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3D printing and CAE analysis of spraying nozzles for different orifice sizes

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Abstract
The solid model of the nozzles was created, and the prototype was produced with the help of a 3D Stratasys printer. Afterwards, an analysis of three flat fan nozzles (N_1, N_2, and N_3) with different orifice sizes (1.050 mm, 1.150 mm, and 1.340 mm) using Computer-Aided Engineering (CAE) techniques. The purpose of the analysis is to evaluate the structural and computational fluid dynamics aspects of these nozzles. In the analysis, the nozzles were subjected to external forces 1N, 2N 3N and total deformation (mm), equivalent elastic strain, equivalent stress (MPa) parameters were evaluated theoretical calculations are done and CFD simulations are also done on the nozzles surface using ANSYS Workbench software version 2021 R1 and computational fluid analysis of nozzle. The objective of conducting this analysis is to identify potential points of failure and evaluate the structural performance of the nozzle under the given external forces. By understanding the behavior of the nozzle under these conditions, design improvements can be made to minimize the risk of failure during its operational use. The validation of these formulae is carried out using the Computational Fluid Dynamics (CFD) software ANSYS Fluent.

Keywords: CFD analysis, fluent flow, nozzle design, structural analysis and 3D Stratasys Printer

Introduction

The level of automation in contemporary agricultural equipment is rising. The field of farm machinery research now has a favorable opportunity to use soft skills in the design of farm machinery in general and precision equipment in particular because to recent developments in computational and system engineering. It is essential to advance with technological advancements and reduce the cost and time incurred in the design and testing of farm machinery in order to meet the goal of generating farmer-friendly equipment meant to save costs and time. Due to the variety of the soil, the deformation of the soil, and the varying loads put on the working implement, agricultural machinery operates under a variety of conditions. The standard design processes below frequently don't produce the expected results during the design process. Thus, simulation studies aid in the development of a viable prototype that can function in a variety of settings for sustainable agricultural production by helping to predict the physical and behavioral diversity in real-world systems. In order to forecast how a prototype will perform in the actual world, simulation modeling is the process of building and analyzing a model of the prototype. Designers and engineers utilize simulation modeling to better understand whether, how, and under what circumstances a part could break as well as what stresses it can withstand. Fluid flow and heat transfer patterns can also be predicted with the aid of simulation modeling. It uses simulation software to analyze the rough working conditions [1]. The UN DESA report "World Population Prospects - The 2015 Revision" (UN DESA, 2015) predicts that the present global population of 7.3 billion people will increase to 8.5 billion by 2030, 9.7 billion by 2050, and 11.2 billion by 2100. There is no doubt that one of the most important requirements for producing enough food on the existing available agricultural area is the use of well-designed machinery and high-tech aided mechanization. Advanced computer-aided design (CAD) and engineering (CAE) applications are especially necessary for the manufacturing processes in the agricultural engineering sector [2]. Design and analysis are consisting of preprocessing, solution, post processing; the use of computer software for performance in order to improve product designs or assist in the resolution of engineering problems for a wide range of industries.

This includes simulation, validation, and optimization of products, process, and manufacturing tools, CAE cycle as shown in Fig.1.1. The computational fluid dynamics (CFD) techniques used to achieve it, with which the effects of variables on the drift and dispersion can be studied in isolation. Nowadays, as the finite element analysis method, CFD has become a robust design tool in agriculture application [3]. The proposed method of research introduces systematic procedural steps for entering in to design, fabrication and performance validation to finalize the final mass production of spraying nozzles using software [4].

