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Structural Analysis of Agricultural Machinery: A Case Study For a Transport Chassis of a Spraying Machine

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Abstract: Today, spraying machines have an important role in agricultural mechanization applications. There are different models according to types and use areas. Especially in recent years, turbomatic sprayers with high fan speed have been increasing to be use. Turbomatic spraying machines that moves through tractor P.T.O transfers the water with pesticide that is atomized under pressure. Again with the movement from P.T.O it provides pressured air outlet. It can be applied to all types of fruit trees, vineyard, high trees, citrus fruit trees etc pesticide. Because of initiating the production and new production of this machine, structural engineering studies are insufficient In particular, the machine chassis where the pump and storage block is placed on must be shaped accordingly to determine the load distribution. In this study, structural stresses in a commercially available turbo atomizer have been analyzed in transport chassis. Determined to this stresses in exiting machine, the finite element method has been performed on chassis in three different working forces. Industrial design of the parameters has been determined depending on the obtained values. In addition, recommendations will be offer for re-shaping of chassis and working conditions.
Key words: FEM, structural analysis, spraying machine, agricultural machinery

INTRODUCTION

The first examples of auxiliary air flow mechanical sprayer have been developed during the spraying orchards and vineyards in order to take advantage of the positive aspects of small drops pulverized. The field ramp-jet sprayer which works with this method has been developed and used in recent years.

Small droplets created by power nozzles in the auxiliary air flow mechanical sprayer have been delivered to the target with a strong airflow. Hydraulic nozzles are placed as the liquid sprayed in air flow provided by fan (Yağcıoğlu, 1993). Although the main task of air flow drops moving to the target, provides again breakdown of large drops which are in outside the wall of the sprayed from hydraulic nozzles. These machines use the orchards. In Turkey, due to the orchards increases, production and use of these machines have been increasing. According to data from Tarmakbir in the year 2009 in Turkey, about 20 the company produces the spraying machines. The number of 13 companies produces the drawn from the tail shaft-driven turbo-type atomizer (Tarmakbir, 2009). According to TUIK data, while 103.490 units atomizer produced in 2008, 105.036 units atomizer were produced in 2009 (TUIK, 2010). However, machine used in the study area can be produced as various sizes and 100 units have been producing in a year. These machines are manufactured as 1000 lt and 2000 lt storage capacity. Therefore, the weight of the machine is quite heavy. Chassis of machine is very important for the transport and safe operation of the machine. Variable and static loads come on the chassis during the working and transportation. In this study, three different scenarios were applied on the turbo-sprayer chassis produced in our country, and static stress analysis on the chassis and the boundaries of the study was to determined.

MATERIALS and METHOD

Material

A turbomatic atomizer used as material in this study was produced and it is widely used in our country. This machine's technical features and shapes are given in Table 1 and Figures 1. Turbomatic spraying machines that moves through tractor P.T.O Again with the movement from P.T.O it provides pressured air outlet. In addition, polyethylene tank, dual turbo mammalian system, easy to clean filters, duplex tires, two-speed gearbox, adjustable tow arm-filling system, 4-diaphragm pump are available. Chassis of the sprayer width, length and height are 700, 2250, 65 mm, respectively.

Method

Chassis of the turbomatic atomizer was modeled using Solidworks 3D parametric design software. Then stress analysis was performed for static loading condition with 3 forces (10000, 20000, 40000 N) by finite element analysis (FEA). Cosmosworks commercial FEA code was used for simulation. As results of FEA, stress distributions were presented. In addition, in the FEA, material of chassis of the turbomatic atomizer's chassis elements was assumed as AISI 1045 (structural steel). Some mechanical properties of AISI 1045 were presented in Table2.

