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DEVELOPMENT OF RAISEDBED MACHINE FOR SMALL-SCALE FARMERS TO IMPROVE WATER USES EFFICIENCY IN IRRIGATED ECOSYSTEMS

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Abstract

The locally manufactured small-scale agricultural machinery in Egypt has recently acquired high importance in order to localize technology and innovation at the farm level. This study aims to design a cost-effective multi-seed planting raisedbed machine to rationalize water use and enhance land productivity in the Nile Delta of Egypt. The small farmers will adopt this technique to enable water, energy, seeds, and effort saving. The design of the machine went through a systematic process of tests to ensure that the design fit for purpose considering a set of design criteria such as soil type, crop type, and varieties as well as seeds size, planting rates, roads networks, farm sizes, cost-effectiveness, and available existing traction forces. The analyses using SolidWorks, a solid modelling computer-aided design and engineering application program, and Ansys simulation software were carried out to the loads and stresses subjected to different parts of the machine in order to identify the proper thickness and materials to manufacture the machine. Based on the stress and strain analysis, the machine structure and its components were designed. The main components of the machine include the main skeleton, seed drill box, planter seed box, feeding chambers, and cells as well as a feeding tube, gearbox, ditchers, ground-driving wheel and transmission mechanism, and mounting triangle. After building the machine components, various investigations were performed by subjecting the used materials to ascending loads to analyze shearing force, normal stress, shear stress, strain, and strength analysis in a micro meshes scale in all machine components. These tests enabled the identification of deformations, equivalent elastic strain, and Safety factor on different machine parts. The simulated values of the machine's parts in thicknesses and dimensions were in good correspondence and consistency with the actual design values. The model showed that the boundary conditions were accurate and rational, and it would provide a scientific basis for the optimum design of the raisedbed machine under multiple and interlinked loads.

Key words**:** *laying hens, carbon footprint, egg production, methane, nitrous oxide, carbon dioxide equivalent*

INTRODUCTION

World's population is constantly increasing and creating pressure on agrifood demand thus leading to increasing the importance of food production. One of the ways to increase food production is the agricultural mechanization and the agrifood industry. The agricultural sector is facing several challenges, amongst is lack of skilled and cost-effective labour to efficiently and timely carry out agronomic practices. Therefore, agricultural mechanization can significantly contribute to overcoming these challenges.

Agricultural mechanization aims to perform efficiently and effectively several agricultural operations in a short time with less labour and energy. Agricultural mechanization is an important input to agricultural production in reducing the cost of farming and maximizing the utilization of inputs (seeds, fertilizer, chemicals, and water). It is also improving the quality of the yield and reducing drudgery in farm operations [6].

Sowing techniques and types of seeding machines play an important role in seed placement and seedling emergence which ultimately affect crop growth and grain yield.

In crop production systems, seed germination and crop establishment potential are primarily determined by the soil conditions and land preparation that exist immediately prior to planting (tillage depth, land leveling, soil salinity, the quality of the seed, and seedbed environment) as well as weather influences during the establishment period. To successfully establish crops under the conditions that are likely to exist at planting, the sowing machine should be able to open furrows, properly places the seeds in the targeted place with appropriate soil cover, firm the seedbed, and perform other functions as needed such as weed and pest control [3].

Generally, the planter is made up of a frame that includes seed hoppers, a precision measuring device, a bed forming, and a power transmission system. Most of the planters are mounted and get the draught from a tractor, and the drive to the seed metering mechanism is transmitted from the ground drive wheel via chain and sprockets or from the tractor's PTO. There are some studies conducted on wheat planting in beds such as a manufactured planter designed by [15] which can sow wheat on pre-established broad beds and seeding while simultaneously establishing beds. Raisedbed farming systems (RBs) combine the majority of the elements of conservation agriculture leading to encouraging results under various environmental conditions. The RBs have the potential to reduce soil compaction and restore physically degraded soil structure as well as water saving and crop yield increasing while reducing the risk of water logging [19].

The agricultural machine is a device that performs mechanical movements to transform energy, materials (e.g. seeds, fertilizers, chemicals) and information (e.g. digital extension or automated machinery) to facilitate the agronomic practices. These machines consist of parts which are designed collectively then manufactured separately thereafter assembled in a systematic process. The parts are partially or completely combined into nodes then these nodes assembled in units that have a common functional purpose. Complex components may include several simple nodes (sub-nodes) for example; a gearbox includes bearings and shafts with gears mounted on them [25]. Agricultural machine constructions used for crop planting are exposed to a very corrosive environment while used in the field. Non-uniform corrosion deterioration can have a substantial impact on the function of different machines' structural elements and devices, thus on the machine's performance. Therefore, the most prevalent kinds of corrosion such as pitting, soil reaction, and general corrosion may be identified during the machine design stage [5]. In order to avoid or minimize machine performance deficiency, the electrical and mechanical characteristics of iron must be investigated and properly identified in the subject of material science (steels).

Developing and testing of agricultural machines become a complex process that should be well-studied. Due to agricultural areas expansion, the locally-customized agricultural machines become the main factor to increase agricultural production. Agricultural machines developed and tested in some countries are not necessarily to provide same performance with the same results in another location. Therefore, local conditions such as climate, soil, energy source, operators, and machine purposes all should be considered as these factors could influence the operational functions and capacity of those machines. Thus, developing, testing, and evaluating those machines are important under local conditions [1].

The ideal machinery can have obtained by several designs and manufacturing changes as emphasised by [7], [9] and [2] which led to many shortcomings including backward design methods, low design accuracy and efficiency, incapable pre-assembled parts and interference with assembly tests, and un-intuitive graphical expression. They explained this by indicating that the above-mentioned problems, machinery parts, and components for parametric modelling and virtual design should be adopted by parametric modelling software to resolve the former design problems. In their research, they studied components of the single-line potato harvester using the three-dimensional modelling software SolidWorks based on the practical problems of potato production.

The mechanical strength of compacted material is defined as the compressive strength/stress of the composites at maximum loading [14]. Stress stability refers to a body's or system's capacity to return to a previously established steady state after being perturbed. It also refers to a body's ability to re-establish equilibrium at the moment of any distortion [16]. SolidWorks software program and ANSYS are used to analyse the stress, strain, and deformation forces and ensure accurate machine design. Furthermore, ANSYS is a general-purpose modelling tool used to solve a wide range of mechanical problems theoretically. These challenges include static/dynamic, linear, and nonlinear structural analysis, heat transport and fluid problems, as well as acoustic and electromagnetic difficulties [12]. SolidWorks is an industrial standard for three-dimensional solid modelling, automated design, engineering analysis, and product preparation for any complexity and purpose.

Three SolidWorks primary system configurations are available depending on the type of work under investigation, namely; SolidWorks standard, professional, and premium [17]. Nishit [11] studied the Machine's chassis designed using ANSYS analysis and SolidWorks software programs. The structural material characteristics were employed in their study because most manufacturing materials are either cast iron or structural steel. The highest equivalent elastic strain they found was 2.4973e-005 m/m, while the minimum was 3.1335e-008 m/m. The greatest major elastic strain observed was 1.9219e-005 m/m, whereas the minimum was 6.0353e-009 m/m. The greatest total deformation is 37.539 m, while the minimum total deformation is 5.1243e-002 m.

A fracture is the spread of micro-fractures/cracks within specific parts of a material caused by excessive/residual stress created in the sample. A material point of fracture is a point on the stress-time curve where the sample separates into sections due to near and different fractures within specified portions of the material under the action of increasing load in a compression test. The yield point is a stress-time point. Above the proportionality area, there is a curve where a rapid rise in unit stress does not correlate to a comparable unit increase in time [4]. A model material's stress stability might suggest a rise in stress that corresponds to an equivalent increase in time. The stress/time relationship in such compacted material could not accommodate fracture and rupture points up to the yield point [13].

The current study focused on the design, testing, and evaluation of a small-scale multi-function raised bed machine using SolidWorks and ANSYS software programs to support small farmers to rationalize water use and enhance water consumption and land productivity in irrigated agriculture.

MATERIALS AND METHODS

The concept of raisedbed planting is nothing new for Egypt-delta farmers; it has been used a long time ago. The ancient Egyptians, simply, were making furrows and planting seeds on top of the beds. Raisedbed planting has a better performance as there is less need to apply water to the whole field, leading to decreased water losses. Planting wheat on the ridges insures good aeration of the roots, better use of solar radiation, efficient use of fertilizer, and easier weed control and other agricultural practices. Nowadays, the Nile Delta farming system is an intensified agriculture; farmers are widely using raisedbed planting for several seasons utilizing the same farm layout of the previous crops to save time and land preparation costs for the next crop. This is a cost-effective way of conservation farming. The current planting technology ensures the proper implementation of the raisedbed dimensions and saves the seeds and farming time.

