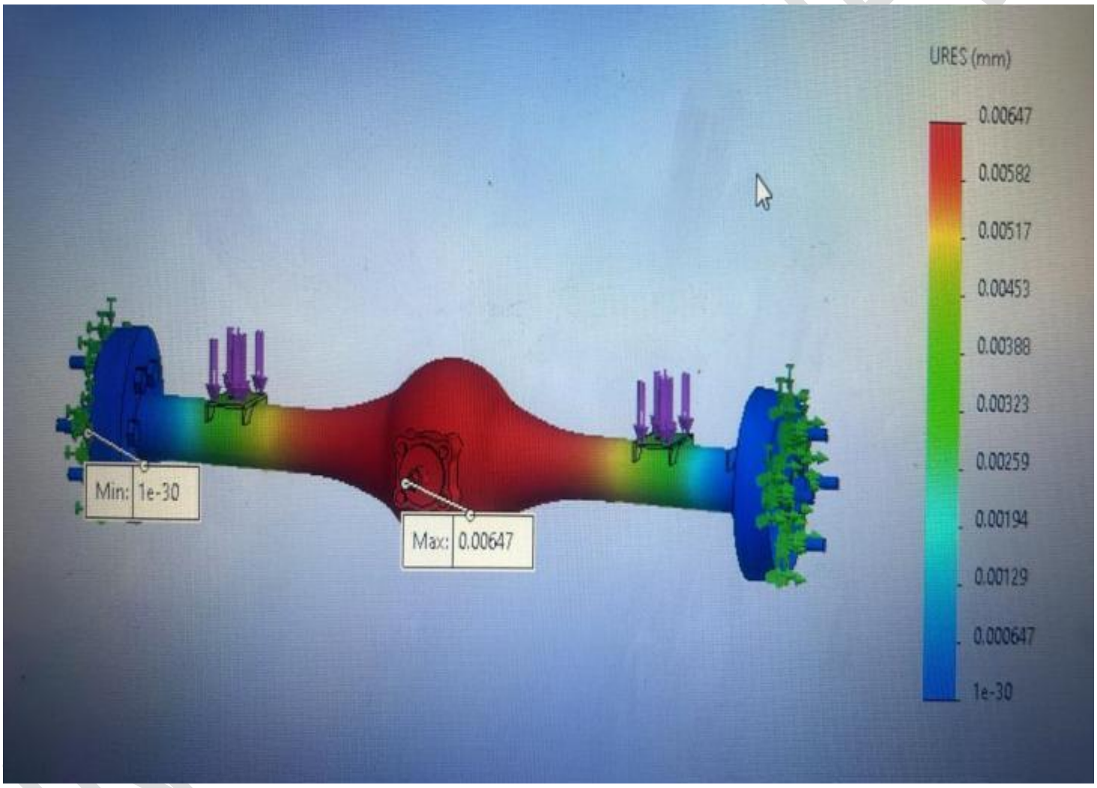


**Fig 4**. Deformation distribution over differential chassis frame

From the fig. 4 it was observed that, Max deformation of 0.0647mm was observed at Centre of differential and minimum deformation of $1x10^{-3}$mm was observed at edges of brake drum.

### 3.3. Factor of Safety:

When performing stress testing on a model of an object, one of the parameters used as a reference is the safety factor (Wang et al. 2019). To prevent a failure and establish operability of the tool design, considering safety factor is necessary. The review procedure uses the safety factor, which ensures the proposed design is secure and serves as a gauge for an element's strength (Wibawa et al., 2020).

