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Full Length Article

Design and Optimization of an Automated PVC Pipe Cutting System for Industrial Applications

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ABSTRACT
Industrial automation has become increasingly important in modern manufacturing industries due to the growing demand for high production rates, improved quality, and reduced operational costs. Pipe cutting is one of the major operations performed in construction, plumbing, irrigation, and industrial manufacturing sectors. Conventional manual cutting methods are time-consuming and often result in inaccurate dimensions, poor surface finish, material wastage, and increased labor requirements.
This paper presents the design and optimization of an automated PVC pipe cutting machine intended for industrial applications. The developed system utilizes a motor-driven cutter assembly integrated with gears, shafts, bearings, rollers, and a structural support frame. The machine was designed using CATIA V5 software and analyzed using ANSYS finite element analysis tools.
Structural analysis including stress, strain, and total deformation was carried out to evaluate the reliability and safety of the machine under operating conditions. The results obtained from ANSYS confirmed that the machine operates within permissible stress limits and provides stable cutting performance with minimal vibration and deformation.
The developed machine improves cutting accuracy, minimizes manual effort, reduces production time, and enhances industrial productivity. The proposed system is suitable for industrial manufacturing applications where efficient and accurate pipe cutting operations are required.

Keywords: *PVC Pipe Cutting Machine, CATIA V5, ANSYS, Structural Analysis, Finite Element Analysis, Automation, Industrial Manufacturing.*

INTRODUCTION

PVC pipes are widely used in plumbing, irrigation systems, drainage systems, construction industries, and industrial manufacturing because of their corrosion resistance, lightweight nature, durability, and cost effectiveness. Pipe cutting is one of the most important operations during manufacturing and installation processes.

Traditional pipe cutting methods mainly involve manual cutting operations using hacksaws or simple cutting tools. These methods require significant labor effort and often produce inaccurate dimensions, rough edges, increased material wastage, and low production efficiency. Manual cutting processes also increase operator fatigue and reduce industrial productivity.

Automation in manufacturing industries has become essential for achieving high production rates and maintaining consistent product quality. Automated cutting systems improve operational efficiency, reduce labor requirements, and provide accurate and repeatable cutting operations. The use of motorized mechanisms and optimized transmission systems significantly improves cutting precision and machine reliability.

The proposed automated PVC pipe cutting machine was designed to perform smooth and accurate cutting operations with minimal vibration and reduced operational effort. The machine utilizes a rotating cutter mechanism driven by an electric motor through a spur gear transmission system. Rollers are provided to support and align the pipe during cutting operations.
To design an automated PVC pipe cutting machine.
To improve cutting accuracy and production efficiency.
To reduce manual effort and operational cost.
To perform structural analysis using ANSYS software.
To validate machine safety and reliability under operational conditions.

The integration of CAD modeling and finite element analysis enabled effective optimization of the machine structure before fabrication.

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LITERATURE REVIEW

Several researchers have contributed to the development of automated and pneumatic pipe cutting systems.

Pandit Mandar Bipin Chandra et al. proposed an automatic pipe cutting machine designed for industrial mass production applications. Their work focused on reducing manual effort and improving cutting speed using pneumatic systems. The developed system improved productivity and minimized human intervention during cutting operations.

P. Bala Shanmugam and G. Bala Subramanian developed a pneumatic pipe cutting machine utilizing double acting cylinders and directional control valves. Their design improved motion control and provided efficient cutting operations with reduced operational effort.

Shital K. Sharma et al. introduced a semi-automatic PVC pipe cutting machine aimed at reducing power fluctuations and improving production efficiency. Their study emphasized machine reliability and improved cutting performance.

Nimbalkar Shripad et al. designed a pneumatically operated pipe cutting machine suitable for PVC and mild steel pipes. Their research mainly focused on low manufacturing cost, easy maintenance, and simple operation.

Menghani et al. proposed an automatic cutting machine for industrial applications capable of increasing production rates and reducing operator fatigue

Most previous studies concentrated mainly on pneumatic cutting systems and automation techniques. However, limited research was carried out on complete structural optimization and finite element analysis of the machine assembly. Therefore, this project focuses on CAD modeling, structural analysis, and optimization using CATIA V5 and ANSYS software.
Strain Equation: The present work differs from previous research by emphasizing:

Structural optimization of machine components.
Stress and strain analysis using finite element methods.
Reduction of deformation and vibration.
Improved structural stability and operational safety.
6. Methodology (Block Diagram / Mathematical Concept)
Methodology
The methodology adopted for this work includes:

Conceptual machine design
CAD modeling in CATIA V5
Assembly development
Finite element analysis in ANSYS
Structural validation
Result evaluation
Major Components

The automated PVC pipe cutting machine consists of:

Spur gears
Shafts and bearings
Pipe support rollers
Cutter assembly
Electric motor
Structural support frame
Pressure dies

Each component was modeled individually using CATIA V5 software. The complete machine assembly was developed using assembly constraints.

