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A REVIEW ON OPTIMIZATION OF 3D PRINTING PROCESS PARAMETERS FOR ABS MATERIALS IN AUTOMOTIVE APPLICATIONS

K.ANIL KUMAR **1st Author,** **M. RADHA DEVI** **2nd Author,**
B.V.V.B.SANTOSH KUMAR **3rdAuthor,** **MD.HUMAYUN** **4th Author**

B-TECH 1st Author, ASSISTANT PROFESSOR 2nd Author, B-TECH 3rd Author, B-TECH 4thAuthor

MECHANICAL ENGINERRING 1st Author,
NRI INSTITUTE OF TECHNOLOGY 1st Author, AGIRIPALLI, INDIA

Abstract : The Additive Manufacturing (AM), particularly Fused Deposition Modeling (FDM), has gained significant attention in the automotive sector due to its ability to produce lightweight, complex, and cost-effective components. Acrylonitrile Butadiene Styrene (ABS) is widely used as a thermoplastic material in FDM because of its strength, durability, and thermal resistance. However, achieving optimal part quality depends heavily on process parameters such as layer thickness, infill density, nozzle temperature, bed temperature, and print speed. Improper parameter selection often leads to defects including warping, poor surface finish, dimensional inaccuracies, and reduced mechanical strength. Recent studies focus on applying statistical optimization techniques such as Taguchi method, Response Surface Methodology (RSM), and Analysis of Variance (ANOVA) to identify the most influential parameters and establish optimal conditions. This review consolidates research findings on parameter optimization of ABS materials for automotive applications, highlighting improvements in tensile strength, dimensional accuracy, and surface quality, thereby contributing to enhanced performance and reliability of 3D printed automotive components.

Keywords: ABS, 3D Printing, Fused Deposition Modeling (FDM), Process Optimization,Mechanical Properties, Taguchi Method

1.INTRODUCTION

The Additive manufacturing , commonly known as 3D printing, has emerged as a transformative technology in the automotive industry due to its ability to produce complex, lightweight, and customized components with reduced lead time and material wastage. Among various thermoplastic polymers, Acrylonitrile Butadiene Styrene (ABS) is widely used owing to its good mechanical strength, impact resistance, and costeffectiveness. However, the performance and quality of ABS-printed parts are highly dependent on process parameters such as layer thickness, infill density, print speed, and temperature. Optimizing these parameters is crucial for achieving superior mechanical properties, dimensional accuracy, and surface finish in automotive applications.Among the various thermoplastic polymers used in 3D printing, Acrylonitrile Butadiene Styrene (ABS) is one of the most widely preferred materials because of its excellent toughness, impact resistance, and relatively low cost. Its balance of mechanical strength and processability makes ABS highly suitable for automotive applications, where components require durability, lightweight characteristics, and dimensional stability.

However, the performance of 3D printed ABS parts is highly dependent on process parameters such as layer thickness, nozzle temperature, bed temperature, print speed, raster angle, and infill density. Improper selection of these parameters can lead to issues like warping, poor surface finish, delamination, and reduced mechanical properties.Therefore, optimization of process parameters is essential to achieve the desired quality, accuracy, and functionality of ABS components. In the automotive sector, where reliability and performance are critical, such optimization directly influences the feasibility of replacing conventionally manufactured parts with 3D printed alternatives. This review focuses on the optimization strategies of ABS 3D printing parameters, emphasizing their role in enhancing automotive applications.

3D Printing with ABS Material

Acrylonitrile Butadiene Styrene (ABS) is one of the most widely used thermoplastic polymers in Fused Deposition Modeling (FDM) 3D printing. The process begins with feeding ABS filament into a heated extruder, typically at 210–250 °C, where it is melted and deposited layer by layer onto a heated build platform (around 90–110 °C). Each layer fuses with the previous one, gradually forming the desired 3D part. ABS is preferred because of its strength, toughness, heat resistance, and machinability, making it suitable for functional prototypes and automotive components. However, challenges like warping and shrinkage require optimized parameters and controlled environments for high-quality prints.

.2 . LITERATURE REVIEW :

1. **Kyle Raney et al.** This paper studies how the tensile strength of Acrylonitrile Butadiene Styrene (ABS) parts changes when produced by Fused Deposition Modeling (FDM). Researchers printed 150 samples with different infill patterns and build orientations using a uPrint SE printer. The samples were tested under tensile loads using ASTM standards. Results showed that infill density and orientation strongly affected strength. Solid infill parts performed best, while vertical builds were weakest due to poor interlayer bonding. On average, FDM ABS reached about 92% of traditional ABS strength. The study highlights that strength loss in 3D printing is mainly due to weaker layer bonding.