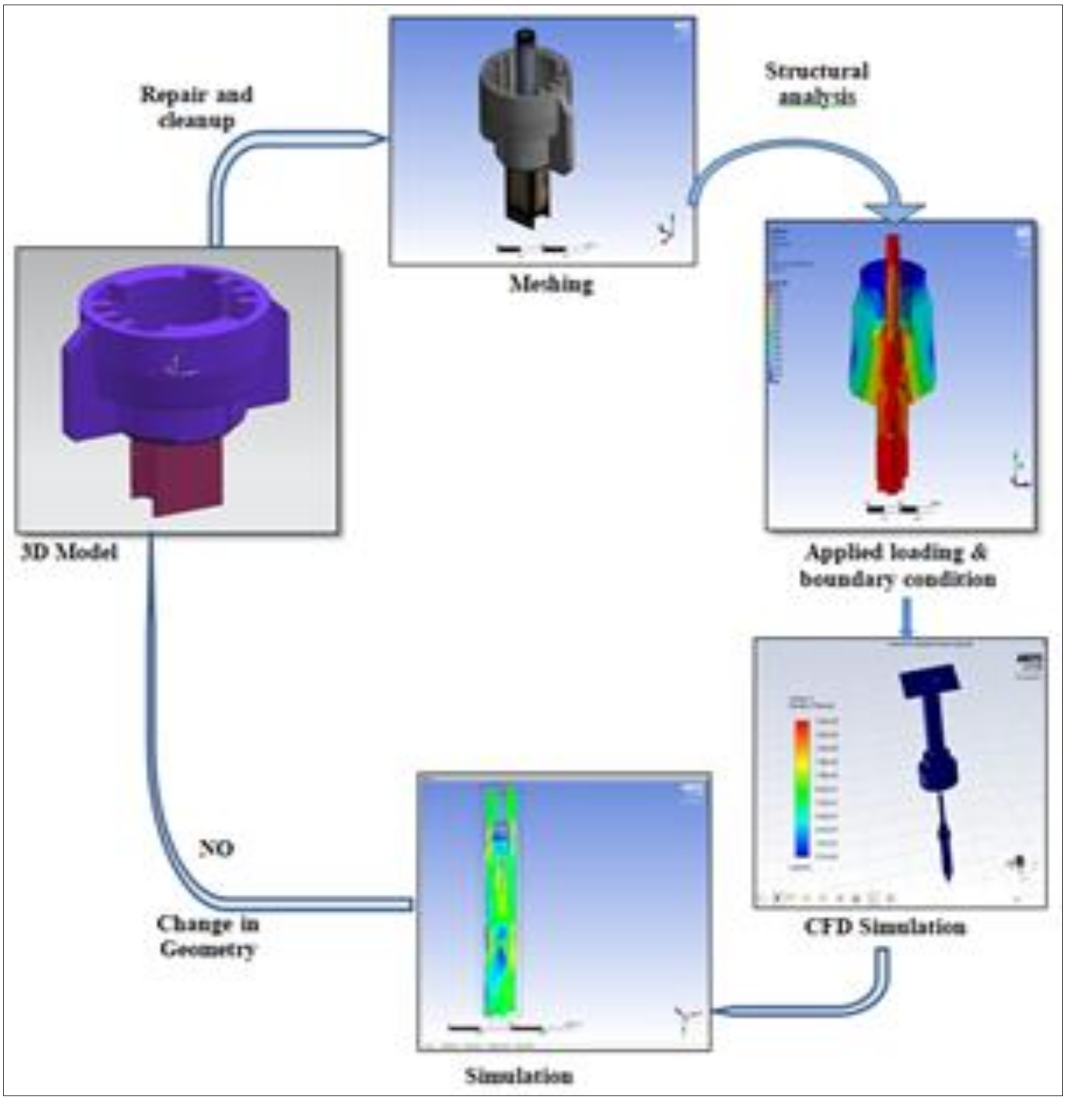

Fig 1: CAE cycle

Methodology

CAD Model

The creation of the CAD modeling of three flat fan nozzles (N1, N2, and N3) is carried out using heterogeneous methods (parametric or nonparametric) with different orifice sizes (1.055 mm, 1.155 mm, and 1.340 mm) is done using Solidworks software. Procedures applied at this stage; clamping adjacent surfaces, creating radius and chamfers, and realizing geometric constraints [5]. The ANSYS fluent Software is used to carry out the Analysis section of the nozzle. Ansys Fluent is widely used to carry out the fluid flow used simulation works. The modeling and analyzing of the nozzle were referred [6].

