ORIGINAL RESEARCH

Computer-aided Stress Analysis of a Model of Tractor Mounted Auger Drill

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Abstract

Auger drilling, which is a digging method that a large helical drilling part gets out the soil from the earth. Different types of auger drillers are available today, and they are widely used in agricultural works. In this study, an 300 mm diameter auger drill was modeled for agricultural works, and it was analyzed efficiently in Autodesk Inventor software with the help of Nastran in computer-aided design (CAD) module. According to the analysis, Von Misses stress analysis result was found as maximum 2266 MPa and minimum 0 MPa. Also, Safety Factor analysis result was found as maximum 15 uL and minimum 0.11 uL.

Keywords: Agricultural Machinery, Auger drill, Computer-aided design, Stress analysis, Stress distribution.

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Introduction

Nowadays, many useful agricultural machines are designed and developed for different agricultural aims. For example, Bhavsar *et al.* (2017) developed twin wheel weeder to reduce the labor force and chemical usage. Gautam *et al.* (2018) designed and developed tractor drawn seed cum pressurized aqueous fertilizer drill for precision seeding of different crops in deficit moisture condition areas. It is possible to add many examples to design and development of agricultural machines. One of them is tractor mounted auger drillers. Digging is a process of drilling a hole with a machine that uses sharp parts to do it on the earth's surface. Hole drilling on the earth's surface has many reasons like extraction of oil, electricity poles, flag posts, masts, buildings, etc., but mainly in agricultural use for fence poles and tree planting pits with the saved time and without labor needs (Eliud 2006). Different types of auger drillers are available today. There are big and powerful auger drillers which are used in construction and other industries, but in the farming, middle size ones to use. The standard tractor mounted hole has several commercially essential aspects. Also, it is designed with a specific profile to drill holes in an agricultural area. Auger drilling machines are used to drill holes for fence poles, forest trees, and fruit tree planting holes. As an example, an auger-drilling machine can open holes between 300 per hour (Erdogan 2012). Hole drilling with drilling machine-mechanisms or hand tools for planting trees is a critical activity in agriculture. Trees are long-living plants, and some of them live thousands of years old when compared with the other agricultural plants. They are vital pieces of our lives with their natural beauty, foods, and other benefits.

An auger driller is mounted on an auger drive telescopic arm, which can move vertically in a steel machine body. The steel machine body has mounting arms to attach to a three-point hitch on the tractor. Drive gears are connects with an automatic torque limiter with the help of extensible shaft. It takes its movement from the power take-off of the tractor and rotates the auger driller as vertically. At vertically placed the augers, tip resistances occur. This resistance depends on several parameters, the sum of the vertical load on the bit from the machine, weight of auger with the captured soil, flanges inclination angle, etc. (Boldyrev and Novichkov 2016).

Also, control of the hole depth can be done with the help of double acting hydraulic cylinders that are rigidly fastened together. By this way, telescopic arms and machine body can move vertically with aimed direction. Also, the auger drive moves vertically with the connection of the telescopic arms with two hydraulic cylinders fastened together. When starting drilling, it is ensured that the drill is perpendicular to the ground surface. Moving parts must be protected from harmful effects of soil layers like stones and rocks during drilling. The gearbox should be checked for oil at regular intervals.

Moreover, the movable transfer elements must be lubricated from time to time with grease. The telescopic arms of the heavy steel machine body to allow mounting the machine body approximately 1 meter behind the connections of the mounting arms of the three-point hitch of the tractor. Upward and downward movements can be done with a pair of hydraulic cylinders that minimize or maximize the whole length of it.

Upside part of the three-point hitch can set its maximum and minimum sizes with turning it around. This upside part and the

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downside extensible locking arms can be set as a triangle form; by this way, the auger takes a vertical position to the soil (Jones 1992). Auger requires additional pressure on heavy soils when entering the soil under its weight and cutting angle of the blade. The hydraulic system of the tractor provides this additional force. The auger drill can work in both directions. Especially in the reverse direction, it is necessary to exit from the soil. The drilled soil by an auger as its handler, are piled up around the hole. This is then important regarding closing the holes.