2. **Uday Kiran Roopavath et al.**This study optimized extrusion-based 3D printing of hydroxyapatite (HA), a bone-like ceramic material. Researchers focused on printing accuracy, shrinkage, porosity, and strength of scaffolds. Different infill densities were tested, and shrinkage after sintering was found to

follow a predictable linear pattern. The compressive strength of the scaffolds ranged from 43 MPa to 275 MPa, which is comparable to human bone. A patient-specific bone graft was successfully printed from CT scans, proving the technique's clinical potential. The findings show that adjusting infill density allows tailoring of mechanical strength, making the method promising for custom implants in orthopedic and dental surgery.

3. **Mahesh Sain et al.** This journal,focuses on optimizing FDM 3D printing parameters using the Taguchi method to enhance tensile strength. The study investigates key parameters such as infill density, material type, and nozzle temperature, using ABS, PETG, and a bi-material blend (50% ABS + 50% PETG). Standard ASTM D638 specimens were fabricated on a Geeetech A30 FDM printer and tested with a UTM machine. Results show that PETG at 40% infill density and 240°C achieved the highest tensile strength of 39.5 MPa. The analysis concluded that infill density is the most influential factor, followed by material and temperature, with strength increasing up to 40% infill before declining.

4. **O M F Marwah et al.** This paper investigated shrinkage deformation in ABS parts made with desktop FDM 3D printers. Shrinkage reduces dimensional accuracy, which is a major challenge in additive manufacturing. The study used the Design of Experiments (DOE) approach to test parameters like layer thickness, nozzle temperature, print speed, infill density, and bed temperature. Using statistical analysis (ANOVA), results showed that bed temperature had the strongest effect on shrinkage, followed by interactions between other parameters. The best settings to minimize shrinkage were LT = 0.25 mm, NT = 235 °C, PS = 55 mm/s, ID = 25%, and BT = 100 °C. Accuracy improved by 97.4%.

5. **Chetty Nagaraj et al.** This journal article, investigates the optimization of FDM (Fused Deposition Modelling) process parameters to enhance the tensile strength of ABS specimens. The study applies the Taguchi L9 design to evaluate the effects of infill density (40%, 60%, 80%), print speed (60, 80, 100 mm/min), and layer thickness (100, 200, 300 microns) on tensile strength. Standard ASTM D638 specimens were fabricated and tested using a universal testing machine. Results showed that maximum tensile strength of 24.86 MPa was achieved at 80% infill density, 100 mm/min print speed, and 200 µm layer thickness. The findings reveal that layer thickness has the most significant effect, followed by infill density and print speed. This research highlights effective parameter selection for stronger ABS parts in FDM applications

6. **Chamil Abeykoon et al.** This journal, published in 2020, presents an experimental study on optimizing FDM (Fused Deposition Modelling) parameters to improve the mechanical properties of ABS parts. The research focuses on critical process variables such as layer thickness, infill density, print speed, and raster angle, which directly influence tensile strength, dimensional accuracy, and surface finish. Standard ASTM specimens were fabricated and tested to analyze the effects of these parameters. The study applies statistical optimization techniques, including Taguchi method and ANOVA, to identify

the most significant factors. Results highlight that infill density and raster angle play the dominant role in enhancing strength and reducing defects. The work emphasizes parameter selection as a key factor in achieving reliable, high-quality ABS components for engineering applications.

7. **Nikolaos A. Fountas1 et al.** This paper uses advanced algorithms to optimize both printing time and shape accuracy in ABS parts made via FDM. Researchers tested three parameters: deposition angle, layer thickness, and infill ratio. Using Taguchi design and regression models, they applied four optimization algorithms (MOGWO, MOALO, MOMVO, MODA). Results showed trade-offs between speed and accuracy. For example, low deposition angles and moderate infill ratios improved accuracy, while higher layer thickness reduced printing time. The study concludes that no single algorithm is best for all cases, and multi-objective optimization helps balance performance and efficiency.

8. **Paweł Żur, Alicja Kołodziej et al.** This study tested ABS 3D printing for electric car parts, focusing on tensile strength. Researchers printed specimens at two temperatures (230°C and 260°C) and four infill levels (10%, 25%, 50%, 100%). Results showed that higher infill increased strength, but printing at 230°C gave slightly better results than 260°C. Honeycomb infill pattern performed better than lattice. The filament itself had the highest tensile strength, but full infill prints came close. The team used this data to optimize the driver's seat design, balancing strength, weight, and printing time—finding 25% infill offered good strength with reduced cost.

