

USE OF SOLIDWORKS IN DESIGNING AGRICULTURAL MACHINES (A SAMPLE: ROTARY TILLER)

¹Department of Agriculture Machinery & Technologies Engineering, Faculty of Agriculture, Ondokuz Mayıs University, Atakum, Samsun, TURKEY

²Akdeniz University, Vocational School of Technical Science, Antalya, TURKEY

Abstract: Nowadays, computer and software technologies which are progressing rapidly are spreading in machine design applications as it is in many areas. In the past sixty years, systems have been successfully implemented in which computers, software and numerical methods are integrated. The data show that more than five million people around the world are interested in machine design. One of these is SolidWorks, a three-dimensional solid modelling design program that is most commonly used in the world open to development, easy to use and able to work comfortably in the windows applications. In this work, the general features of the program and its ease of use will be mentioned and the usage of the agricultural machine design will be tried to be explained with the example of the rotary tiller.

Keywords: Cad, cam, SolidWorks, rotary tiller, machine design

1. INTRODUCTION

Agricultural mechanization is defined as the mechanization of agricultural production activities with the use of power sources and agricultural machines and includes the power sources necessary for the application of advanced production techniques in agriculture and the design, production, development and use of agricultural equipment and machines (Akıncı İ.. 2011). In the course of historical development, human powered hand tools were first replaced by animal powered tools and then mechanized by the development of mechanical systems (Okursoy R.. 2006). However, short-term, high-quality and low-cost design and development of different type and function agricultural equipment and machines have gained importance in order to meet different needs arising in agricultural works.

In addition, in order to meet the different needs arising in agricultural work, it has become important to design and develop various types and functional agricultural tools and machines in a short time with a high quality and low cost. Computer and software technologies that step in the direction of these demands, especially in the design and manufacture of complex multifunction systems offer great benefits in terms of cost, time and labour savings.

Computer-integrated applications have some important advantages over conventional manufacturing applications (Çelik and Akıncı. 2012) (table 1). Computer-aided design (CAD) as critical module of a computer integrated manufacturing (CIM) system is an interaction of human and machine working together to optimize design and manufacture activities of products in product development environment (PDE). Generally, it is used to design a product to be produced by the introduction of computer technology, for example, architects and engineers have access to 3D Computer Aided Design (CAD) tools, which not only help them build a virtual prototype, but also simulate the structural integrity of their model (Fristcher and Pigneur. 2014) and finally this advantage reduces engineering costs for any company and also results in products getting to market much faster (Ayağ Z.. 2015).

CAD applications are based on reinforced geometry. The first applications of CAD technology started in the 1950's with numerical control studies. However, in 1960, Ivan E. Sutherland's work at the Massachusetts Institute of Technology (MIT) showed the basic principles and applicability of computer-aided technical drawing applications (Sanders N.. 2008).

Nowadays, CAD software can be classified in 3 basic areas as "General CAD. Custom CAD and Design CAD with Template" depending on the usage area and the ability to model complex structures (Ariadi Y.. 2009).

- General CAD software is more suitable for multi-module and general purpose applications. Depending on the modules required, the purchase prices may change.
- Custom CAD software has been developed for more complex surface work. Using the CAD software requires a great deal of knowledge. At the same time the costs are higher.

Table 1. Comparison of classical manufacturing methods with computer integrated systems

Parameters	Computer-integrated applications	
Design costs	15-30 %	↓
Manufacturing time (per part)	30-60 %	↓
Productivity	40-70 %	↑
Saving parts based on product quality	20-50%	↑
Design speed	3-30 times	↑

— Designed CAD software is used according to the concept of designing and assembling previously prepared and defined elements in software.

More than five million people around the world are interested in machine design. However, only one of them is using the existing CAD software. The percentage of market share of CAD software used in design works around the world is given in figure 1.