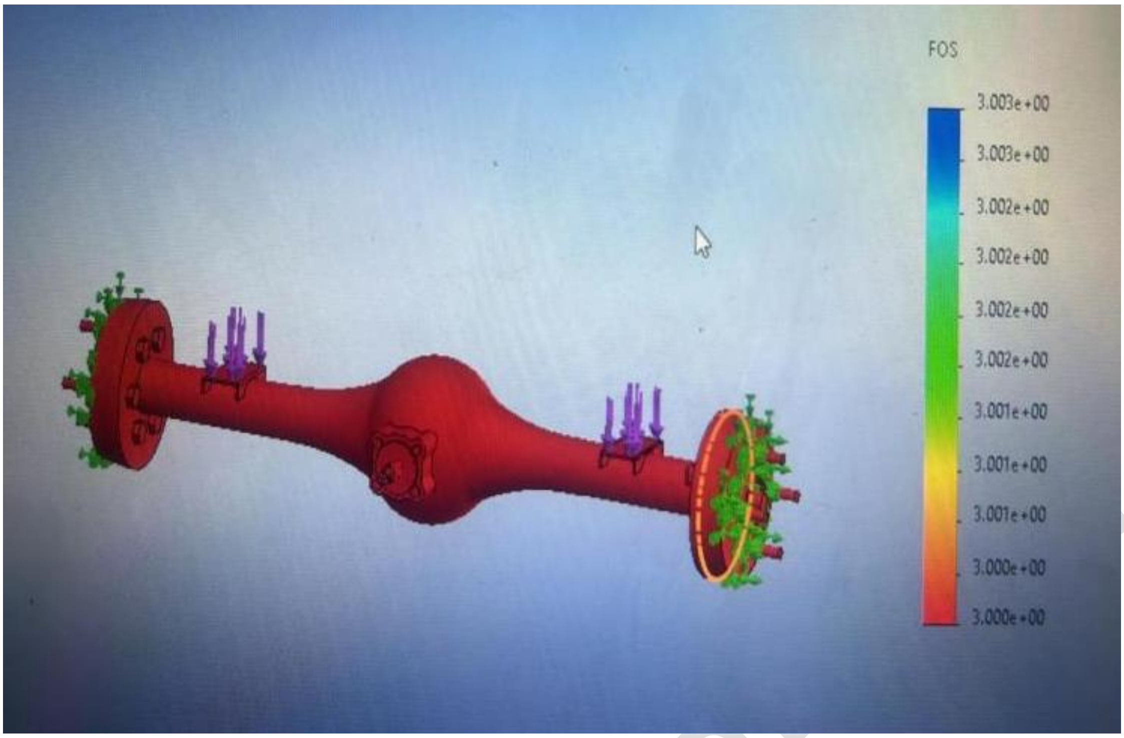


**Fig. 5**. Factor of safety diagram of finite element analysis

When rated load of 2943N applied, the factor of safety was observed as 3 which suited for carrying dynamic loads (Wibawa et al., 2020). Hence the differential chassis selected was suitable for development of axle system up to 2000 N dynamic load.

## 4. CONCLUSIONS:

The rated load of 2943N applied on differential chassis as per design calculation, lowest value of von Mises stress 0.112 N/m$^2$ was observed at the Centre of differential where drive chain attached portion and highest von misses stress of 3.12x10$^6$ N/m$^2$ was observed at brake drum edges where axle sprocket attached. Max deformation of 0.0647mm was observed at Centre of differential and minimum deformation of 1x10$^{-3}$mm was observed at edges of brake drum. When rated load of 2943N applied, the factor of safety was observed as 3 which suited for carrying dynamic loads. Hence the differential chassis selected was suitable for development of axle system up to 2000 N dynamic load.

## REFERENCES:

1. AlShammari, M. A., Qasim , H. B., Al-Waily, M., & Hasson, A. (2020). Fatigue Behavior of Steel Beam Coated with Nanoparticles under High Temperature. Journal of Mechanical Engineering Research and Developments, 43(4), 287-298.
2. Al-Waily, M., & Abud Almalik Abud Ali, Z. (2015). A Suggested Analytical Solution of Powder Reinforcement Effect on Buckling Load for Isotropic Mat and Short Hyper Composite Materials Plate. International Journal of Mechanical and Mechatronics Engineering, 15(4), 80–95.
3. Baihaki, M. I., &Bintoro, C. (2021). AplikasiDesainGeneratifPadaRangkaSepedaDenganMenggunakanPerangkatLunakSolidworks Dan Matlab Simulink. Jurnal INOVTEK Seri Mesin,2(1), 2-5.