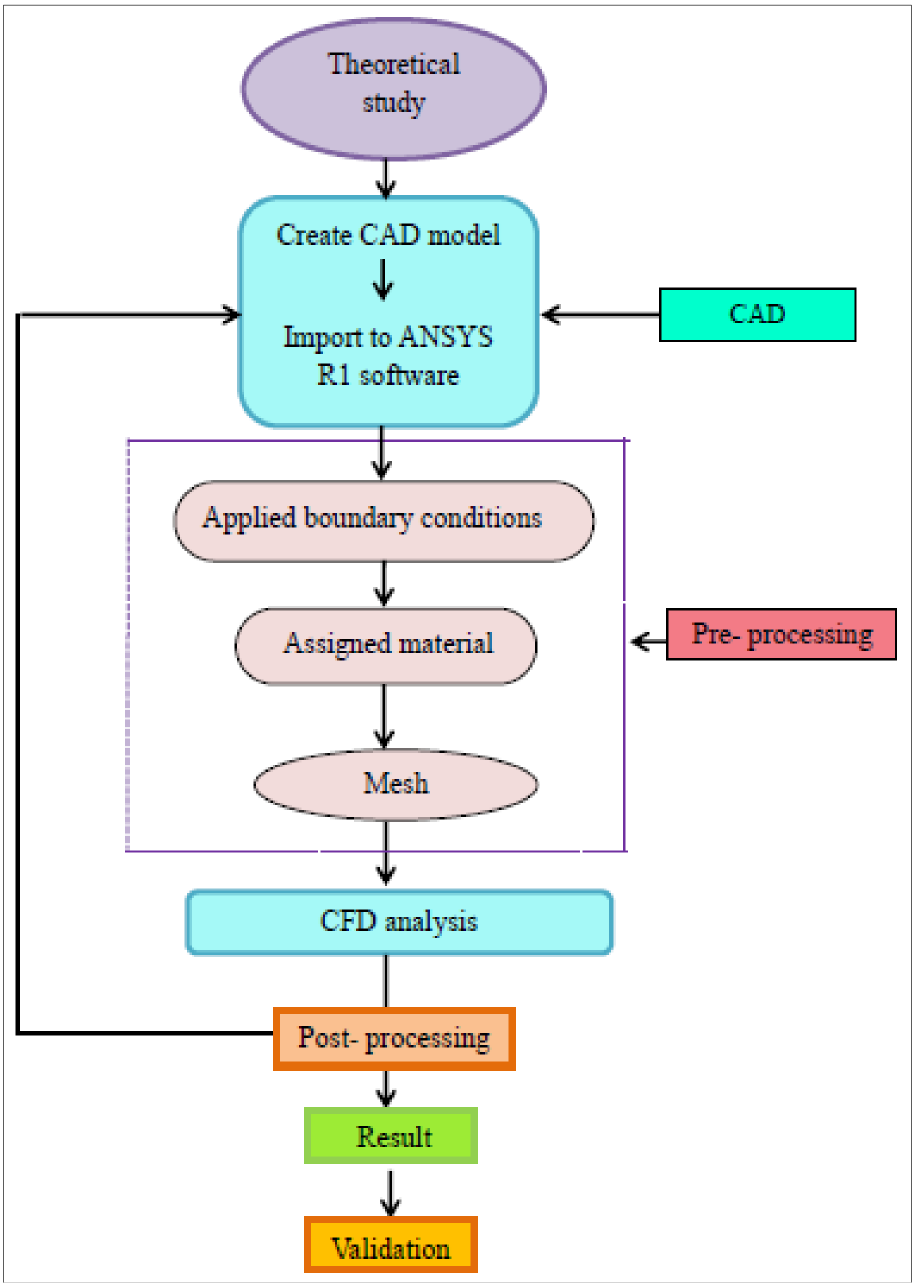

Fig 2: Flow chart of product design

Flow chart of product design is as shown in fig. 3.1and required dimensions for design for nozzle in table 1 and material input and properties are used for analyze nozzle are mentioned in table 2 which consist of density, sp. Gravity, etc.