2. MATERIAL AND METHOD

— **Some basic features of the SolidWorks program**

SolidWorks Corporation is a commercial company founded in 1993 by Jon Hirschtick in Concord, Massachusetts. The first version of the software was released in 1995. In 1997, Dassault Systems SolidWorks Corp. has purchased the program. It is the first 3-D solid modelling program (3D CAD) integrated in Windows in the world. With SolidWorks. a 3D design program, the following operations can be performed sequentially:

- » It can allow to measure and vector-based three dimensional drawings.
- » Allows the work to be carried out on other similar programs.
- » Technical data can be obtained through drawing.
- » By means of the assembly module, the individual tasks can be put together and simulated by running them together.
- » It is possible to perform impact, static and similar tests on the finished parts and the detailed analysis results of these tests can be obtained.
- » Because SolidWorks works with the principle of parasolid, it allows the user to intervene at every stage of the design, allowing the dimension, size and details of the model to be modified as desired. It makes it possible to make technical drawings and settings in very short time intervals.
- » The sequence of operations performed with the feature tree and the structures can be changed. If the changes are made on this page, the assembly and technical drawings that are made will update immediately. This gives the user a chance to intervene in the technical drawing or assembly.
- » SolidWorks is also a program with the application " smart mate ". Apart from this, sheet metal parts can be expanded and elongation quantities can be calculated.
- » All transactions can be recorded or transferred in IGES. DXF. DWG. SAT. STL. STEP. VDA. VRML format
- » Allows you to reuse objects frequently used with the object library.
- » Applications such as drag-and-drop, cut-and-paste used in Windows can be executed in SolidWorks.
- » Allows the configuration of different sizes from one part to be automatically obtained by creating a table in Excel. (URL-1).

— **General usage areas of SolidWorks**

The SolidWorks have wide range of applications in industries (figure 2) such as aerospace, defence, automotive, transportation, machinery, heavy equipment, electronics, sheet metal work, process plant, consumer products, mold & tools design, energy conservation, construction, medical tools, product design and other engineering services.

3. RESULTS

— **A sample: Rotary Tiller**

With the rapid spread of computer technology in the world, especially after the 1990s. We are seeing a lot of different ideas and speed up our original work which will make our life easier like many other custom designs. This area has been enhanced with software and in all other areas, computers have been provided to function as a virtual workshop and situations that can vary greatly in very different environments have begun to take place in a short time and with considerable labour and material savings.

It is possible to see examples of these studies in the field of agricultural machinery production. Many researchers around the world have conducted different studies on this subject. For example; Topakçı et al. (2010) worked on the optimization of the subsoiler. They have done a subsoiler tine, design and used finite element method (FEM) to simulate stress solutions on the subsoiler tine. Biriş et al (2016) studied the stress and strains distribution

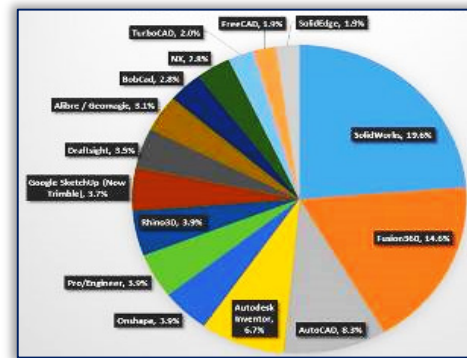


Figure 1 – 2016 Overall Cad market share (CNCCookbook-2016) (URL-2)

First five Cad software and others		Market Share [%]
1.	SolidWorks	19.6
2.	Fusion360	14.6
3.	AutoCAD	8.3
4.	Autodesk Inventor	6.7
5.	Onshape-Pro/Engineer	3.9
6.	Others (nine programs)	46.9

in the frame of agricultural cultivators using the finite element method. Shinde et al (2011) designed rotary blade from three different materials and they studied at the different working conditions as a soil structure in computer environment when working with tractors with 35 and 45 hp. Mandal et al (2013) studied the rotary tillers' blade design optimization and development in their research. Similarly, Yegül et al (2014) worked on the optimum geometry parameters of tine harrow without any plastic deformation under defined condition. It is possible to increase the number of such works.



Figure 2 – Some example of SolidWorks usage

If these works are studied carefully, they will be seen to have similar and different aspects of the designers' perspectives and analysis stages, even though they work on similar issues. In our work, we tried to explain the steps that took place in the design of a sample rotary tiller.

In agricultural processes, even though the soil conditions are in very good condition, soil treatment results in a maximum power consumption of 60% in general (Gözübüyük et al. 2012). Thus, soil treatment is the most expensive process. The largest part of the measures to reduce the cost of agricultural operations can cover land processing costs. With some measures to be taken, the cost of tillage can be reduced by 30-50% (Baran et al. 2013).