Design of the Raised Bed Multi-Crops Planting Machine

Small farm mechanization in Egypt is a difficult process due to economic concerns when purchasing and operating farm machinery. Small farm size in the Nile Delta requires simple machines to do hard work in a short time due to intensive agriculture practices in very fragmented lands. The selection of an appropriate machine is a critical factor for sustainable use under Nile Delta's conditions. So it has to be thoughtfully and carefully selected. The key factors associated with machine selection for the Nile Delta are: 1) the machine size is suitable for fragmented small farms, 2) the cost-effective machine is suitable for poor-resources communities, 3) the machine weight is suitable for clay soil to avoid soil compaction and 4) the machine operation is in passive energy mode.

The scope of this work was to simplify the mechanized raised-bed planting to accelerate the farmers' adoption of raised-bed planting subsequently, save the applied water, and enhance water productivity. The existing machines are unsuitable for farm size in the Nile Delta. So, the key objective is to design, develop, and test a cost-effective raised bed machine for small/medium size farms in the Nile Delta. The use of the developed machine showed that the raised-bed system as an irrigation water-saving technique has dramatically reduced water losses and water applied and significantly improved crop yields. The raised-bed multi-crop planting machine was designed using SolidWorks software considering the following factors:

-Cost-effective compared to the existing machines

-Passive energy operation suitable for more land types.

-Locally manufactured with available spare parts in the local market

-Suitable for small and medium farm sizes of the Nile Delta

-Suitable for intensive canopy cover crops (e.g. wheat, berseem, rice, and other crops) and interspaced crops (e.g. corn, sugarbeet, fababean, and other crops)

-Minimum mechanical/movable parts with simple and easy to maintain

-Simple metering system and easy to maintain

-Quick adjustable sprocket set customized for each seed rate, seed size, and crop type

-Land wheel rubber tires for less traction force, less drive wheel slippage, and better seed spacing

-Tractor mounted for easy cultivation

-Suitable for any tractor type/capacity

The dimensions and shape of the raised-bed machine shown in Figures (1 to 14) demonstrating the final prototype design of the machine.

Stress, Strain, and Strength Analysis

After performing the machine design, the prototype machine was investigated through ANSYS 18.1 software program to analyse the structural material properties because most of either cast iron or structural steel is used as a fabrication material. Mesh hexahedral mesh with 1,045,708 nodes with a maximum cell size of 1 mm and a minimum cell size of 0.15 mm. The time required to tackle this challenge is 240 hours. The material employed in the analysis is structural steel as shown in Fig. 15.

Material Data

The Structural steel was used to build the machine parts (Figure 1) with specifications shown in Table (1).

Table 1. Structural Steel Constants

Items	Value
Density	7.85e-006 kg/mm^3
Isotropic Secant Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Isotropic Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Isotropic Resistivity	1.7e-004 ohm mm

Source: Authors' determination.

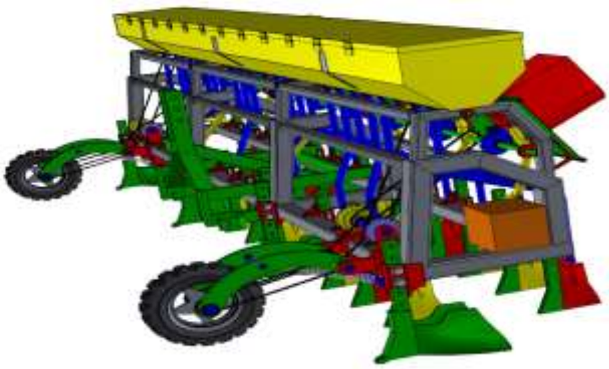

Fig. 1. Raisedbed Machine (RBM)
Source: Authors' determination.

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The Raisedbed Machine (RBM) Design and Structure

The RBM consists of the main structure, two seed boxes, feeding cells, feeding tubes, vents of the MRB machine, ditchers, driving wheels and transmission system, and mounting triangle.

(1)The Main Structure

The primary structure is separated into two sections:

(A)Lower Base Chassis:

This is the most solid section of the machine, carrying the machine's entire load of components, including seeds, vents, and ditchers that formulate the beds and farrows. The cross-section of the lower base of the main skeleton was designed as a square section from steel type ST-37 with dimensions of 80 x 80 mm with a thickness of 8 mm that is solid enough to accommodate the potential loads without bending or twisting the chassis. It also provides a uniform distribution of traction forces from the tractor to the rest of the various sections. ST-37 was chosen in accordance with the German common produced quality standards DIN17100 and complies with Egyptian regulations. This steel well withstands welding. The yield stress is greater than 235 Mpa and the tensile stress (maximum stress) ranges between 360 and 510 Mpa, making this type of steel quite safe in that design. It corresponds to the following codes: EN: S235JR, JIS: SS400, ASTM: A283C, and UNI: FE360B.

(B)Upper Chassis:

A square section beam with dimensions of at least 40 x 40 mm and a thickness of 5 mm of ST-37 iron was considered for the upper chassis. It is firmly welded into the body of the lower chassis. This chassis carries seed boxes as well as feeding and transmission gears as shown in Figure 2.

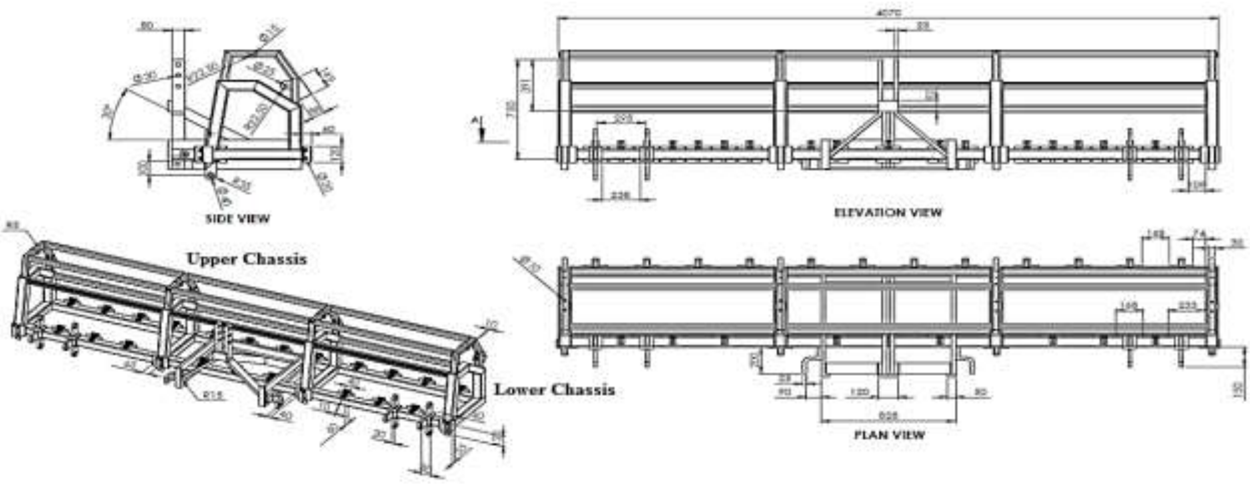

Fig. 2. The main structure of the machine’s lower and upper chassis.
Source: Own determination.

(2)Seeding Boxes

The machine contains two independent seeding boxes constructed of steel sheets with thicknesses of 3 mm with a volume capacity enough to load the needed seeds amount to at least 4 acres in one filling. The boxes are adequately coated with paint to protect them from corrosion. The seed boxes' dimensions and specifications are described as follows:

(A) Seed-Drill Box:

The dimensions of this box are 4110 x 410 x 295mm in length, width, and depth respectively as shown in Figure 3. This seeding box is used for small seeds with modest dimensions and sizes and for intensive crop plantings such as wheat, barley, clover, and sesame. Before planting starts, this box is filled with an adequate amount of seeds (approximately 0.5 m3). The box is triangular in outside shape, with a cony shape from inside to maintain seeds directed to the metering system of growth. The box's bottom is outfitted with three Plexiglas sections (external gauges) that allow the driver or farmer to continually monitor the seed level in the tank as shown in Figure 3.