Table 1: Dimensions of nozzle

Sr. No.	Parameters	Dimensions
1	Length of nozzle	22 mm
2	Diameter of nozzle cap	14.8 mm
3	Outer diameter of nozzle	8 mm
4	Spray angle	120^0

Table 2: Nozzle material Polyvinylidene Fluoride (PVDF)

Sr. No.	Properties	Value
1	Density	1775 kg/cm^3
2	Specific gravity	1.76
3	Coefficient of friction	0.2-0.4
4	Poisson's ratio	0.34
5	Young’s modulus	2450 MPa
6	Tensile modulus	2 GPa
7	Coefficient of thermal expansion	110×10^{-6} K^{-1}

8	Thermal conductivity	1.75 $Wm^{-1} K^{-1}$
9	Compressive yield strength	44.5 MPa
10	Tensile yield strength	75.5 MPa
11	Tensile ultimate strength	364 MPa

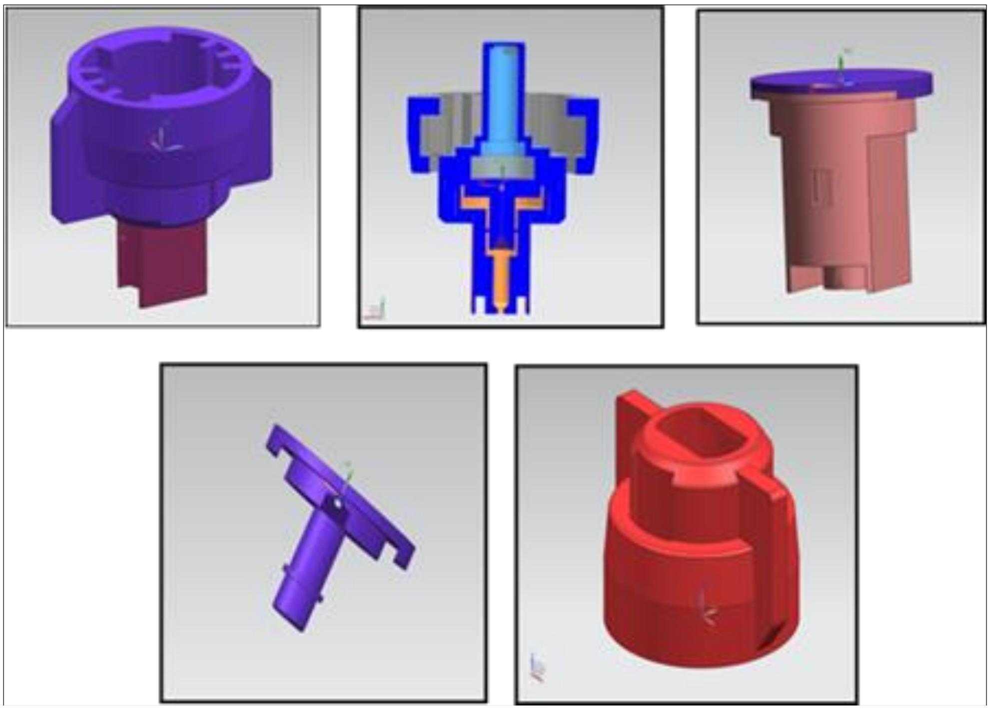

Fig 3: 3D view of nozzle designed in Solidworks Software

Result & Discussion

Rapid prototyping methods were examined and procedures were carried out using the systems available.

Computational Fluid Dynamics (CFD)

Computational Fluid Dynamics is the analysis of fluid flows using numerical solution methods. Using CFD, able to analyze complex problems involving fluid-fluid, fluid-solid or fluid-gas interaction.