In conventional tillage methods, where mostly pulled tools are used, there are undesirable increases in time and energy consumption along with field traffic, since seed beds can be prepared with only a few passes (Çelik A. 1998). These negative aspects of the pulled type tools have been tried to be solved by using rotating tillage machines by moving from tractor PTO's shaft. The rotary tiller is considered to be the most important of the tillage machines that operate by moving from the PTO's shaft.

— Design stages of a sample rotary tiller

Rotary tillers, generally, can be examined in three main sections; processing (active parts) carriers and protective and transmission sections. Before designing the rotary tiller, it is necessary to specify the blade parameters and boundary conditions (input parameters for the analysis) that can be used during design. The related parameters of sample rotary tiller are tried to be given in table 1 and table 2 respectively. Values may vary depending on design features.

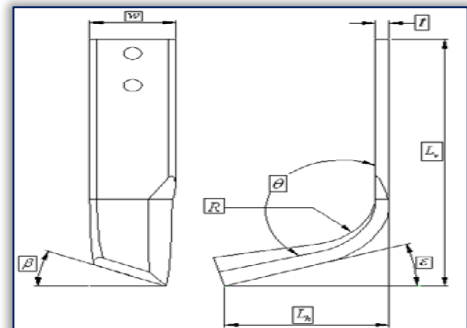


Figure 3. Rotary tillers parameters

Table 1. Blade main parameters and values

Parameters	Notations	Units	Values
W	Blade span	mm	-
L_v	Effective vertical length	mm	-
L_h	Blade cutting width	mm	-
R	Curvature between L_v and L_h	mm	-
θ	Blade angle	°	-
β	Clearance angle	°	-
t	Blade thickness	mm	-
ϵ	Bending angle	°	-

Table 2. Some other input parameters dealing with rotary tiller

No	Parameters	Units	Value
1	Working depth of rotary tiller	mm	-
2	Working width of rotary tiller	mm	-
3	Rotor reevaluation	rpm	-
4	Blade peripheral velocity	m/s	-
5	Total number of blade	Number	-
6	Number of blades on each side of the flanges	Number	-
7	Prime mover forward speed	m/s	-
8	Number of blades which action jointly on the soil	number	-
9	Prime mover power	HP	-
10	Traction efficiency	μ	-



— Design of active parts (First stage)

According to the determined parameters, the blades were started to be designed in the first stage. In this example, an L-type blade is selected (Figure 3). The reason of this is the fact that in most of the studies carried out, the best performance on the cutting of organic material on the surface of the soil, the control of weeds and the uniform fragmentation of the soil are generally achieved in L-type blades (Çelik A.. 1998; Ashok et al. 2013).

After the blades were designed, it was decided how many blades were in a flange. The number of blades per flange was determined by taking into account the speed of the rotor rotation unit and machine speed. In this design operation, four blades are mounted on the flange with a 90° (Figure 4). Bolts and nuts are available from SolidWorks' part library, which are the fasteners. The diameter of the rotor is one of the important points in the installation of the blades. The diameter of the rotor is directly related to the peripheral speed. As the rotor diameter increases at constant feed rate, the peripheral speed increases. In this design study, the rotor diameter is designed to be 500 mm.

After the blades are mounted on the flange, the number of flanges on the rotor shaft is determined. Depending on the working width of the machine. Depending on the soil conditions, blade geometry and velocity ratio, the interference of the backside of the blade and the uncut soil may result in severe soil compaction and high power consumption. This is the main reason that causes vibrations, which are a result of the reaction of soil upon the tiller blades. The proper design of the rotary tiller blades is essential to efficient operation (Mandal et al. 2015). In this sample the blades are mounted together tangentially so that they do not touch each other at certain intervals (Figure 5).

— Design of carrier and protective parts (Second stage)

In this sample, a hanging type rotary tiller was designed. After the design of active parts, the standard arm openings of the tractor must be considered so that the tool can easily be connected to the tractor three-point linkage. After the connection was designed, the protective sheet and back cover were designed to cover the blades (Figure 6). The 3-point linkage unit is then mounted on the protective cover according to the centre of gravity. The hinge system is used to open and close the back cover at desired ratios. One of the important factors in the disintegration of soil in processing with soil tillage is the shape and position of the back cover. The disintegration increases as the cover is lowered to the rotor, while the disintegration decreases as it is removed (Bell B. 1985). By mounting the upper roof and the rear cover connection, the rotor bearing plates, which are referred to as side shields, are designed and assembled. The working depth can be easily adjusted with the slides mounted on the side guards.