Table 1. Some technical features of the Turbomatic spraying machines

Model:	Turbomatic
Pump, (lt/min)	145/170
Warehouse, (LT):	2000 Lt
Pressure, (Bar):	0-50
Power, (hp):	5 and 6
Propeller, (m^3-h)	85000
Injector, (Units):	18
Weight, (kg):	780
Width, (mm):	1700
Length, (mm):	3600
Height, (mm):	2300

Figure 1. Turbomatic spraying machines

Table 2. Material properties of chassis material AISI 104

Property Name	Value
Elastic modulus (N/m^2)	2.05e+011
Poisson's ratio	0.29
Shear modulus (N/m^2)	8e+010
Mass density (kg/m^3)	7850
Tensile strength (N/m^2)	6.25e+008
Yield strength (N/m^2)	5.3e+008
Thermal expansion coefficient (K)	1.15e-008
Thermal conductivity W/(m.K)	49.8
Specific heat J/(kg.K)	486

After 3D modeling operation, boundary conditions were defined. Static loading case was assumed in the simulation. In the simulation, the loads were applied as 10000, 20000, 40000 N. Cosmosworks meshing function was utilized for the mesh structure of chassis (Cosmosworks, 2010). 9924 total elements, 17471 nodes were obtained in meshing operation. The FEA was set in assumption of 3D, static, linear material properties.

RESULTS and DISCUSSION

At the post process of FEA, equivalent (Von Misses) stress and displacement, strain results were obtained for chassis in Table 3.

A maximum stress of 1584.9 MPa was occurred in 40000 N and maximum displacement was measured in 40000 N as 133.045 mm for all construction. The Von mises stress distributions; displacement and strain behavior of chases for all forces are presented in Figure 2, 3, 4. Detail maximum stress point on the chassis was given in Figure 5. Maximum displacement was found to be in tractor port of the machine for all forces. In additionally, Safety factors of chassis' elements were computed. Maximum equivalent stresses of elements and its safety factors are presented in Table 4.

Table 3. According to the applied forces, results of the FEA on chassis of the turbomatic sprayer

Forces	10000 N	20000 N	40000 N
VON: von Mises Stress (MPa)	395.0	790.0	1584.9
URES: Resultant Displacement (mm)	33.1684	66.3369	133.045
ESTRN: Equivalent Strain	0.00110741	0.00221482	0.00444666

Table 4. Working safety coefficient for chassis

Chassis Force	Yield Stress [σyield] [MPa]	Von Mises [σvon] [MPa]	Safety Coeff. [K coeff.] = [σyield / σvon]
For 10000 N	530.0	395.0	1.34
For 20000 N	530.0	790.0	0,67
For 40000 N	530.0	1584.9	0.33

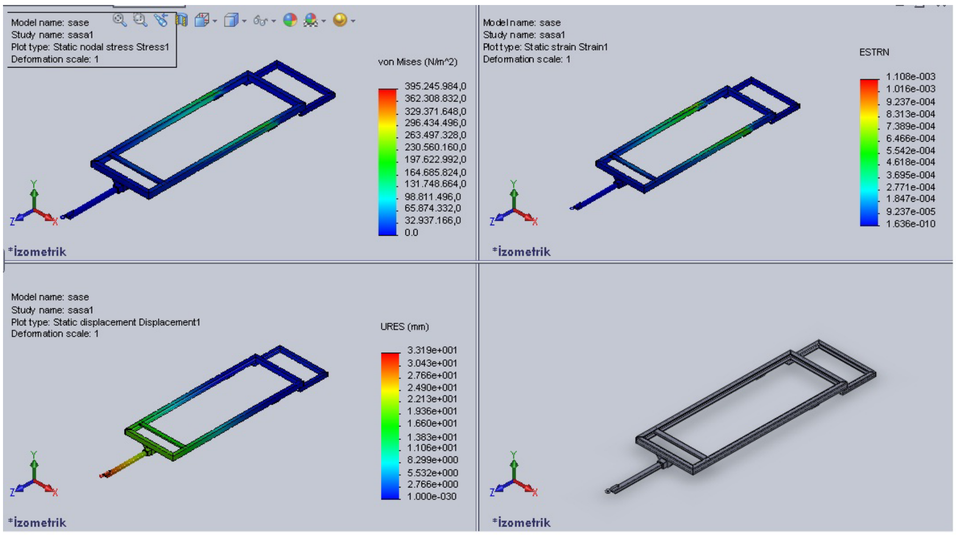

Figure 2. Von mises stress distributions; displacement and strain analysis for 10000 N applied force