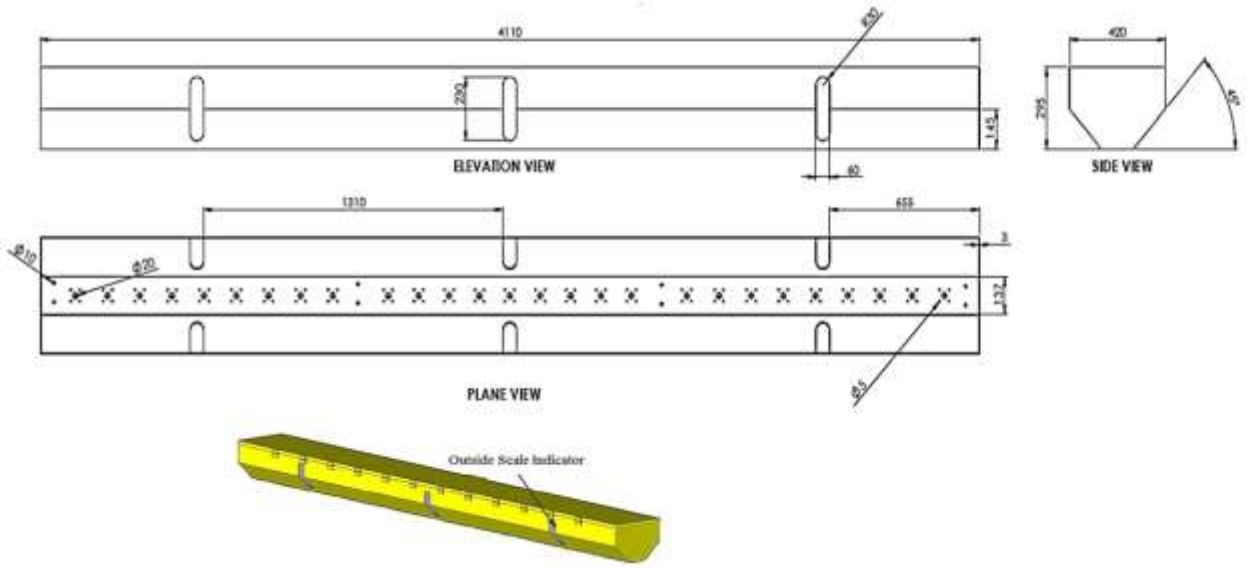

Fig. 3. Seeds Box for Small Seeds in dimensions and sizes
Source: Authors' determination.

(B)Planter Box:

It is used to sow large seeds for interspaced crops such as beans, corn, and sugarbeet. It is a distinct set of nine buckets with a capacity of 20 liters each. It nourishes the matching seeds' transfer gear. All buckets are constructed with a semi-circular, 20 cm diameter stream from the bottom to allow seeds directed toward the metering system without leaving any seeds in the bottoms of the boxes as shown in Figure 4. Figure 5 shows a combined image of the two large and small seed boxes. The design addresses the separation of motion transmission for the feeding gears of the other box. This allows operating the planter metering system separately from the seed-drill metering system (Figure 6).

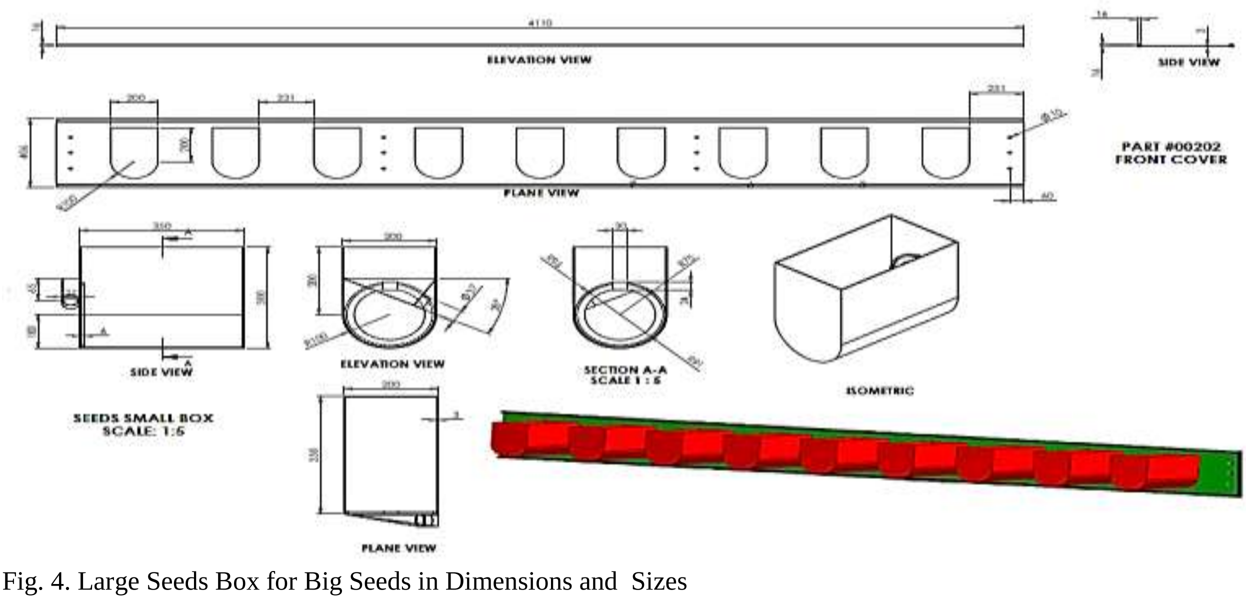

Fig. 4. Large Seeds Box for Big Seeds in Dimensions and Sizes
Source: Authors' determination.

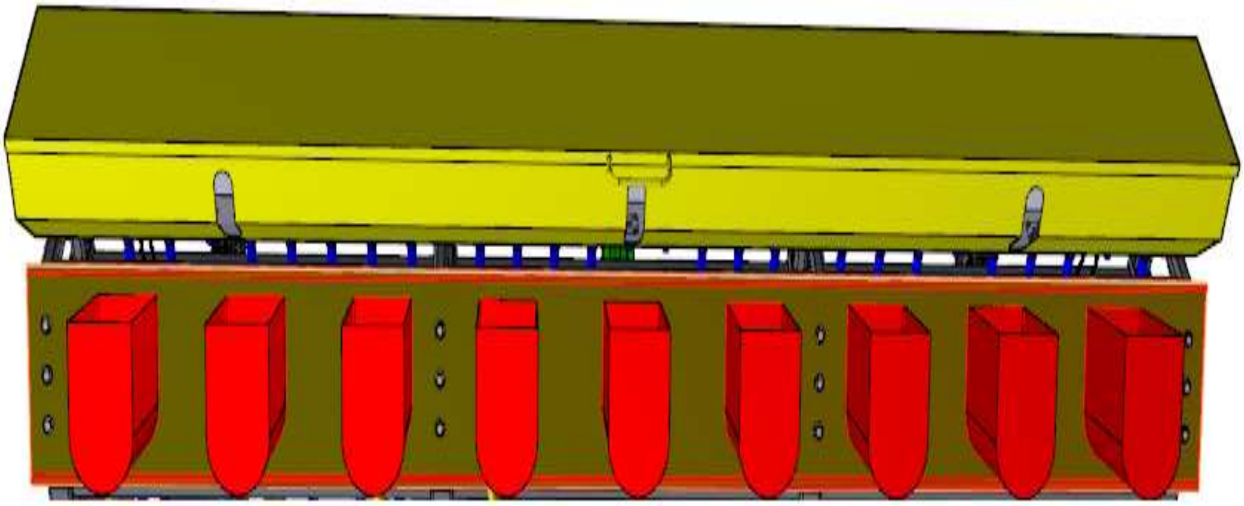

Fig. 5. A combined image of two large and small seeds boxes
Source: Authors' determination.

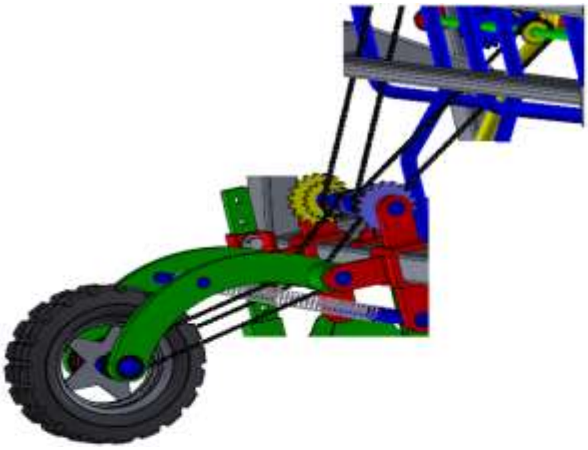

Fig. 6 Feeding Gears Set.
Source: Authors' determination.

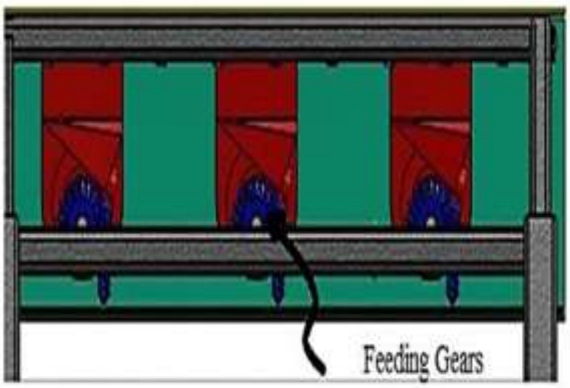

Fig. 7. Feeding Gears.
Source: Authors' determination.

(3)Feeding Cell

It is a set of gears, Fig. 7, with a fixed number of teeth estimated based on the diameter of the transmission wheel powered by soil friction and making interstitial distances within the soil between each, the seeds are inserted.

(4)Feeding Tube

It is a collection of hoses (plastic springs) with widths ranging from 2 to 3 inches (Fig. 8) that are used to swiftly convey seeds from the feeding set to the agricultural vents. It is broken into two sections as follows:

1-The hoses used to transfer the seeds from the little seeds box are the same number as the sowing seed vents, which are 21 in total, divided into three groups of seven vents for each. Farmers may also adjust the density of germination by closing the aperture of one of the hoses with a hand grip.