CFD analysis steps as following

A) Pre-processing Grid Modeling

- Numerical formula
- Set boundary regions
- Governing equations
- 2D/3D modeling
- Generation of grid

B) Solving the governing equation

- Set boundary conditions
- Matrix Solving
- Convergence Criterion
- Steady or Unsteady

C) Post-processing Visualization

- Velocity
- Pressure
- Temperature
- Flow path

Analysis

The tool used to fluid flow analysis is ANSYS 21 and the solver chosen is Ansys fluent. The Energy, Momentum and Continuity equations are the main equations used to solve for the solution. To find the solution theoretically, Reynolds Averaged Navier Strokes (RANS) equations are used generally. But a numerical method must be used to replace the RANS equations with the algebraic approximations for the real fluid flow problems. Nozzles were modeled in Solidworks is imported to Ansys Workbench 21 where the solver chosen is Ansys fluent. As the nozzle flow simulation is an internal flow type, there is no further construction of geometry is required. Meshing is done after modeling and importing of the design by giving respective details in ANSYS. Von-Mises's method is used for solution of nozzles (N1, N2, and N3) total deformation, equivalent elastic strain, and equivalent stress. Maximum Total deformation is 0.00027104 MPa at 0.3 N and Minimum Total deformation is 0.00010955 MPa at 0.1 N, Maximum equivalent elastic strain is obtained at 0.3 N is 0.00015017 and minimum equivalent elastic strain at 0.1 N is 0.000076573 for nozzle N3 as shown in Fig. 3.1 and 3.2 Total deformation vs applied force and equivalent elastic strain vs applied force as shown in Fig. 3.3 and 3.4.

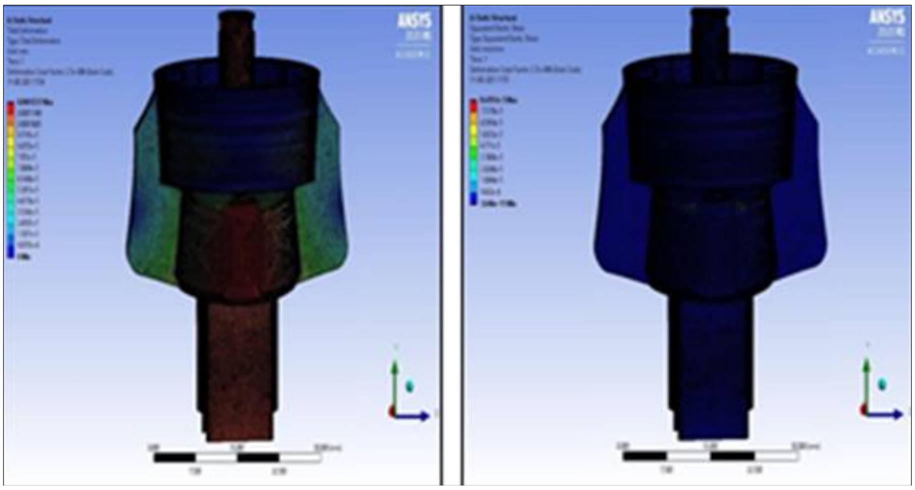

Fig 4.1: Total deformation **4.2:** Equivalent elastic strain

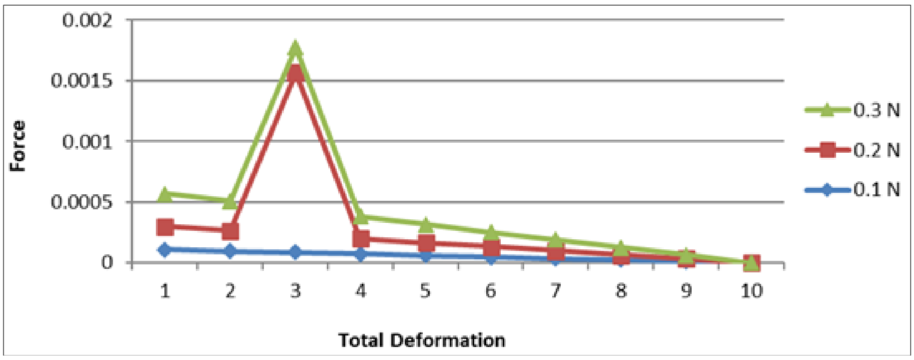

Fig 5: Effect of 0.1 N, 0.2 N and 0.3 N forces on total deformation for nozzle N3