Auger driller machines are essential in most of the agricultural work. Because of this reason, it is proposed to design a machine that can easily be used to drill holes for planting trees, or other agricultural activities in appropriate areas. For this aim, in this design and analysis study, an auger drill was modeled and analyzed for agricultural works in Autodesk Inventor software with the help of Nastran in CAD module.

Materials and methods

Today, in Turkey, different kinds of tractor mountable auger drilling machines are producing which move with the help of power can take off the connected shaft and the three-point hitch of the tractor (Fig. 1).

A standard auger driller machine, which is mountable to the tractor, has five main parts (Fig. 2). These consist of the parts as auger drill, telescopic arms, extendable shaft, fork hanger, rear auger arms. The horizontal and vertical adjustment of the auger-drilling machine is necessary to make the right hole. Also, care must be taken to ensure that the power take-off to make 540 RPM and that the safety devices on the shaft in the drilling operation.

Holes can be drilled with the help of various auger drilling machines which has different diameters and shapes for the different diameter and depth holes (Fig. 3). The diameter of the opened holes varies between 20 to80 cm (Edogan 2012).

With the additional extension, the auger drilling machine depth can reach up to 1.2 meters. There are various types of auger drilling machine, and some of them can be seen in Figure 2. There are also types of auger drillers driven by hydraulic motors. When the tractor power is sufficient, more than one auger can be operated at the same time with the help of hydraulic motors and extendable shafts (Fig. 4).

In places where the tractor is not used, and there is no practical possibility, this motion can be provided with movable thermic motor support at auger drilling machines for getting the hole what the farmers need. However, with this type of auger drilling machines, there is no possibility to work in heavy construction soil. In Figure 5, there can be seen an auger drill driven by a 52 cc 3 HP two-stroke gasoline engine, with three drillers at 100 mm, 150 mm, 200 mm diameters. The power these engines generally have 1.5 kW.

Attention should be paid, the presence of the protective cover of the shaft on the auger drilling machine and the working power take off the tractor. Precautions should be taken to prevent from the moment of operation. Also, when the hole is opened, the accidents can happen during the drilling operation; for example, the tractor may fall because of a state of overturning. To avoid any accidents, it is necessary to attach front weights to the tractors.

The auger drill model is designed to drill a hole of 300 mm diameter and a maximum depth of 550 mm (Fig. 6). The holes to be produced by the machine will be of uniform diameter. It is also possible to drill holes of different diameters by just changing the different size of the auger drill. The designed machine model is driven by the tractor power take-off (PTO). The PTO shaft will be connected to the vertical shaft by a set of straight gears at 90°. The vertical shaft is holding the auger drill at the bottom. Also, the critical features of the designed machine are ease of transportation to the drilling from the driving power easily. For this aim, the designed tractor mounted auger drill model were analyzed by using Autodesk Inventor software with the help of a Nastran CAD module (Fig. 7).



Fig. 1: Locally produced standard auger drilling machine for agricultural works (Anonymous 2018b)

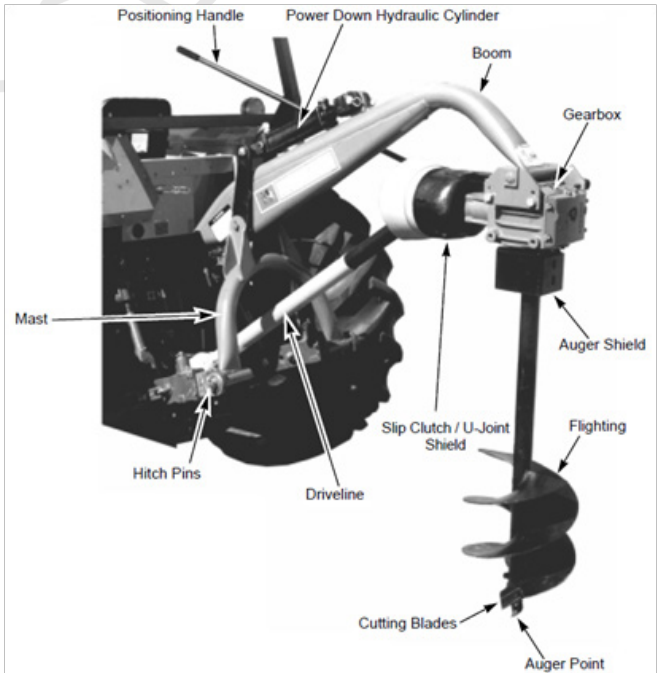

Fig. 2: Main parts of a standard soil auger driller machine with a tractor connection (Anonymous 2018f)