2-Hoses were used to transport seeds from the enormous seed box, and only nine were separated into three groups and planted on three terraces

(5) Seeds Cultivation Vents or Flakes (Seeds Liner) Stairs

The number of these seed liners is 21 vents made of iron and placed in three groups, with each group consisting of seven crumbs for each terrace, which is spread in two phases, with three in front and four in back, as shown in Fig. 9.

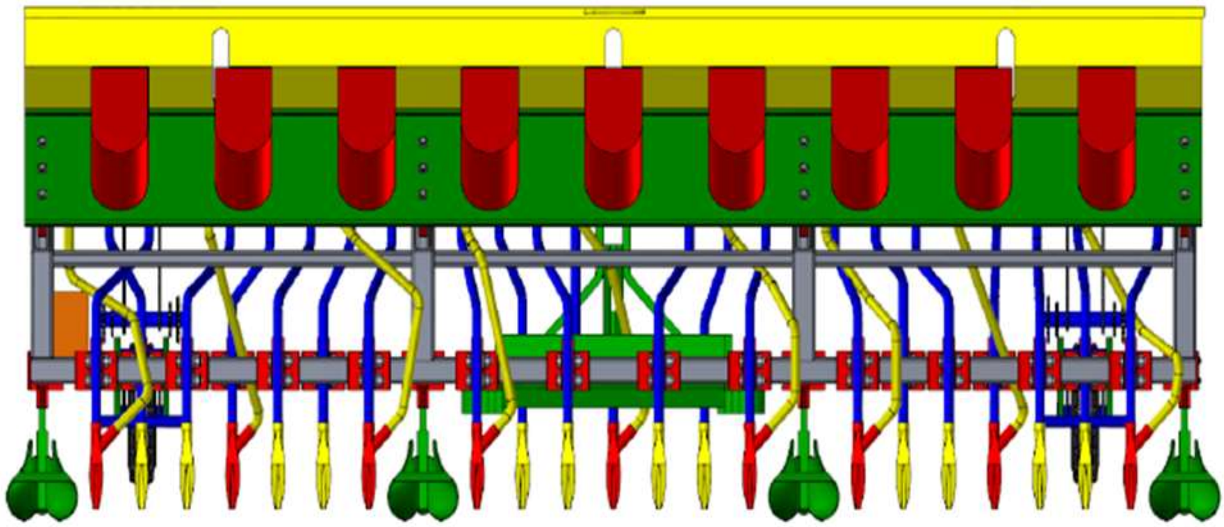

Fig. 8. Transmission hoses of seeds connected to the feeding gears.
Source: Authors' determination.

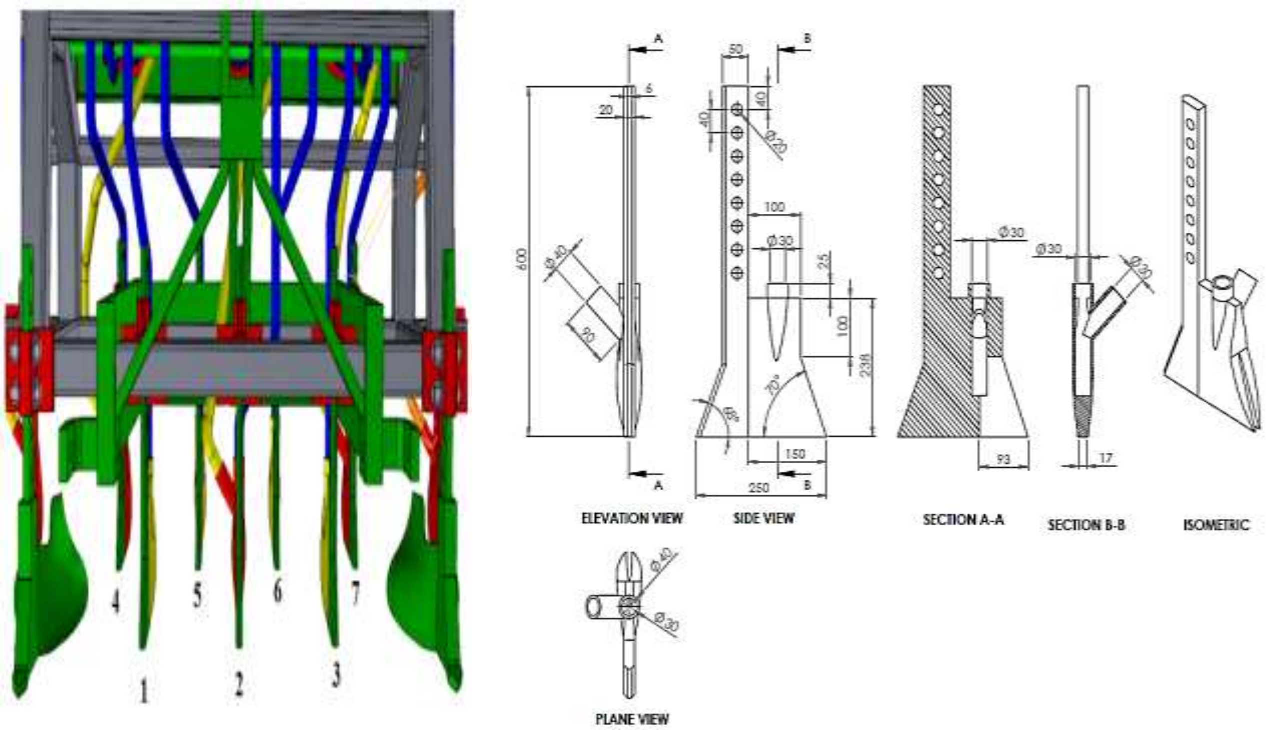

Fig. 9. Seeds cultivation vents and Seeds liner (left) structure
Source: Authors' determination.

(6)Ditchers (Farrows Openers)

The machine has four ditchers to be able to formulate three beds and four farrows, each with two sides of iron with a thickness of at least 7 mm that meet together at an angle of 86° when covering the gaps that allow penetrating the soil and opening the ditches, as illustrated in Figure (10). It is not suggested to use an MRB machine for unattended soil ploughing in order to avoid damaging the vents or failing to completely shut them, which would indicate a flaw in the cultivation process

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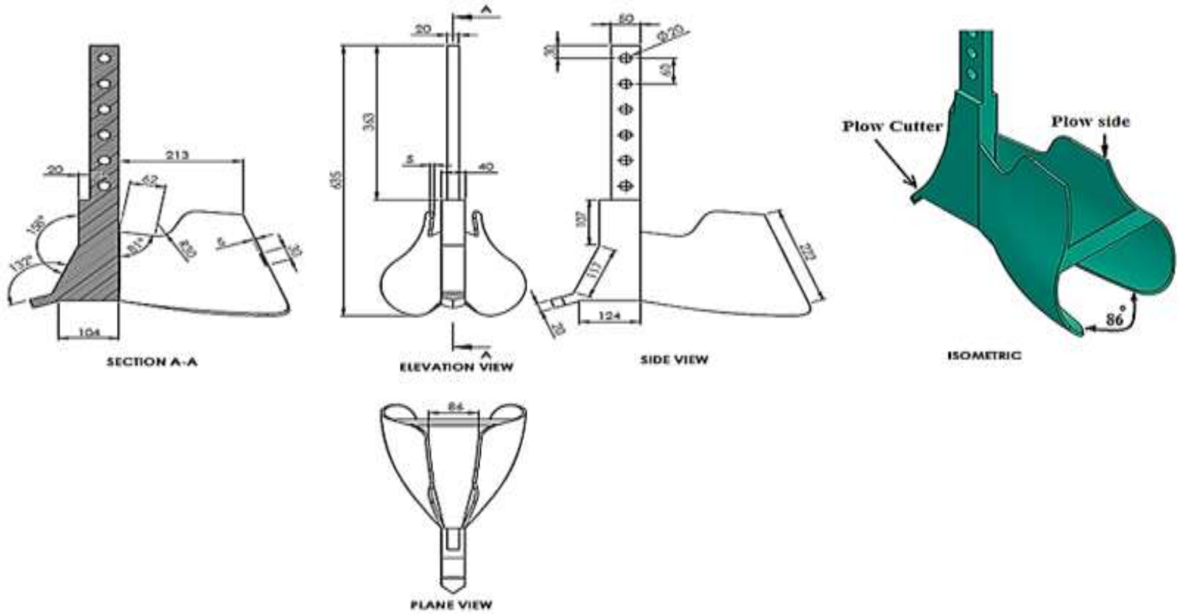

Fig. 10. The ditcher vents (farrow opener)
Source: Authors' determination.

As shown in Fig. 11, the distance between ditchers is 130 cm as recommended by previous research conducted by Swelam et al (2016) who identified the optimum dimensions of the raised bed in clay soils for several crops mainly wheat, clover, cotton, and fababean.