The CAD model was imported into ANSYS software for structural analysis. Tetrahedral meshing was used to improve simulation accuracy.
Block Diagram

Design Parameters → CAD Modeling → Assembly → Meshing → Load Application → Structural Analysis → Result Evaluation → Final Design

Mathematical Concepts

Stress Equation:

$\sigma = A/F$
Where:

σ = Stress
F = Applied Force
A = Cross-sectional Area
$\varepsilon = \Delta L/L$
Where:

ε = Strain
ΔL = Change in Length
L = Original Length

Static structural analysis was performed by applying rotational loads and fixing support constraints at the machine frame.

IMPLEMENTATION

Implementation

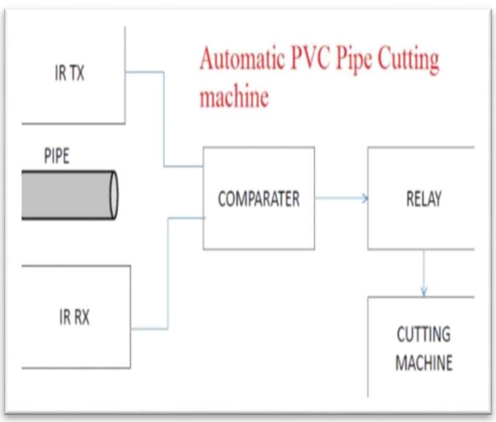
The implementation process started with conceptual machine design based on industrial requirements. Individual machine components such as gears, shafts, rollers, cutter assembly, and support structures were modeled in CATIA V5 software.

The electric motor transmits rotational motion to the cutter assembly through a spur gear mechanism. Bearings reduce friction and improve rotational stability. Rollers support the PVC pipe and maintain alignment during cutting operations.

The developed assembly was imported into ANSYS software for structural analysis.

Algorithm
Design machine components in CATIA V5.
Assemble all machine components.
Import the assembly into ANSYS.
Apply material properties.
Generate tetrahedral mesh.
Apply loads and boundary conditions.
Perform structural analysis.
Evaluate stress, strain, and displacement.
Validate machine performance.

Block Diagram



TESTING

Testing of the automated PVC pipe cutting machine was carried out using ANSYS structural analysis tools. Different machine components such as gears, shafts, support frame, pressure dies, and cutter assembly were analyzed under operational loading conditions.

The support frame was fixed while rotational forces were applied to the cutter shaft and motor assembly. Meshing quality was optimized to improve analysis accuracy.

The following parameters were evaluated:

Equivalent stress
Equivalent strain
Total deformation
Structural stability

Testing results confirmed that the machine components operate safely within permissible stress limits without excessive deformation.

Fig. 1: Model design of APPCM in CATIA-V5

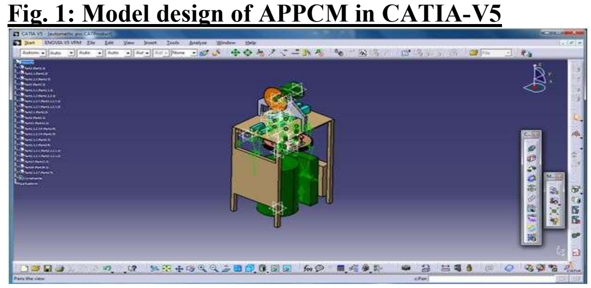


Fig. 2: Model arrangement of gears mechanism in CATIA-V5

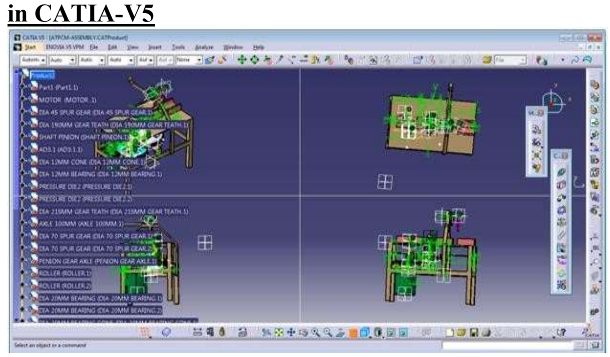


Fig. 3: Using Multi View Command

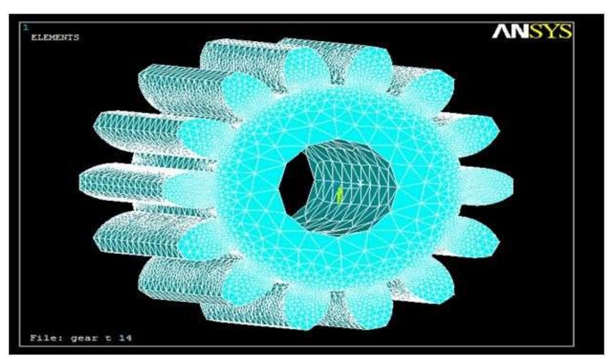


Fig. 4: Spur Gear T14 Meshing

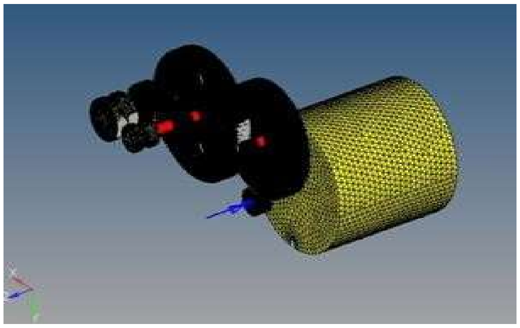


Fig.5: Meshing Of Pipe Cutting Machine

RESULTS (Screenshots / Comparative Table)