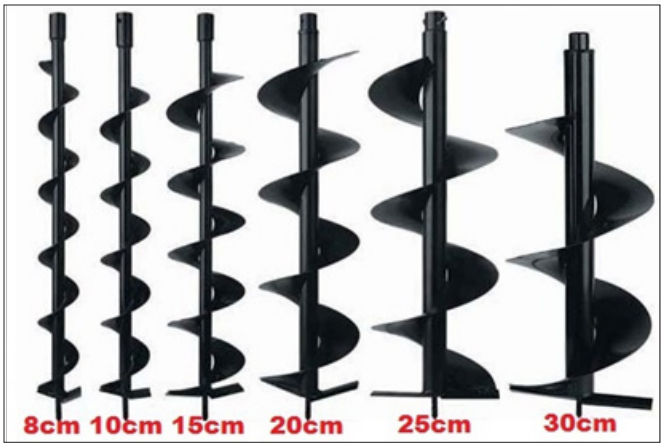

Fig. 3: Auger drill diameter samples (Anonymous 2018c)



Fig. 4: Multiple auger driller powered with extendable shaft connections (Anonymous 2018d)



Fig. 5: Movable thermic motor supported at auger drilling machine sample (Anonymous 2018e)

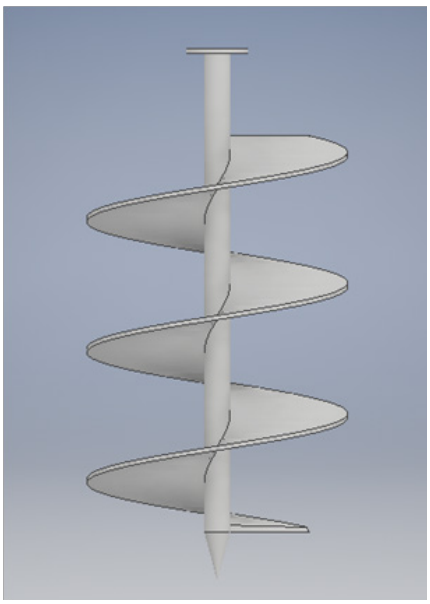

Fig. 7: Designed auger drill model in Autodesk Inventor software

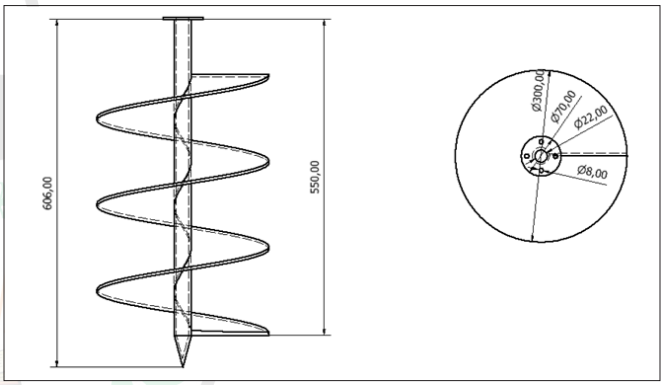

Fig. 6: Basic dimensions of the auger drill model

Autodesk Nastran Solver

Analysis of the developed model had been done by using Autodesk Inventor 2017 software which has Autodesk® Nastran® In-CAD module in it. Autodesk® Nastran® In-CAD software, a general purpose finite element analysis (FEA) tool embedded in Autodesk Inventor CAD systems. AutoCAD Inventor software powered by the Autodesk® Nastran® solver in this study. This solver offers simulation across multiple analysis types. These are linear and nonlinear stress, dynamics, and heat transfer. Nastran® In-CAD module is available for various CAD platforms. It is providing a better experience and eliminating the need for numerous simulation technologies. It has high simulation technology and embedding advanced FEA technology directly into the Autodesk® Inventor® software for the CAD-embedded workflow to make great analyses. Also, Autodesk Nastran is a general purpose FEA solver known for its accuracy in analyzing linear and nonlinear stress, dynamics, and heat transfer of structures and mechanical parts. Additionally, it enables us to obtain more accurate results for sophisticated analysis.