(7)Wheels and Transmission Set

The number of wheels turned by soil friction is estimated based on the number of terraces to be prepared, which defines the overall length of the machine (a wheel for every two terraces and about 416 mm diameter). The rate of movement and speed was modified to meet the number of seeds to be fed, as shown in Figures (12 and 13). The gears were also connected to big and small grain sowing boxes in two sets. Each group had three gears that controlled the density of grown seeds.

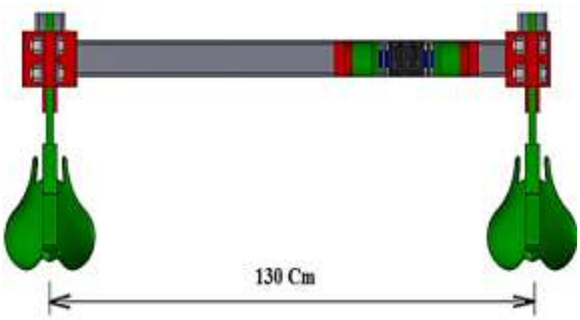

Fig. 11. Soil Light Plows
Source: Authors' determination.

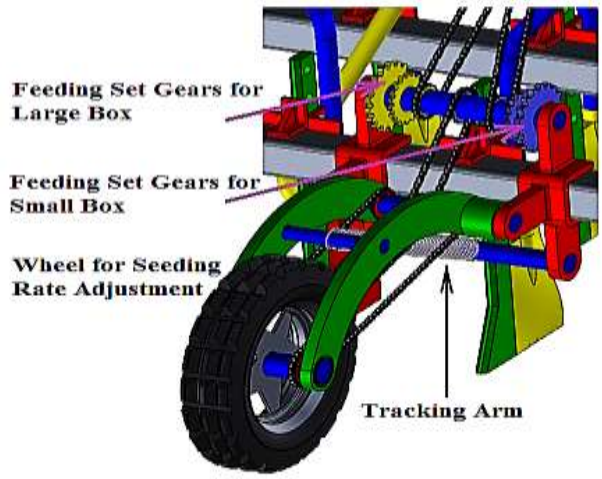

Fig. 12. A 3D schematic drawing of the set of gears and driving wheel.
Source: Authors' determination.

Traction Arm

It is made of steel (ST-37) with a thickness of not less than 25 mm to withstand the weight of the machine as well as the additional loads such as seeds' weight and soil resistance. It is designed in two levels to fit the small and large tractors and help us to control the level of planting seeds in the soil. The upper and middle holes are utilized to manage the load. The bottom and Center holes are used to adjust depth. The three holes are used to modify the distance that the plow and pits penetrate the soil based on soil resistance so that the waterways are suitably lightened and the seeds are well buried inside the soil, as illustrated in Fig. 14.

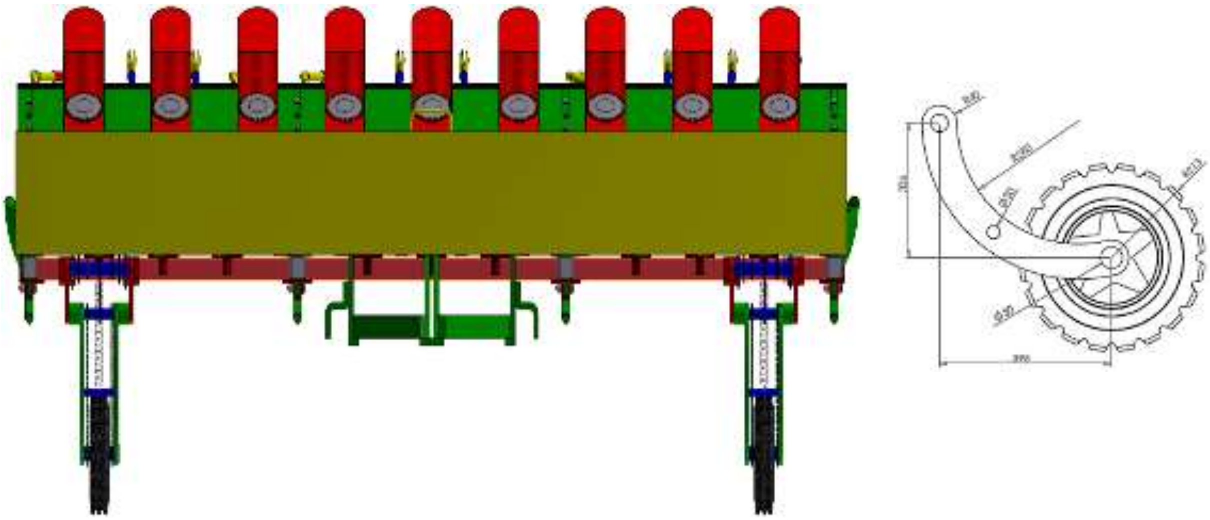

Fig. 13. Driving Wheels
Source: Authors' determination.

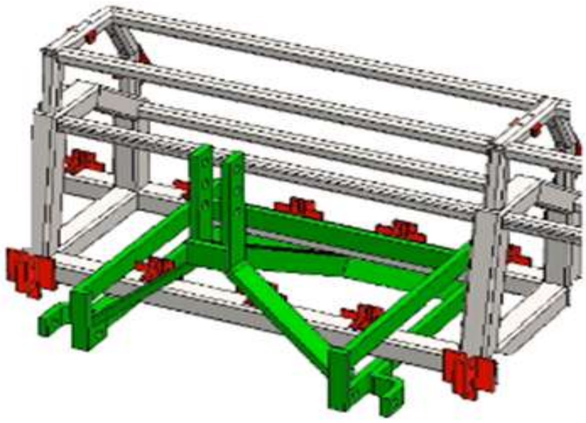

Fig. 14. Traction arm and tractor attachment Source: Authors' determination.

Engine Power and Specifications

MRB is suitable for different kinds of tractors. Large tractors are preferred so that they can carry or move the machine easily during planting or while moving from one place to another. The proper specifications for the tractor engine needed to tow the machine are shown in Table 2.

Table 2. The specification of the tractor engine

No.		
1	Compression ratio	19.5: 1
2	Number of cylinders	4
3	Displacement	2,523 cm^3
4	Maximum Power	49.5 horsepower (36.4 kW) at 2,800 rpm
5	Engine Type	diesel engine

Source: Authors' determination.

MRB Characteristics

It is characterized by suitable size for the agricultural areas intended to be used in both small and large field capacities and also transferred from one place to another without problems. Also, MRB control is easy in driving and guiding during the cultivation through the use of the appropriate tractor during the seeds distribution and concealment properly. The amount of seeds used during agriculture is reduced by up to 50%, which has a significant yield on users, enabling them to grow the best seeds even if the price increases. Ideal and regular distribution of seeds on the available land area with the possibility of controlling the intensity of agriculture is according to the desire of the farmer and the nature of the cultivated land by changing the distance between the seeds of sowing.

The efficiency of water use is improved where water saving rates reach 30% of the total water used in regular agriculture, where water can reach the seeds directly, quickly, and rationally, especially in countries where water is scarce. Saving time and the effort exerted in the process of agriculture leads to the increase of cultivated areas and good use of the agricultural season. The number of employed workers is significantly decreased with higher accuracy of the cultivation process and the

productivity of agricultural crops increases as a result of ensuring good and sound agriculture according to the MRB usage.
MRB machine is one of the safest machines for the agricultural tractor driver or farmer with ease of use, operation, and maintenance and the machine is eco-friendly as it does not produce any residues or harmful gases to the environment, whether during the process of manufacturing or during the operation or maintenance.

RESULTS AND DISCUSSIONS

The simulated results shown in this part are presented for the MRB in the next main parameters as follows: Total Deformation, Equivalent Elastic Strain, Equivalent Stress, Shear stress, Normal stress, Maximum Shear Stress, and Safety factor. These parameters are selected because they explicitly cover the characteristics for MRB design and testing to be available for future computational and experimental discussions. The 3D model was created by SolidWorks 2016 while the model is meshed by Ansys- 18. Structural Steel is the material used in analysis with Compressive Yield Strength, Tensile Yield Strength, and Tensile Ultimate Strength equal 250, 250, and 460 MPa respectively. Young's Modulus was 2.e+005, Mpa Bulk Modulus 1.6667e+005 Mpa Tensile Yield Strength 250 Mpa [21].