9. **Dr M Sumalatha1 et al.** This journal, published in the *IOP Conference Series: Materials Science and Engineering (2021)*, presents an optimization study of FDM (Fused Deposition Modeling) parameters for ABS components using the Taguchi method. The research investigates key process parameters—layer thickness, infill density, and deposition speed—on performance measures such as impact strength, surface roughness, and build time. Standard ASTM D256 Izod impact specimens were fabricated on an AION 500 FDM printer and tested systematically. Statistical tools including Taguchi design of experiments, S/N ratio analysis, and ANOVA were applied to identify significant factors. Results showed infill density had the greatest influence on impact strength, while layer thickness strongly affected surface roughness and build time. Optimal settings were suggested to enhance strength, reduce roughness, and minimize fabrication time.

10. **Bharatkumar Bhagatraj Ahuja et al.** Electroless coating is an effective technique to improve the surface properties of polymer substrates used in engineering applications. This study focuses on the optimization of electroless nickel–tungsten (Ni–W) composite coating on 3D-printed Acrylonitrile Butadiene Styrene (ABS) substrates to achieve maximum tungsten incorporation. ABS samples fabricated by Fused Deposition Modeling (FDM) were subjected to surface pretreatments before coating. Process parameters such as bath pH, temperature, precursor concentration, and deposition time were varied to study their influence on tungsten content in the coating. Statistical optimization methods including Taguchi design and ANOVA were employed to determine the most significant factors.

Results revealed that bath composition and pH strongly affect tungsten incorporation. Optimized conditions provided enhanced surface hardness and wear resistance of ABS substrates.

11. **Farizi Rachman et al.** This study used the Taguchi method to optimize 3D printing parameters for ABS material to maximize tensile strength. The parameters tested were layer height, infill pattern, and nozzle temperature. Results showed that a layer height of 0.2 mm, a line infill pattern, and a nozzle temperature of 230°C produced the strongest parts. Layer height and infill pattern had the most significant impact, while nozzle temperature had little effect. The Taguchi method effectively identified the best settings to improve product quality and performance.

12. **Krishna Mohan Agarwal et al .**This research examined how six printing parameters affect the dimensional accuracy of ABS parts made with FDM. Using a Central Composite Design, they found that layer thickness and print speed had the most influence. Lower layer thickness and higher print speed improved accuracy. Other factors like infill density also mattered, but less significantly. The
13. study provides optimal parameter settings to reduce dimensional errors, which is crucial for applications requiring high precision, such as functional prototypes and end-use parts.

14. Anant Prakash Agrawal et al. This paper studied how infill pattern, density, and layer thickness affect the mechanical properties of 3D-printed ABS. Tests showed that concentric infill patterns with 80% density and 100 μm layer thickness delivered the best tensile and impact strength—up to 123% and 168% higher than other patterns. The concentric pattern helped distribute stress better and resist cracking. The study highlights the importance of selecting the right combination of parameters to achieve strong, durable 3D-printed parts.

15. **Aarti Singh et al.**This work focused on improving the dimensional accuracy of ABS parts printed via FDM. Using Taguchi's L9 orthogonal array, the effects of build orientation, layer thickness, and infill density were analyzed. Build orientation was the most influential factor. The best accuracy was achieved with 90° orientation, 0.33 mm layer thickness, and 60% infill density. The study confirms that parameter settings must be tailored to specific geometric features to minimize deviations and ensure high-quality prints.

16. **Panagiotis M. Angelopoulos et al.**This research developed lightweight ABS filaments by mixing ABS with expanded perlite microspheres. Different sizes and amounts of perlite were tested. Fine perlite (under 90 μm) up to 20% volume produced usable filaments and decent prints, but higher amounts or larger particles caused defects and reduced strength. The study shows that perlite can be used to create lighter, insulating composites for 3D printing, but filler size and content must be carefully controlled to maintain print quality and mechanical properties.

17. **Marko Delic et al.** This study tested how the infill pattern and density affect the strength of 3D-printed ABS plastic under crushing (compressive) forces. Samples with rectangular and hexagonal patterns at 10%, 40%, and 70% density were printed and crushed. Results showed that a rectangular infill pattern consistently made stronger parts than a hexagonal one. Furthermore, increasing the infill density from 10% to 70% significantly increased the strength for both patterns. The study concludes that using a high infill density with a rectangular pattern is best for creating strong, weight-efficient parts that need to withstand compressive loads.