The software does these analysis types (Anonymous 2018a):

- *Nonlinear:* Computes advanced nonlinear solutions such as large displacements/rotation, large strain, plasticity, hyperelasticity, creep, etc.

- *Thermal:* Supports analysis of thermal loads. Solves heat transfer problems with linear and nonlinear thermal boundary conditions that vary over time.
- *Fatigue:* Determines the life of parts subjected to cyclic loads and easily extends a linear static or random response analysis to calculate the fatigue life and fatigue damage.
- *Buckling:* Assesses stability under loads; examines structures for sudden failure modes caused by compressive forces.
- *Dynamic response:* Determines displacements, loads, stresses, and strains in structures subjected to transient or frequency-dependent loads.

In this study, a static stress analysis was applied to the auger drill. Because of a highly corrosion resistant and soil connection needs stainless steel was selected as auger drill product material. Material properties can be seen in Table 1.

Connection ring was fixed with frictionless and auger drill shaft were forged with a moment 2500 Nm. Also, the gravity added as 9.810 m/s^2 to auger hole drill (Fig. 8).

Table 1: Stainless steel material properties

Name	*Stainless steel*	
General	Mass density	8 g/cm^3
	Yield strength	250 MPa
	Ultimate tensile strength	540 MPa
Stress	Young's modulus	193 GPa
	Poisson's ratio	0.3 uL
	Shear modulus	74.2308 GPa

Results and Discussion

The results of this design study can be expressed as design of 300 mm diameter auger drill was analyzed efficiently, and design of various diameters of the auger drill other than