Mesh Generation

In Fig. 15, Mesh hexahedral mesh with a total number of nodes equals 1045708 and has Max. Cell size 1 mm and Min. cell size 0.15 mm. For bounding box dimensions X, Y, and Z were 4070, 80, and 80mm. Meshing is the most critical and persuasive parameter in any model of simulation

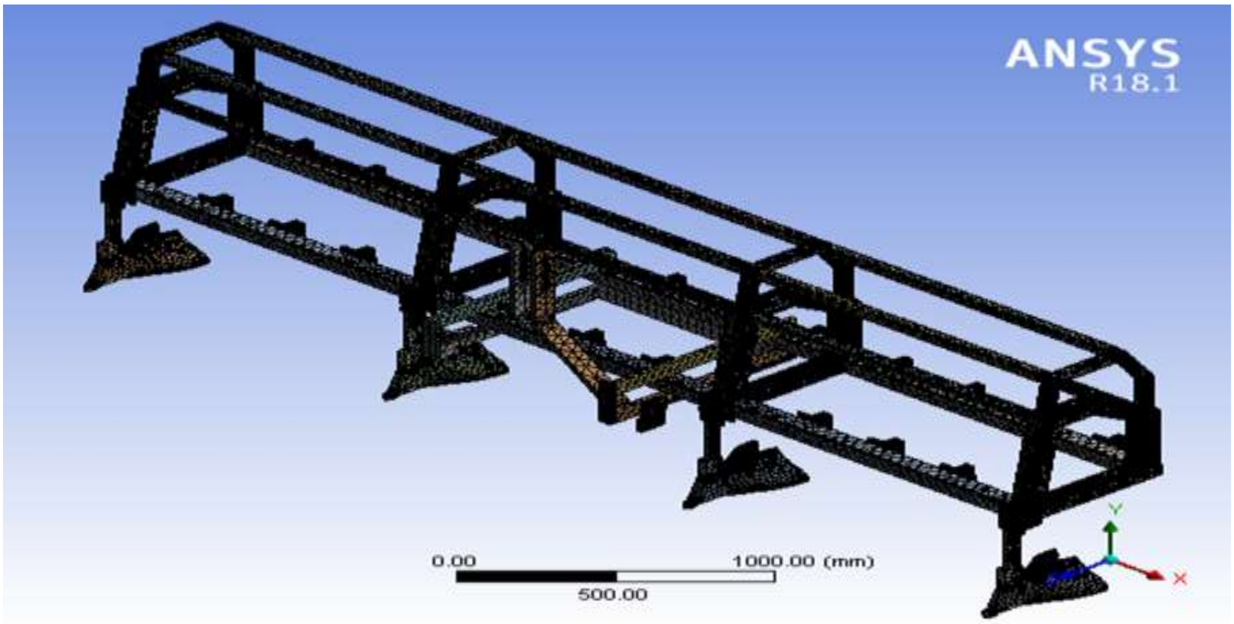

Fig. 15. Mesh generation (Total number of nodes 1045708).
Source: Authors' determination.

The selection of Hexahedron mesh provides higher accuracy and efficiency, in the results, than Tetrahedron for the identical number of nodes. Therefore, it is the recommended type for structural design applications. However, it may not be applied for all geometries especially complex ones where Tetrahedron is more suited but it is enough for MRB design simulation.

Moreover, generating Hexahedron mesh usually requires modifying and dividing the geometry into different sweepable faces through CAD modification variations or Virtual Topology. This may sometimes omit some important features or generate low-quality mesh, if not carefully applied, which is a common case if it is intensely used to force the generation of a certain method and solution rather than just simplifying the simulated model [20].

Total Deformation

Figure 16 shows the maximum range of the total deformation of 1.9706 mm. Deformation in continuum mechanics is transforming a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. Deformation may be caused by external loads, body forces (such as gravity or electromagnetic forces), or changes in temperature, moisture content, or chemical reactions. Finally, the maximum nominal total deformation equals 0.68 mm which is favourable and in the safe range. Strain is considered a description of deformation in terms of relative displacement of particles within a body, excluding rigid body motion. Various equivalent choices can be made to represent the strain field, depending on whether the strain field is defined in the initial or final configuration of the body, and whether the metric tensor or its dual is considered.

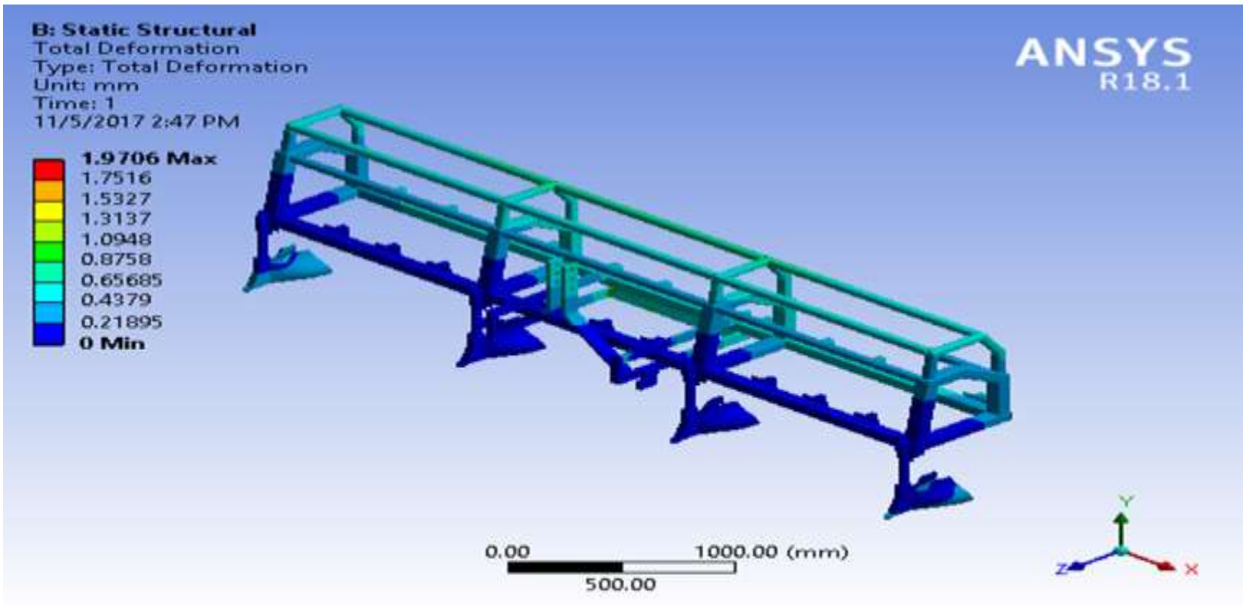

Fig. 16. Total deformation
Source: Authors' determination.

Equivalent Elastic Strain

Figure 17 shows the maximum Equivalent Elastic Strain is 0.0012312 m/m and the minimum Equivalent Elastic Strain is 2.0263 e-8 mm/mm. The internal Strain within metal is either elastic or plastic in type. In the case of elastic strain, this is observed as a distortion of the crystal lattice while the plastic strain is observed by the presence of dislocations; the displacement of part of the crystal lattice. Most quasi-brittle materials exhibit different properties under tension and compression due to their high heterogeneity and anisotropy. Elastic strain energy density can be decomposed into two parts: tensile stress and compressive stress. This allows for better exclusion of spurious failures in compression parts and more accurate crack paths and structural responses [22].

A material can fully recover its original shape after unloading if the induced stress is below the yield point of the material in the elastic response. From the point of view of metals, this behaviour is due to the stretching of chemical bonds between atoms, not breaking.

The elasticity is due to the elongation of this atomic bond, so it is fully recoverable. Moreover, these elastic strains tend to be small. The nominal equivalent elastic strain is 0.0001368 mm/mm. The higher strain locations are at the connection places while all body is in the safe range.

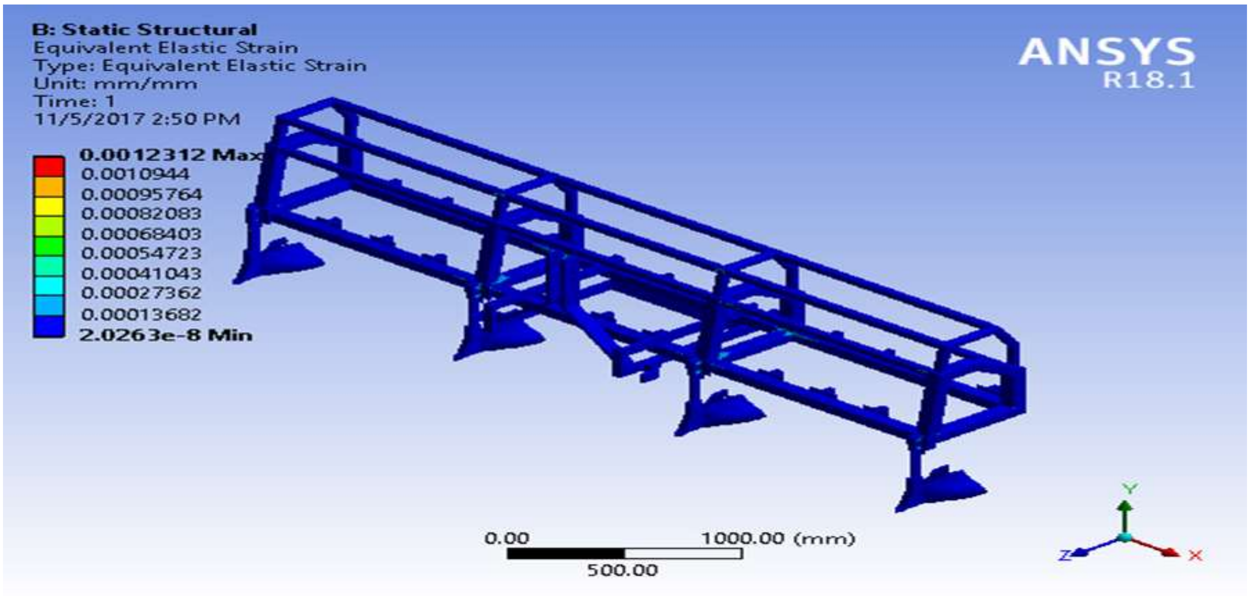

Fig. 17. Equivalent elastic strain
Source: Authors' determination.