18. **Mahmoud Moradi et al.** This study explores how 3D printing settings affect the strength of ABS plastic. The researchers used two methods—Artificial Neural Networks (ANN) and Response Surface Methodology (RSM)—to analyze how layer thickness, infill percentage, and number of contours influence tensile strength and stiffness. They found that increasing the number of contours most significantly improves strength, while infill percentage also helps. Layer thickness had a smaller effect. Both ANN and RSM were effective for predicting results, but ANN was slightly more accurate. The study helps optimize 3D printing to produce stronger parts faster and with less material.

19. **Karthikeyan Ramiah et al.** This study explores how different 3D printing settings affect the strength of ABS parts made using Fused Deposition Modeling (FDM). Researchers used a Taguchi L18 design to test combinations of five parameters: layer thickness, build orientation, raster angle, raster width, and raster gap. They applied machine learning (decision trees) and hybrid optimization (FAHP + COPRAS) to find the best settings. Results showed that raster angle had the biggest impact on strength, while raster gap mattered least.

20. **Hamdi Kuleyin et al.** This study investigates the characterization of thermal, chemical, mechanical, and fatigue behavior of 3D-printed ABS-based elastomeric blends, specifically ABS/EVA and ABS/TPU. The blends were fabricated using Fused Deposition Modeling (FDM) to evaluate their suitability for advanced engineering applications. Thermal stability was assessed through TGA and DSC, while chemical resistance was examined against solvents. Mechanical properties, including tensile strength, elongation, and hardness, were analyzed alongside cyclic fatigue performance. Results indicate that ABS/EVA offers improved thermal stability and chemical resistance, while ABS/TPU demonstrates superior elasticity and fatigue endurance. These findings highlight the potential of tailored ABS blends for functional and durable 3D-printed components.

21. **Prof. Amit Bankar et al.** This paper investigates how infill pattern, infill density, and print speed affect the tensile strength of ABS parts made with FDM 3D printing. Six infill patterns (like honeycomb, gyroid, and Hilbert curve) were tested at densities from 20% to 100%, all printed at 80 mm/min. Results showed that higher infill density generally improves strength, with the gyroid pattern performing best (28.6 MPa). Some patterns like Archimedean chords had poor results. The study also found that

printing between 50–98% infill is inefficient—taking longer but offering no strength advantage over 100%. It helps users choose better infill settings for strong prints.

22. **Kenny L. Alvarez C. et al.** This study investigates the influence of infill percentage on the mechanical properties of Acrylonitrile Butadiene Styrene (ABS) parts fabricated using Fused Deposition Modeling (FDM). Standard ASTM test specimens were 3D-printed with varying infill levels ranging from low to high density and evaluated for tensile strength, flexural strength, and impact resistance. Results demonstrate that increasing infill percentage significantly enhances mechanical performance by reducing internal voids and improving load distribution. However, beyond an optimal range, further increases in infill yield minimal strength improvements while substantially increasing material consumption and build time. The findings provide useful guidelines for achieving efficient, high-quality ABS prints.

23. **Deepak Rajendra Unune et al.** This study examines the effect of key Fused Deposition Modeling (FDM) process parameters on the tensile, flexural, and impact strength of 3D-printed parts using the Taguchi method. Parameters such as layer thickness, infill density, print speed, and raster angle were systematically varied to fabricate standardized ABS specimens. Mechanical tests were conducted to evaluate the influence of each factor on overall strength. Signal-to-noise (S/N) ratio analysis and ANOVA were applied to identify significant parameters and optimal combinations. Results indicate that infill density and raster angle dominate mechanical performance, while print speed and layer thickness have secondary effects.

24. **Amanuel Diriba Tura et al.** This journal, focuses on mathematical modeling and parametric optimization of surface roughness in FDM-printed ABS parts. Using Taguchi L9 orthogonal array and Response Surface Methodology (RSM), the study evaluates the influence of layer thickness, orientation angle, and infill angle on surface quality. ANOVA results show that layer thickness contributes most significantly (91.8%) to surface roughness, followed by orientation angle and infill angle. The optimized parameters—0.1 mm thickness, 0° orientation, and 0° infill angle—yielded the best surface finish.