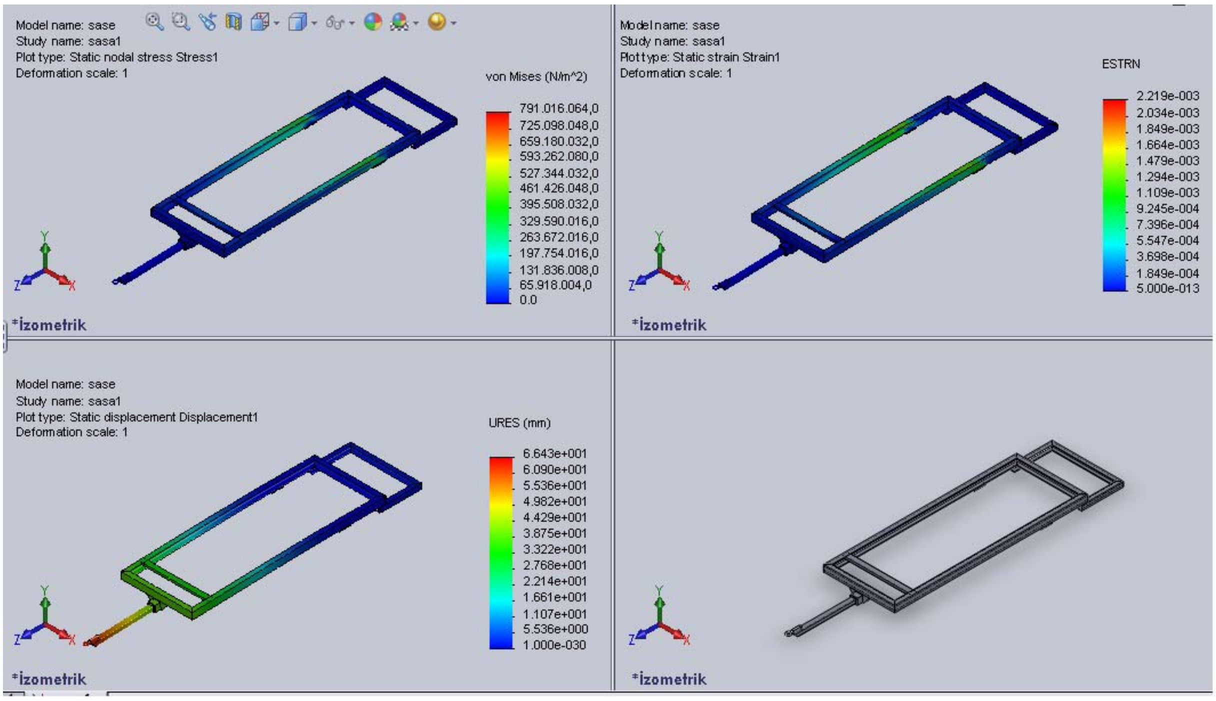

Figure 3. Von mises stress distributions; displacement and strain analysis for 20000 N applied force