Von- Mises Stress

Figure 18 shows the von- Mises stress distributions. As the material properties of damaged models are interpolated by von Mises stress to build the well-posed optimization model, Von Mises stress-strain plays an important role in the numerical simulations for the ductile fracture of structural metallic materials with a large plastic strain [8, 10]. The maximum von-Mises stress equals 226.34 MPa and the minimum equivalent stress is 0.0035538 Mpa. The highest value of the total deformation and the equivalent stress are not reaching near to the critical state.

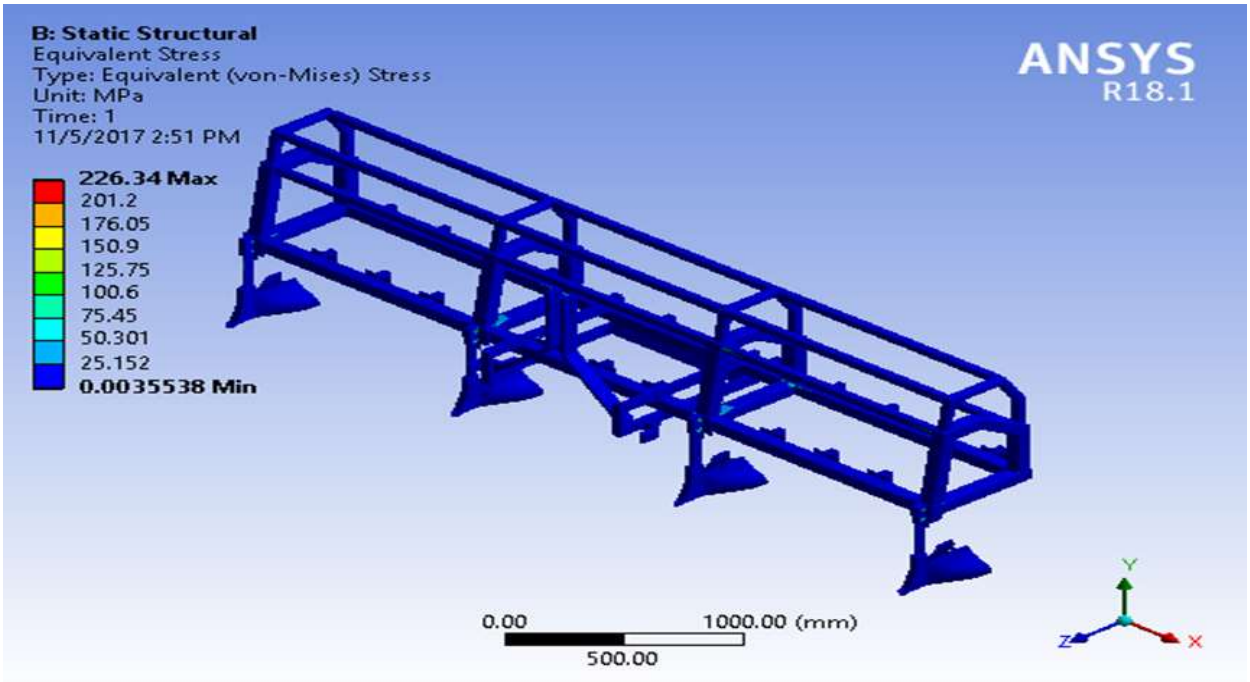

Fig. 18. Equivalent stress
Source: Authors' determination.

Shear stress

The shear stress is regularly denoted as the stress component that coplanar with a material cross-section. This type of stress arises from the force vector component that parallels the cross-section. The presented design shows an overall good agreement with the simulated results. The couple of both chassis beams cross sections and thickness are enough to withstand the shear capacity. The shear capacity of the webs of steel beam is an important performance factor utilized by the steel structures [18]. This shear strength can be affected by the corrosion when the effective thickness is reduced [24]. The elastic anisotropy of a single crystal has a decisive influence on the dispersion of the stress distribution, while the elastic modulus of each crystal direction determines the mean stress of the grain. Furthermore, shear stresses are shown to deviate from the normal distribution with higher anisotropy and be better approximated by a lognormal fit [23].

Figure 19 shows the shear stress allover the whole steel structure and the maximum range is 48.021 MPa as well as the minimum shear stress range is -76.358 Mpa. The whole tractor arm and the two chassis (upper and lower) are in the safe pattern

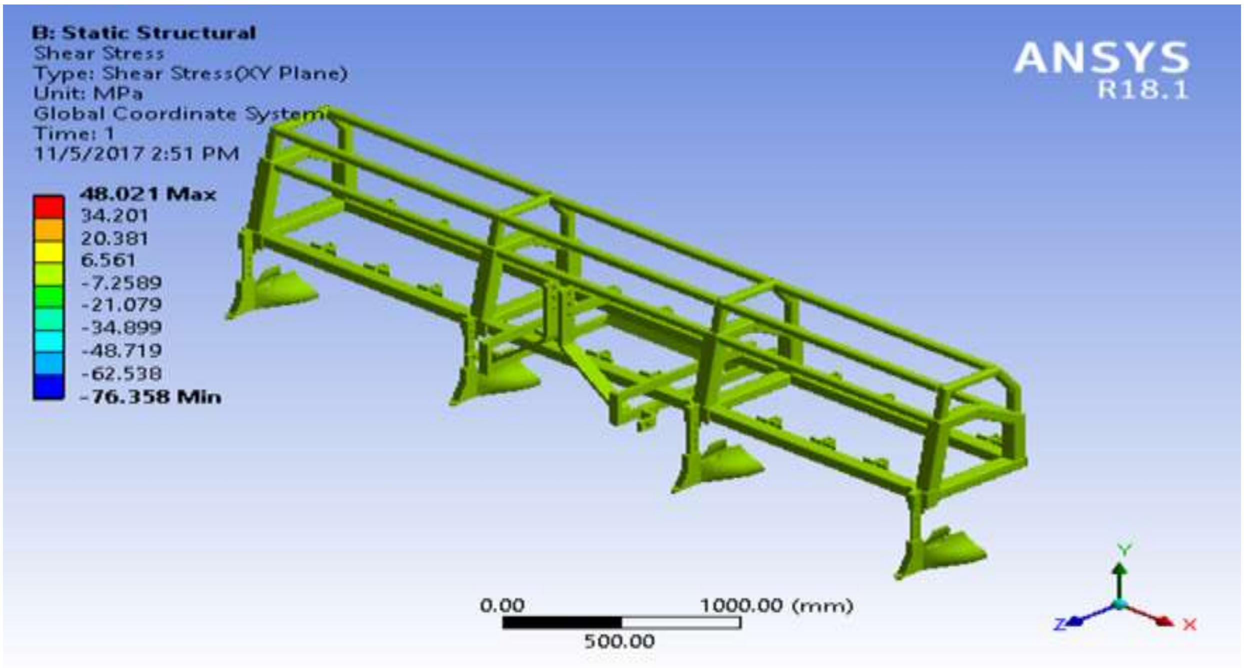

Fig. 19. Shear stress
Source: Authors' determination.

Normal stress

Any external force acts perpendicular to a certain cross-sectional area of any object or body induces a stress in those objects or body recovers its original shape.

The stress produced by the perpendicular action of a force on this given area is called a normal stress.

This normal stress arises from a perpendicular force vector.

The normal stress is subdivided into two stresses; tensile stress and compressive stress. In the tensile stress, the force acts perpendicular to the sectional area of the object, pulling it to stretch from its original shape while in the compressive stress; the force acts perpendicular to the surface area of the object, pushing and compressing it to deform its shape.

Figure 20 shows that the maximum normal stress is 44.528MPa and the minimum normal stress is -44.177Mpa.

The ditchers' fixation locations have the higher normal stress while this stress is in a safe range against deterioration.

Shear stress arises from shear forces, which are pairs of equal and opposite forces acting on opposite sides of an object.