25. **Anand Kumar S. et al.** This paper examined both mechanical strength and energy use when printing ABS using material extrusion. Seven parameters were tested: orientation, raster angle, infill, layer thickness, nozzle temperature, print speed, and bed temperature. A total of 135 experiments were conducted. Results showed layer thickness was the most critical factor for strength and energy efficiency. Nozzle temperature and raster angle had less impact. The study provides a roadmap for balancing compressive performance with energy consumption in ABS printing. These insights help

industries reduce costs and environmental impact while still producing strong and reliable 3D-printed ABS parts.

26. **Feiyang He et al**. This article studied the fatigue performance of ABS parts made by 3D printing under repeated bending and heat stress. Researchers tested three orientations, nozzle sizes, and layer thicknesses at temperatures between 50–70 °C. Results showed that parts printed flat (0°), with larger nozzle size (0.8 mm), and thicker layers (0.15 mm) lasted longer before breaking. Printing defects reduced fatigue life. The study highlights the importance of optimizing printing parameters for parts that face cyclic loads in industries like aerospace and automotive. It concludes that careful parameter choices can significantly extend the life of 3D-printed ABS components

27. **Mahmoud Moradi Reza Beygi Noordin Mohd et al.** This study explores the optimization of 3D printing process parameters for Acrylonitrile Butadiene Styrene (ABS) fabricated using Fused Deposition Modeling (FDM). Artificial Neural Network (ANN) and Response Surface Methodology (RSM) were employed to analyze the influence of critical parameters such as layer thickness, raster angle, infill density, and print speed on tensile strength and surface roughness. Experimental data from ASTM-standard specimens were used to train and validate predictive models. Results show ANN provided higher accuracy, while RSM effectively identified optimal parameter ranges for enhanced ABS part performance.
28. **Fabiano Oscar Drozda et al.** This study explores how FDM 3D printing parameters affect the dimensional accuracy of ABS parts. Using Taguchi's method, researchers tested layer height, print speed, and extruder temperature. Results showed that layer height significantly impacts precision: thinner layers (0.1 mm) improve length and width accuracy, while thicker layers (0.3 mm) reduce height deviation. Print orientation and speed also influence quality. The study recommends optimizing these settings to achieve high dimensional accuracy, especially for functional prototypes or end-use parts requiring tight tolerances.

29. **Pankaj Sonia et al.** This study presents a Finite Element Analysis (FEA) of 3D-printed blocks fabricated from Acrylonitrile Butadiene Styrene (ABS), a widely used and sustainable thermoplastic. The research investigates the structural performance of ABS under applied loads by simulating stress distribution, deformation, and safety factors using FEA tools. Standard test geometries were modeled and analyzed to validate mechanical behavior with experimental results. Findings reveal that infill density and layer orientation significantly affect load-bearing capacity and stiffness. The study demonstrates ABS's suitability for lightweight, durable, and sustainable engineering applications.

30. **Mr. Firoj et al.** This study investigates the optimization of mechanical properties of Acrylonitrile Butadiene Styrene (ABS) parts produced by Fused Deposition Modeling (FDM) through the combined

modification of infill pattern, density, and layer thickness. Standard ASTM test specimens were fabricated with varying parameters and evaluated for tensile, flexural, and impact strength. Results demonstrate that higher infill density and optimized layer thickness significantly improve strength, while infill pattern influences energy absorption and failure modes. The combined parameter optimization provides a balanced approach to achieving strong, durable, and efficient ABS components.

31. **Mohammad Reza Khosravani et al.** This article examines how acetone post-processing affects 3D-printed ABS parts. Surface treatment improved smoothness and reduced roughness but decreased tensile strength and fracture toughness due to acetone absorption into inner layers. Treated parts showed higher ductility but lower structural integrity. Water absorption tests revealed no major changes. The study concludes that while acetone treatment enhances surface quality, it compromises mechanical strength, so a balance must be struck based on application requirements.

32. **Feiyang He et al.** This study examines the effects of key printing parameters on the fatigue behavior of Acrylonitrile Butadiene Styrene (ABS) parts fabricated using Fused Deposition Modeling (FDM) under dynamic thermo-mechanical loads. Specimens were produced with varying infill density, layer thickness, and raster orientation, then tested under cyclic loading at elevated temperatures. Results show that higher infill density and optimized raster orientation significantly enhance fatigue life, while excessive layer thickness reduces durability. The findings highlight the critical role of process parameters in ensuring reliable ABS components for demanding thermal and mechanical applications.