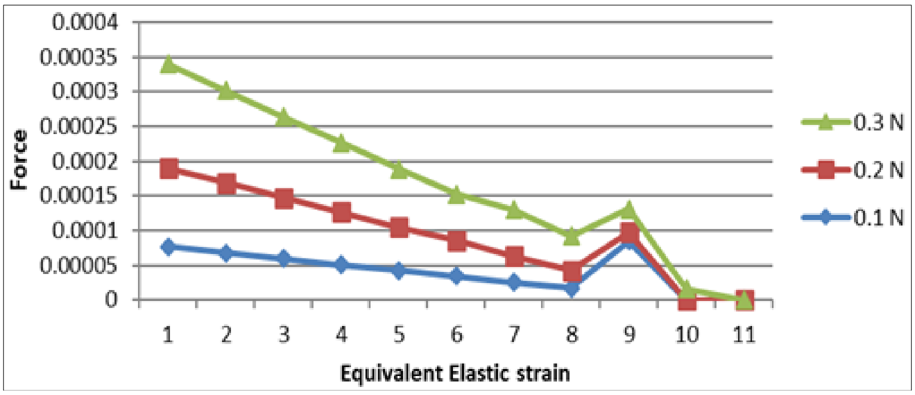

Fig 6: Effect of 0.1 N, 0.2 N and 0.3 N forces on Equivalent elastic strain for nozzle N3

Rapid Prototyping in 3D Stratasys Printer

Rapid prototyping is the process of rapidly producing a physical part with CAD data [7]. Properties and process parameters of ABS (Acrylonitrile Butadiene Styrene) filament material were determined as nozzle temperature 225 ^{0}C, Table temperature 90 ^{0}C, ambient temperature 23 ^{0}C, material density 1.2 kg/m^3, Tensile strength 74 MPa, infill density 50%, printing speed 45 mm/s [8, 9].

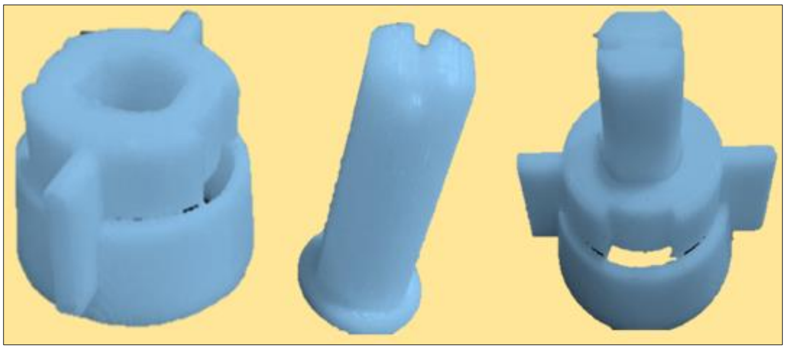

Fig 7: 3D Prototype model of nozzle extruded from 3D Stratasys Printer

Nozzles discharge variation test

Tank was filled with known quantity of water and then pump was operated for one minute. Water volume was collected from all four nozzles in measuring cylinder and determined the total discharge rate and also from each nozzle.

Field trails of selected nozzle N3 form analysis

Experimental trails of selected nozzle N3 was conducted in field at nozzle height from ground 500 cm, 750 cm, and 1000 cm. Fig. 7 shows the droplets obtained from different height as 500 cm, 750 cm and 1000 cm from ground level.