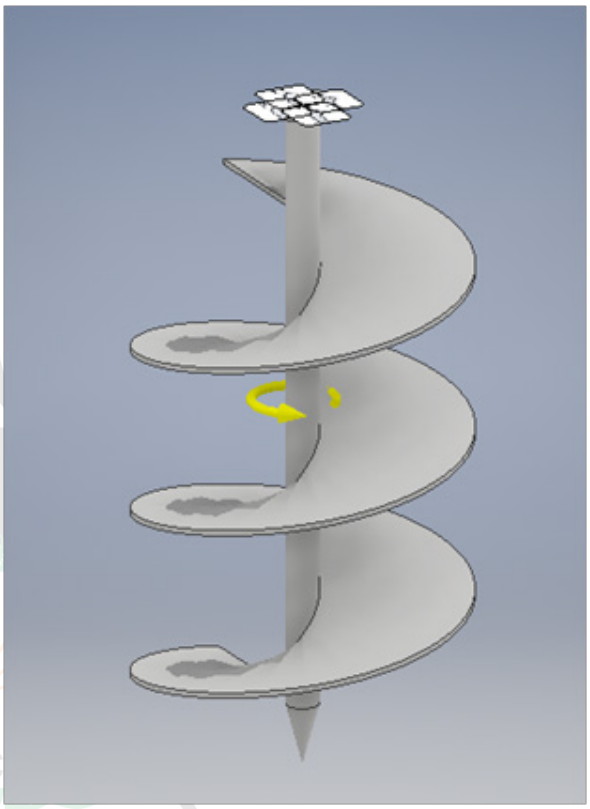

Fig. 8: Applied forge and fixes on the auger drill model

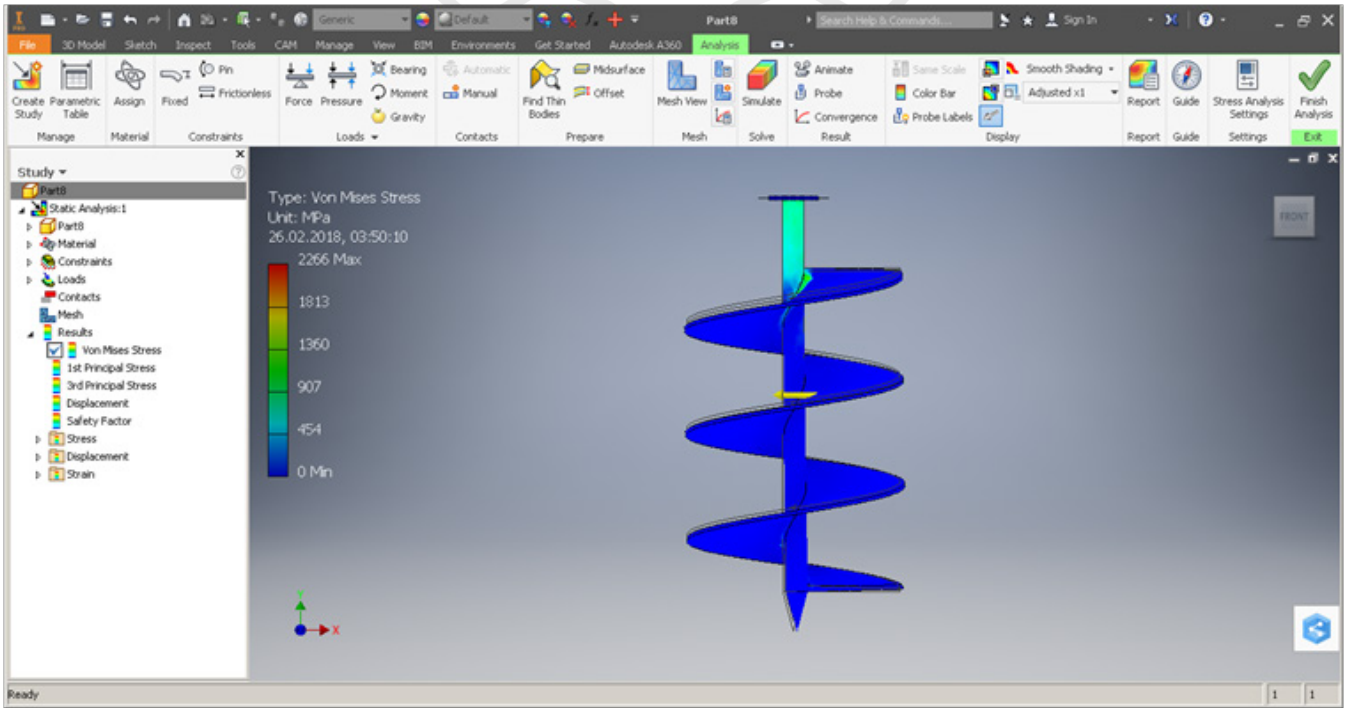

Fig. 9: Autodesk inventor Nastran in CAD module for stress analysis

Table 2: Result summary

Name	*Minimum*	*Maximum*
Volume	1252160 mm^3	
Mass	10.0173 kg	
Von Mises stress	0.341971 MPa	2266.16 MPa
Safety factor	0.110319 uL	15 uL

300 mm can be undertaken (Fig. 9). Result summary for Von Mises stress and safety factor can be seen in Table 2. Additionally, Figure 10 shows Von Misses stress analysis result between maximum 2266 Mpa and minimum 0 Mpa. Also, Figure 11 shows safety factor analysis result between maximum 15 uL and minimum 0.11 uL.

In the study, a different approach for designing the tractor mounted auger drill was explored. In general, there