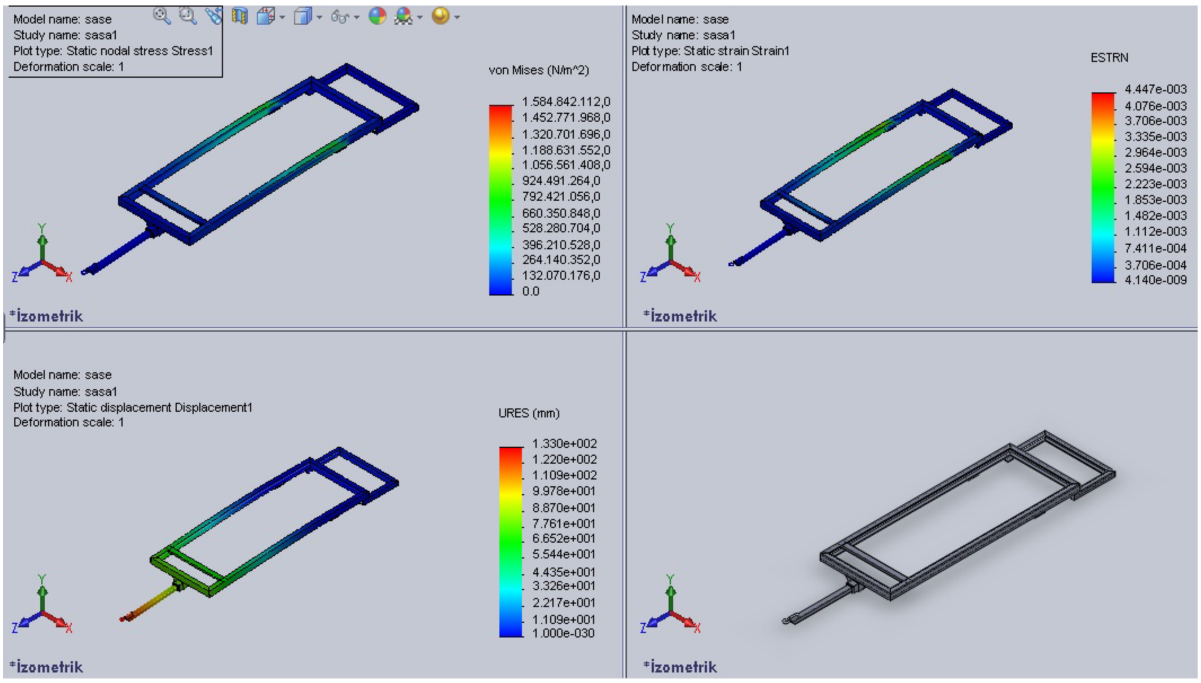

Figure 4. Von mises stress distributions; displacement and strain analysis for 40000 N applied force

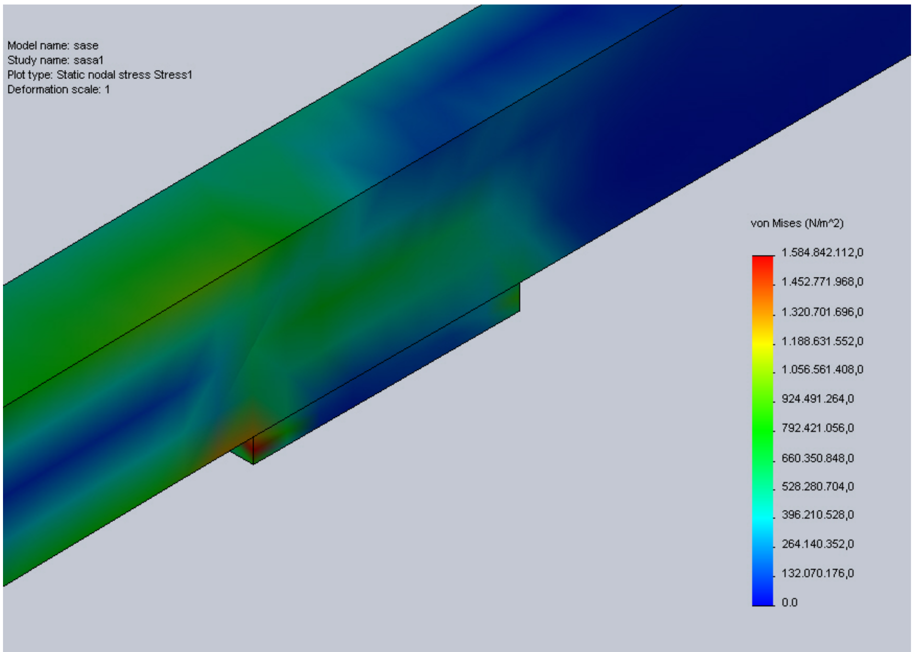

Figure 5. Maximum stress point on the chassis

CONCLUSION

In this study, it was focused that 3D solid modeling and FEM application on chassis of the turbomatic sprayer. Some important points can be summarized as follow;

1. Result of the FEA showed that the maximum stress occurred on 40000 N forced as 1584.9 MPa for chassis of the turbomatic sprayer.
2. Maximum displacement was obtained as 133.045 on contact point of the tractor with machine.
3. The safety factors were computed for chassis elements according to yield strength point of their material.
4. The simulation results showed that safety factor was found greater than 1 for 10000 N, but safety factor of the 20000 and 40000 N was found less than 1. If the machine will be work by 20000 and 40000 N, higher yield stress material should be chosen and the chassis should be manufactured by this material.

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