4. Cekus, D., Gnatowska, R., Paweł, K., & Šofer, M. (2019). Simulation Research of a Wind Turbine Using SolidWorks Software. Journal of Physics: Conference Series, 1398(1). doi:https://doi.org/10.1088/1742-6596/1398/1/012001
5. Chen, H., Zhou, X., Feng, Z., & Cao, S. J. (2021). Application of polyhedral meshing strategy in indoor environment simulation: Model accuracy and computing time. Indoor and Built Environment, 1-13. doi:https://doi.org/10.1177/1420326X211027620
6. Chiad, J. S., Al-Waily, M., & Al-Shammari, M. A. (2018). Buckling Investigation of Isotropic Composite Plate Reinforced by Different Types of Powders. International Journal of Mechanical Engineering and Technology, 9(9), 305-317.
7. Chirende, B., Li, J. Q., & Vheremu, W. (2019). Application of Finite Element Analysis in Modelingof Bionic Harrowing Discs. Biomimetics,4(3),1-11.
8. Dantulwar, N. B., Maske, R. G., & Patel, J. T. (2017). Finite Element Analysis of Ball Valve Assembly for Earthquakes. International Conference on Ideas, Impact and Innovation in Mechanical Engineering, 5(6), 1460–1467.
9. Dobrovolsky, K. Z. (1973). Machine Elements : A Textbook. Moscow: Peace.
10. Doustdar, Mehdi, M., & Kazemi, H. (2019). Effects of Fixed and Dynamic Mesh Methods on Simulation of Stepped Planning Craft. Journal of Ocean Engineering and Science, 4(1), 33-48. doi:https://doi.org/10.1016/j.joes.2018.12.005
11. Elishakoff, I. (2004). Safety Factors and Reliability: Friends or Foes. 1st ed. Springer Netherlands. doi:https://doi.org/10.1007/978-1-4020-2131-2
12. García Pérez, M., &Vakkilainen, E. (2019). A Comparison of Turbulence Models and Two and Three Dimensional Meshes for Unsteady CFD Ash Deposition Tools. Fuel237(September 2018), 806-811. doi:https://doi.org/10.1016/j.fuel.2018.10.066
13. Gheorghe, G. V., Persu, C., Gageanu, I., &Cujbescu, D. (n.d.). Structural and Modal Analysis in Solidworks of Basic Structure of Equipment to Prepare Germinative Bed in Strips. Engineering for Rural Development 17 (May), 818–826.
14. Hertzberg, R. W., Vinci, R. P., & Hertzberg, J. L. (2012). Deformation and Fracture Mechanics of Engineering Materials (5th ed.). Wiley. Retrieved from https://en.id1lib.org/book/3364788/eaccde
15. Hutton, D. V. (2003). Fundamentals of Finite Element Analysis (1st ed.). McGraw-Hill Science/Engineering/Math. Retrieved from https://en.id1lib.org/book/445247/341616
16. Rakesh N, Veera Prasad G., AumSarma and H.V. Hema Kumar, 2018.Development and Evaluation of Small Tractor Drawn Seed Planter with Battery Operated Seed Metering Mechanism.Int.J.Curr.Microbiol.App.Sci 7(3): 1879-1886
17. Srigiri D., Veeraprasad G., Rajkiran B., and Edukondalu L.,2016.Development of single row manually operated multi crop planter. Inter. J. Agric. Sc,6(2); 64--68
18. Vegad, G. M., & Yadav, R. (2018). Design Analysis and Optimization of Rotary Tiller Blades Using Computer Software. AMA, Agricultural Mechanization in Asia, Africa and Latin America,49(1), 43–49.
19. Wang, X., Shi, Q., Fan, W., Wang, R., & Wang, L. (2019). Comparison of the Reliability-Based and Safety Factor Methods for Structural Design. Applied Mathematical Modelling, 72, 68–84. doi:https://doi.org/10.1016/j.apm.2019.03.018
20. Wibawa, L. A., Diharjo, K., Raharjo, W. W., & Jihad, B. H. (2020). Stress Analysis of Thick-
21. Walled Cylinder for Rocket Motor Case under Internal Pressure. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, 70(2), 106–115. doi:https://doi.org/10.37934/ARFMTS.70.2.106115
22. Yin, Z., & Xu, L. (2018). Finite Element Analysis and Optimization Design of Paper Cutter Cutting Blade Based on ANSYS. Proceedings - 2018 International Conference on Robots and Intelligent System, 475–478. doi:https://doi.org/10.1109/ICRIS.2018.00125
23. Yaduraju, N.T. 2012. Weed management perspectives for India in the changing agriculture scenario inthe country. Pakistan Journal of Weed Science Research. 18 (Spl. Issue): 703-710.