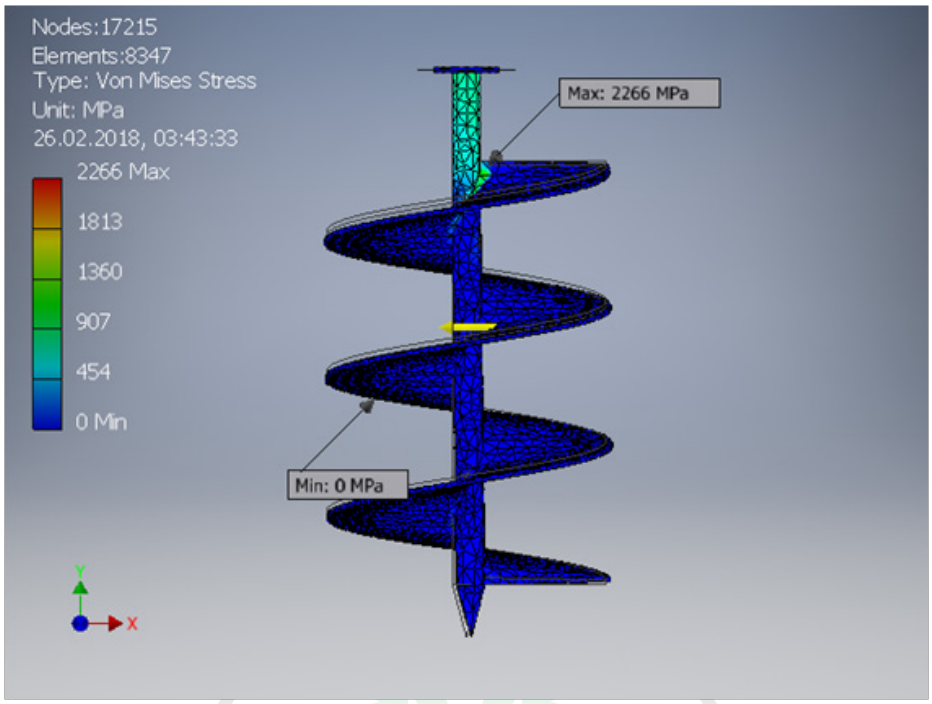

Fig. 10: Von Misses stress analysis result

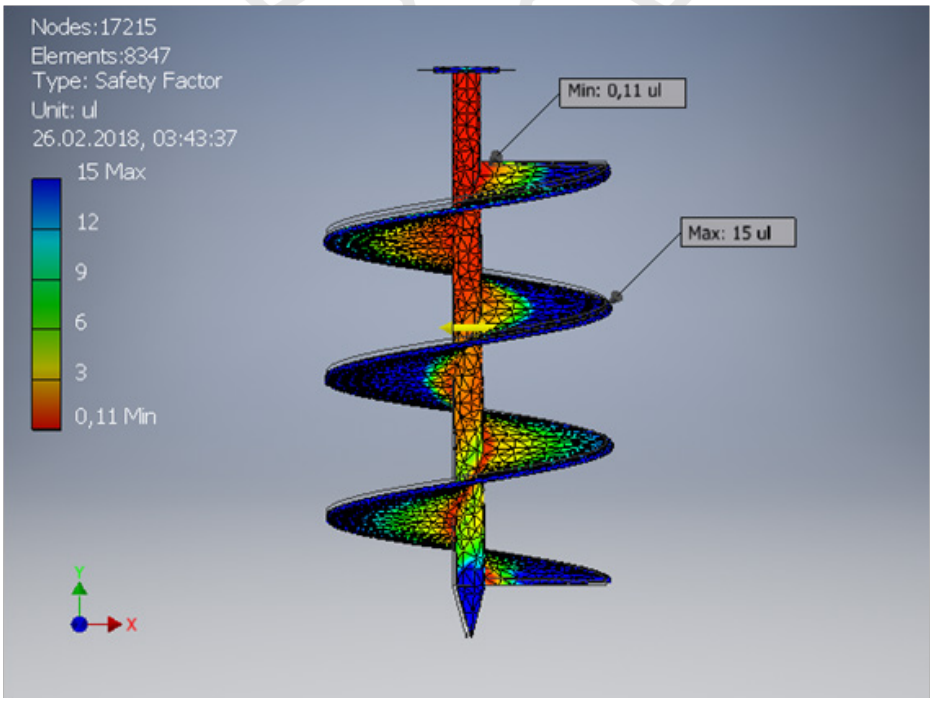

Fig. 11: Safety factor results

are a lot of stress analysis papers in the literature, but there is not enough information about tractor mounted hole digger analysis. Because of this reason the study is important for getting an idea about tractor mounted auger drills. For example, in the literature, Ebrahimia *et al*. (2018) worked on operational modal analysis and fatigue life estimation of a chisel plow arm under soil-induced random excitations. After their analysis on different materials for the fatigue life calculations of the chisel plow arm properties of steel (C = 1.934 × 1012 and k = 3.324) found suitable by them. Demirel and Gölbaşı (2011) studied on stress distribution on a dragline bucket using finite element analysis and they express that 510 Mpa value is suitable for a dragline bucket. According to literature and study results, it had seen that cost analysis of all the components required for the machine and machine parts can be done quickly, and at last a working model of the systems or machines can be analyzed.

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