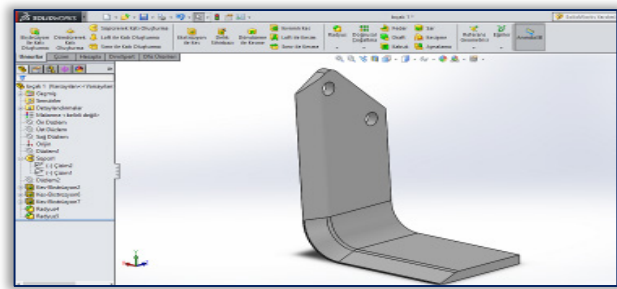


Figure 3 – Some example of SolidWorks usage

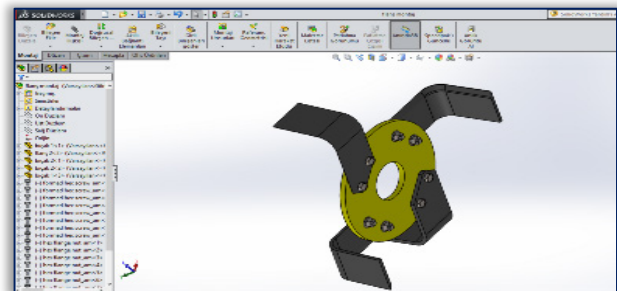


Figure 4 – Flange mounting of blades

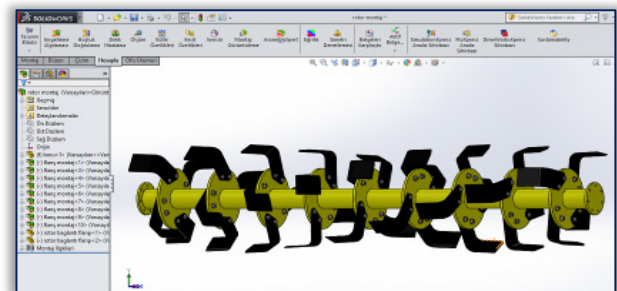


Figure 5 – Rotor assembly of blades

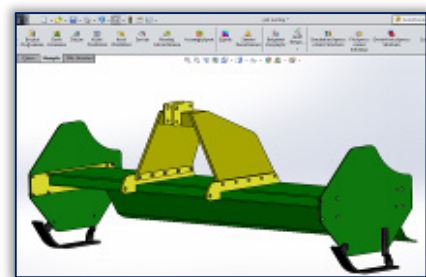
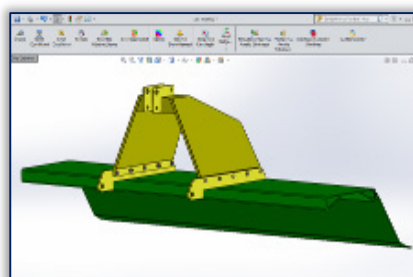
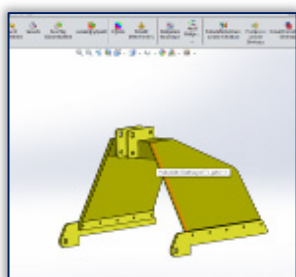


Figure 6 – Design of carrier and protective parts of rotary tiller

— Design of transmission parts (Third stage)

The transmission parts consist of gear teeth in the gearbox and transfer gears that transmit the motion to the rotors. It is recommended that the number of rotation of the rotor be reduced by 1/3 or 2/3 of the standard PTO rotation (Okursoy R., 2012). In this study, the tractor PTO rotation was lowered by means of small gears at first and then adjusted to a speed of 255 rpm with bevel gears having a 1/2 ratio (Figure 7).