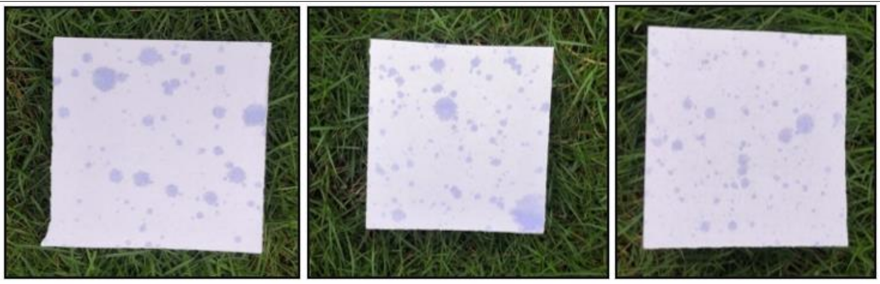

Fig 8: Droplet sample obtained from nozzles N_3

Conclusion

Considering structural and CFD analysis based on optimized orifice size and operating parameters three different flat fan nozzles (N1, N2, and N3) were analyzed in ANSYS workbench 2021 R1 software by applying loading boundary conditions under structural and CFD analysis at different forces. The field trials after CAE-analysis were conducted for performance evaluation and validation for its optimization.

1. Three flat fan nozzles (N1, N2, and N3) of orifice sizes 1.050 mm, 1.155 mm, and 1.340 mm analyzed at three different forces 0.1 N, 0.2 N and 0.3 N in structural analysis.
2. Out of three nozzles: one nozzle N3 (1.340 mm orifice size) were selected form structural analysis shows that total deformation is minimum and equivalent stress is also minimum.
3. The use of Solidworks software and ANSYS software for design and analysis helps to reduce the cost and time of product life cycle trails.
4. In this study, examined the processes of creating a 3D solid model and prototype of a non-uniform agricultural machine part comparing them with each other.

The overall results of this study very useful for uniform application and to the study of nozzle injectors.

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Application of research: Analysis of model in ANSYS software reduces the cost and time cycle.

Research Category: CAE analysis and validation, nozzle prototype

Abbreviations: ABS- Acrylonitrile Butadiene Styrene, CAE- Computer Aided Engineering, N-newton, N1, N2, and N3- Different orifice nozzles, CFD-computational fluid dynamics, Fig.- figure, FEA- Finite element analysis, GPa-Giga Pascal, m/s-meter per second, MPa- Megapascal, mm-millimeter, kg/cm^2- kilogram per square centimeter, kg/cm3- kilogram per cubic meter, PVDF- Polyvinylidene Fluoride, 0 - degree, k^{-1} - per kelvin, W^{-1} mK- watt per meter kelvin.

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References

1. Vinayaka V, Vidya K, Jyoti D. Simulation modelling techniques for design and analysis of agricultural machinery systems. Vol XVIII, Issue 12.
2. Celik HK, Caglayan N, Topakci M, Rennie AEW, Akinci I. Strength-based design analysis of a para-plow tillage tool. 2022.
3. Bartzanas MT, Zhu H, Karmakar S, Tamimi E, Katsoulas N. Computational fluid dynamics applications to improve crop production systems. Comput Electron Agric. 2013;93:151-167.
4. Shinde GU, Kajale SR. Design optimization in rotary tillage tool system components by computer aided engineering analysis. Int J Environ Sci Dev. 2012;3(3):279-282.

5. Benkő P, Martin RR, Várady T. Algorithms for reverse engineering boundary representation models. Comput Aided Des. 2001;33(11):839-851.
6. Steffen FW, Krull HG, Schmiedlin RF. Effect of divergence angle on the internal performance characteristics of several conical convergent-divergent nozzles. National Advisory Committee for Aeronautics.
7. Şahin İ, Şahin T, Gökçe H. Reconstruction of damaged gears using reverse engineering approach. Düzce Univ J Sci Technol. 2017;5(2):485-495.
8. Günay M, Gündüz S, Yılmaz H, Yaşar N, Kaçar R. Optimization of 3D printing process parameters for tensile strength of PLA-based specimens. Politeknik Dergisi. 2020;23(1):73-79.
9. Maguluri N, Suresh G, Rao KV. Assessing the effect of FDM processing parameters on mechanical properties of PLA parts using Taguchi method. J Thermoplast Compos Mater. 2021.