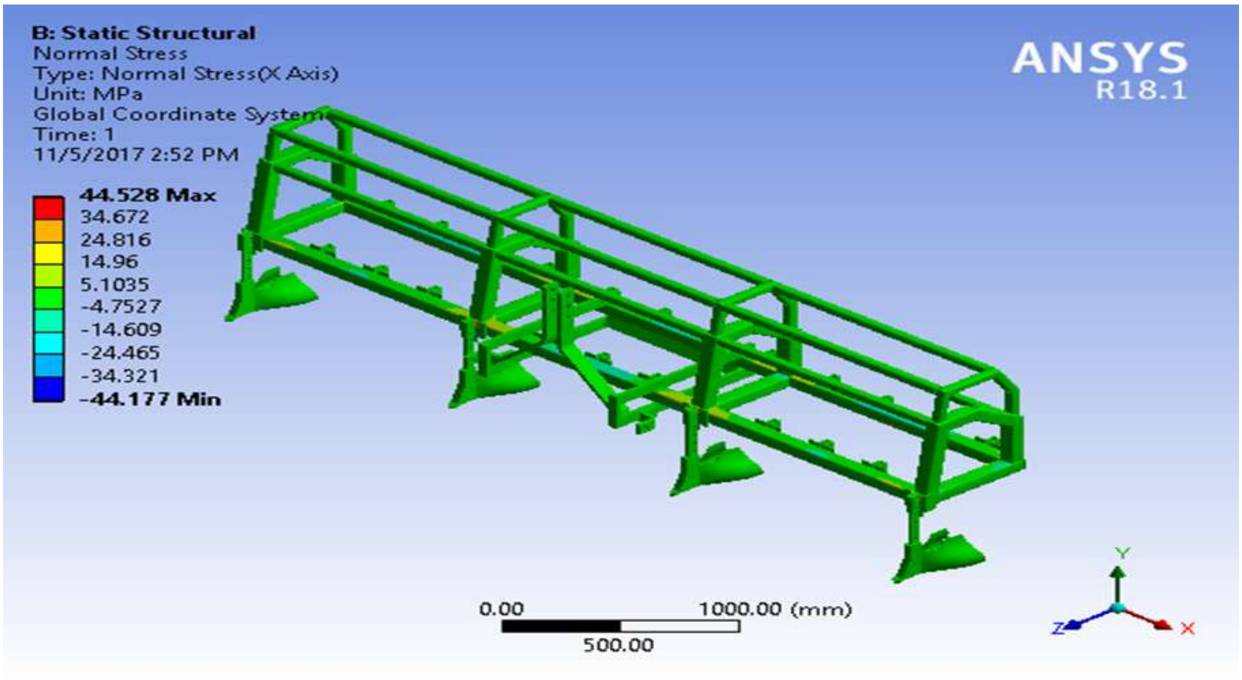

Fig. 20. Normal stress
Source: Authors' determination.

Figure 21 shows the Maximum shear stress which has a maximum value of 130.54 MPa and the minimum value of Maximum shear stress as 0.0019034 Mpa. The same fixation locations have also higher values of the maximum shear stress which are still in a very safe range

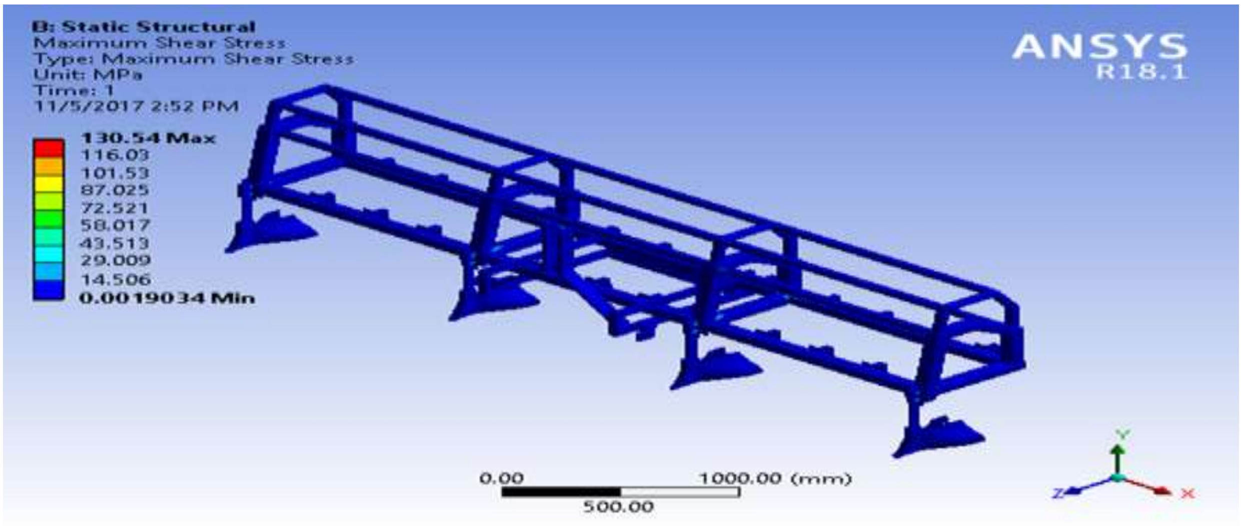

Fig. 21. Max. Shear stress
Source: Authors' determination.

Safety factor

Factor of safety is describing the load carrying capacity of a system beyond the expected or real loads and is demonstrating how much stronger is the system than it usually needs to be for an planned load. Furthermore, it is a constant value intended as a minimum target for system design. Safety factor is often

calculated using a detailed analysis because the comprehensive testing is impracticable on many design models or prototypes, but the structure's ability to carry that load must be determined to a reasonable accuracy. Many design systems are persistently created much stronger than needed for normal usage to allow for misuse, unexpected loads, emergency situations, or dreadful conditions.
The safety factor is a ratio of absolute structural strength (capacity) to actual applied load, which is considered a measure of the reliability of a particular design. It is a design factor of safety or required factor of safety. The realized factor of safety must be greater than the required design factor of safety. Figure 22 shows the safety factor which lies between the maximum of 15 and the minimum factor of 1.1045. Safety factor reaches more than 10 and up to 15 in this case which is very safe for this design issue

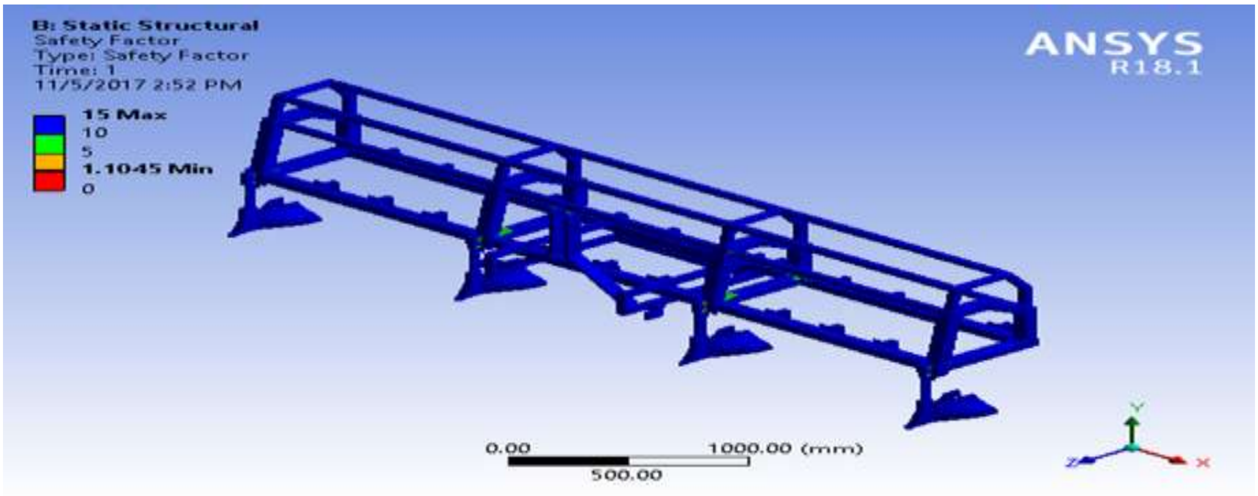

Fig. 22. Safety factor
Source: Authors' determination.

CONCLUSIONS

MRB design prototype provides a cost-effective, passive energy operation, and local manufacturing opportunity. It is suitable for small and medium farm sizes as well as for intensive canopy cover crops and interspaced crops.
The raised bed multi-seed planting machine is designed in SolidWorks software. The Bounding Box dimensions of the of raised bed machine X, Y, and Z are 4070, 80, and 80mm. The SolidWorks design is analysed through ANSYS analysis software. For the analysis, the structural material properties are selected because most of either cast iron or structural steel is used as a fabrication material. Structural Steel is the material used in analysis with Compressive Yield Strength, Tensile Yield Strength, and Tensile Ultimate Strength equal 250, 250, and 460MPa respectively. Young's Modulus is 2e+005 Mpa, Bulk Modulus is 1.6667e+005Mpa and the Tensile Yield Strength is 250 MPa.
The maximum Equivalent Elastic Strain is 0.0012312 m/m and the minimum Equivalent Elastic Strain is 2.063e-8mm/mm while the nominal Equivalent elastic strain equals 0.0001368 mm/mm. MRB machine is also very safe from risky stresses (Normal or Shear). The safety factor was 1.1045 relative to the maximum of 15. The maximum value of the total deformation is 1.9706 mm and the minimum total deformation is 0 m while the maximum nominal total deformation equals 0.68 mm which is favourable and in the safe range.

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