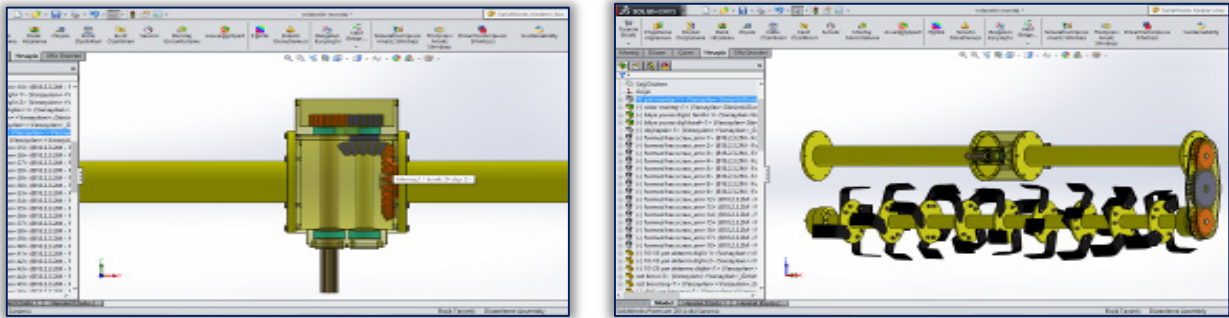


Figure 7 – Design of transmission gears and moving parts

There are two small spare gears in the design. Depending on the soil conditions, working rotation of rotary tiller can be increased or decreased to a certain amount. After the PTO rotation is lowered in gear box, the motion is transmitted to transmission gears. The transfer and gearbox gears are selected from the SolidWorks spare parts library. The number of teeth is determined by calculating the required number of revolutions. After the gears have been assembled, the design of the moving parts is completed by mounting the rotary tiller rotor with the transfer gears. Finally, all main parts are assembled and the design process is completed (Figure 8).

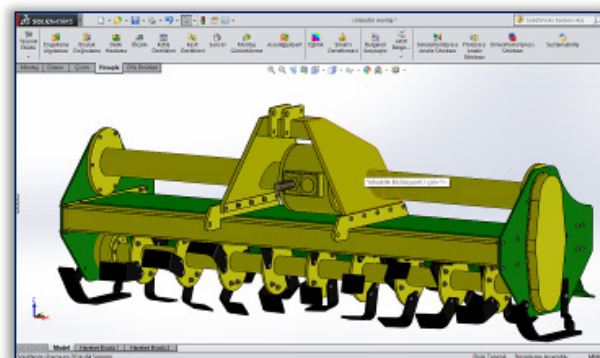


Figure 8 – Rotor assembly of blades

4. CONCLUSIONS

Here, the use of the SolidWorks program has been summarized in the design of a rotary tiller selected as a soil tillage implement. The SolidWorks program is a tool that enables designers to save time and manpower. Therefore, this program which is a virtual workshop must be tested in real conditions after the design of tools and equipments which are considered to work especially in environments with dynamic structure, like soil, and which can show great variability even at very short distances. Also, it should be noted that for this tool, where the design order is given, the path to be traced may vary from designer to designer.

For each designer, these sequences can exhibit variability, the important thing being that the designer can give the basic parameters of the design.

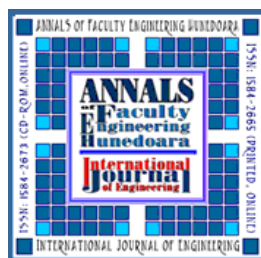
The point that should be mentioned here is that such a program can provide significant cost savings in both time and labour.

Note: This paper is based on the paper presented at ISB-INMA TEH' 2017 International Symposium (Agricultural and Mechanical Engineering), organized by University "POLITEHNICA" of Bucharest – Faculty of Biotechnical Systems Engineering, National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Scientific Research and Technological Development in Plant Protection Institute (ICDPP), National Institute for Research and Development for Industrial Ecology – INCD ECOIND, Research and Development Institute for Processing and Marketing of the Horticultural Products "HORTING" and Hydraulics, Pneumatics Research Institute INOE 2000 IHP, University of Agronomic Sciences and Veterinary Medicine of Bucharest (UASVMB) – Faculty of Horticulture and Romanian Society of Horticulture (SRH), in Bucharest, ROMANIA, between 26 – 28 October, 2017.