Results and Discussion

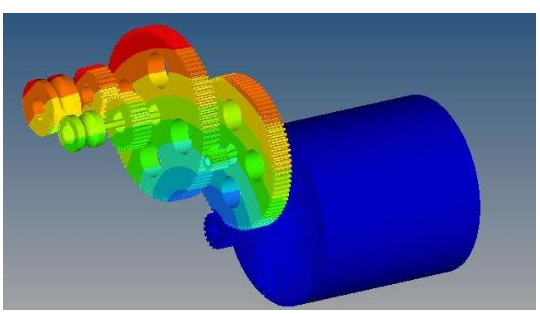
The simulation results obtained from ANSYS confirmed the structural reliability and operational stability of the developed machine.

Parameter	Obtained Value	Observation
Maximum Stress	0.951 MPa	Safe
Minimum Stress	0.669 MPa	Acceptable
Maximum Displacement	Very Low	Stable Structure
Strain	Within Limits	No Failure

Stress analysis indicated that the maximum stress concentration occurred near the motor support and gear assembly regions. However, the obtained stress values were significantly lower than the yield strength of structural steel.

Displacement analysis showed negligible deformation in the support frame and cutter assembly, confirming stable machine operation during cutting processes.

Strain analysis validated that the machine components operate safely without permanent



deformation or structural failure.

The use of finite element analysis helped identify critical stress regions and optimize the machine structure before fabrication.

Fig. 6: Result of Pipe cutting Machine Parts (Displacement

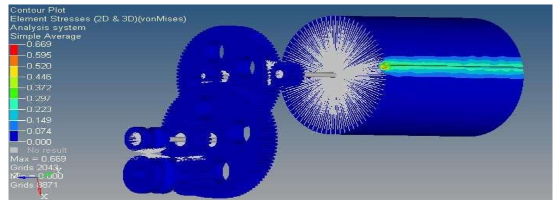


Fig.7: Result of Pipe cutting Machine Parts (Stress)

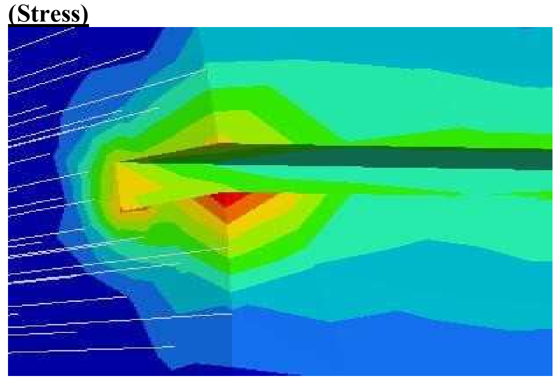


Fig.8: Zoom view location of stress (Which is maximum)

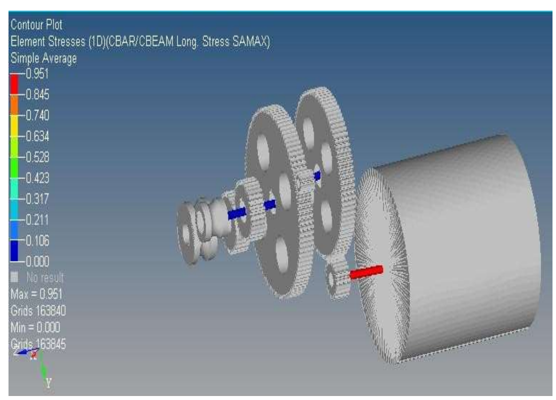


Fig.9: Element stresses (Shafts are build element)

CONCLUSION

An automated PVC pipe cutting machine was successfully designed and analyzed using CATIA V5 and ANSYS software. The developed system improves cutting accuracy, production efficiency, and operational safety while reducing manual effort and material wastage.

Structural analysis confirmed that the stress, strain, and displacement values are within safe operating limits. The machine assembly demonstrated stable and reliable performance under operational loading conditions.

The integration of CAD modeling and finite element analysis enabled effective optimization of the machine structure. The developed system is suitable for industrial applications where productivity, cutting precision, and machine reliability are important.

FUTURE SCOPE

The developed machine can be further improved by integrating advanced automation and intelligent monitoring systems.

Future developments may include:

PLC-based automation

IoT-based monitoring systems

Automatic pipe feeding mechanism

AI-based fault detection

Advanced cutting blade materials

Energy-efficient drive systems

Fully automated industrial production setup

These improvements can further enhance industrial productivity, machine reliability, and operational efficiency.

BIOGRAPHIES

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