References

- [1] url-1. <https://www.slideshare.net/ChrisTurner13/2015-global-cad-trends-from-business-advantage>
- [2] url-2. <http://blog.cnccookbook.com/2016/01/27/cnccookbook-2016-cad-survey-results-part-1-market-share/>
- [3] Akinci İ.. (2011) Agricultural Machinery Lecture Notes, Akdeniz University, Faculty of Agriculture, Department of Agricultural Machinery, Antalya, TURKEY
- [4] Ariadi Y. (2009) Design templates for customising products, Thesis of MSc. Lancaster University, Science and Technology Faculty, Engineering Dept. Lancaster Pro. Development Unit, Lancaster, UK

- [5] Bell B.. (1985) Farm Machinery, Farming Book Series. Farming Press Limited, Wharfedale Road Ipswich Suffolk, UK
- [6] Matani AG., Bhishnurkar AD. (2015) Use of cad tool for design, analysis and development of rotary tillage tool, International Journal of Science and Research (IJSR), 4(5) pp. 215-217
- [7] Ayağ Z. (2015) CAD software evaluation for product design to exchange data in a supply chain network, Int. J Sup. Chain. Mgt., 4(1) pp. 30-38
- [8] Baran MF., Durgut M.R., Kayhan İE., Aydın B., Kurşun İ., Bayhan Y. (2013) Determination of different tillage and sowing methods in terms of technically and economically in second crop sunflower (2nd year), Journal of Agricultural Machinery Science, 9, pp. 35-42
- [9] Biriş SŞ., Maican E., Vlăduț V., Bungescu ST., Ungureanu N., Vlăduț DI. (2016), Stress and strains distribution in the frame of agricultural cultivators using the finite element method, 44. Symposium Actual Tasks on Agricultural Engineering, Opatija, Croatia, pp. 111-117
- [10] Çelik A. (1998) A study on the determination of the effects of different types of rotary tiller knives on soil and their power consumptions, Phd. Thesis. Atatürk University, Institute of Science and Technology, Agricultural Machinery Department, Erzurum, TURKEY
- [11] Çelik HK., Akıncı İ. (2012) Computer aided design of agricultural equipment and machinery. 27th National Congress of Agricultural Mechanization, Samsun, pp.432-440.
- [12] Fritscher B., Pigneur Y. (2014). Computer aided business model design: Analysis of key features adopted by users, 47th Hawaii International Conference on System Science, pp. 3929-3938.
- [13] Gözübüyük Z., Çelik A., Öztürk İ., Demir O., Adigüzel M C. (2012) Comparison of energy use efficiency of various tillage- Seeding systems in production of wheat, Journal of Agricultural Machinery Science, 8(1) pp. 25-34
- [14] Mandal SK., Bhattacharya B., Mukherjee S. (2013) Optimization of Design Parameters for Rotary tiller's Blade, Proceedings of the 1st International and 16th National Conference on Machines and Mechanisms, IIT Roorkee, India.
- [15] Mandal SK., Bhattacharya B., Mukherjee S. (2015) Design of rotary tiller's blade using specific work method (SWM), Applied Mechanical Engineering, 4(3), pp. 1-6.
- [16] Okursoy R.. (2012) Agricultural Machinery Lecture Notes, Uludağ University, Faculty of Agriculture, Department of Agricultural Machinery, Bursa, TURKEY.
- [17] Sanders N. (2008) An industry perspective on the beginnings of Cad, SIGCSE Bull, 40, pp: 128-134.
- [18] Shinde GU., Potekar J M., Shinde R.V., Kajale S R. (2012) Design analysis of rotary tillage tool components by CAD-tool: Rotavator, International Conference on Environmental and Agriculture Engineering, Singapore
- [19] Topakçı M., Celik HK., Canakçı M., Karayel D., Rennie A. (2010) Structural optimization of a subsoiler, Pakistan Journal of Scientific and Industrial Research, 53(5) pp. 281-287
- [20] Yegül U., Eminoğlu MB., Orel O., Çolak A.. (2014) Determination of equivalent stress and total deformation in different types of harrows, Journal of Agricultural Machinery Science, 10, pp. 65-71



ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

copyright © University POLITEHNICA Timisoara, Faculty of Engineering Hunedoara,

5, Revolutiei, 331128, Hunedoara, ROMANIA

<http://annals.fih.upt.ro>