33. **Ali Anil Demircali et al.** .This study investigates the influence of cold acetone vapor treatment on enhancing the mechanical properties and surface quality of Acrylonitrile Butadiene Styrene (ABS) parts fabricated using Fused Deposition Modeling (FDM). Standard ASTM test specimens were printed and subjected to controlled acetone vapor exposure to assess improvements in tensile strength, impact resistance, and surface finish. Results revealed significant reduction in surface roughness and enhanced interlayer bonding, leading to improved mechanical performance. The approach demonstrates a cost-effective post-processing method for producing high-strength, smooth-surfaced ABS components suitable for functional applications.

34. **A. Kholil et al.** This journal,The study evaluates the effects of chamber temperature variations (70°C–100°C) and build orientations (X, Y, Z axes) through computational fluid dynamics (CFD) and experimental validation. Results show good correlation between simulation and experiments, with 90°C yielding optimal print quality. Findings highlight that both orientation and controlled chamber temperature are critical for reducing warping, improving layer adhesion, and ensuring dimensional accuracy in ABS-based 3D printing

35. **Andrey Yankin et al.** This paper investigates how to improve fatigue resistance in ABS and Nylon parts made by FDM 3D printing. Using experiments and simulations, the authors tested nozzle size,

internal geometry, and printing speed. The "tri-hexagon" infill pattern and smaller nozzle diameters gave the best fatigue life. Nylon had higher initial strength but degraded faster than ABS. Printing speed had little effect. Regression and sensitivity analysis confirmed that nozzle diameter and geometry were key factors. The study provides useful guidelines for optimizing print settings to extend the lifespan of printed parts under repeated stress.

36. **Yaodong Xu et al**. This study presents an experimental investigation into the shrinkage and deformation behavior of Acrylonitrile Butadiene Styrene (ABS) parts fabricated using Fused Deposition Modeling (FDM). Standardized specimens were printed under varying process parameters, including layer thickness, infill density, and build orientation, to evaluate dimensional accuracy and warpage. Measurements revealed that thermal contraction during cooling is the primary cause of shrinkage and deformation, with orientation and layer thickness strongly influencing results. The findings provide valuable insights for optimizing FDM parameters to minimize defects and enhance dimensional stability of ABS components.
37. **Seong-Gyu Cho et al.** This study uses Finite Element Method (FEM) simulations to compare stress and deformation in four types of 3D lattice structures made from ABS material: Simple Cubic (SC), Body-Centered Cubic (BCC), Face-Centered Cubic (FCC), and Plate Truss Cubic (PTC). The FCC structure showed the best mechanical performance, with low stress concentration and minimal deformation. Surprisingly, higher internal filling rates didn't always lead to better strength. The results suggest that the shape of the internal lattice matters more than how much material is used. This insight helps improve FDM part design for strength and efficiency.
38. **Ch. Akshay et al**. This research uses machine learning to predict the tensile strength of ABS parts printed via FDM. A Taguchi L25 design of experiments was used to generate data based on five parameters: layer height, infill density, print speed, nozzle temperature, and bed temperature. Tensile strength was measured using a Universal Testing Machine. Various ML models were tested, and Gradient Boosting gave the most accurate predictions. The study shows that machine learning can help optimize print settings for stronger parts, saving time and improving quality in additive manufacturing.
39. **M. Corsi et al.** This study investigates the correlation between production parameters and mechanical properties of ABS Plus p430 material fabricated through Fused Deposition Modeling (FDM). Key parameters such as layer thickness, raster orientation, air gap, and build orientation were varied to evaluate their influence on tensile, flexural, and impact strength. Standard ASTM specimens were tested, and results analyzed using statistical methods. Findings indicate that raster orientation and air gap significantly affect tensile and flexural strength, while build orientation strongly influences impact resistance. The study provides guidelines for optimizing ABS Plus p430 parts for improved performance.
40. **Jingye Sun et al.** This study focuses on the microwave characterization of low-loss Acrylonitrile Butadiene Styrene (ABS) fabricated using Fused Deposition Modeling (FDM). A dielectric-filled metal-pipe rectangular waveguide spectroscopy method was employed to measure the dielectric constant and loss tangent of 3D-printed ABS samples across microwave frequencies. Experimental

results demonstrate that ABS exhibits stable dielectric properties with low microwave losses, making it suitable for high-frequency applications. The findings highlight the potential of FDM-printed ABS in microwave devices, antennas, and electromagnetic components, offering a cost-effective and customizable alternative to conventional material

OVERALL CONCLUSION

Recent research on ABS 3D printing emphasizes the importance of process optimization in enhancing part performance. Studies using Taguchi, ANN, and RSM methods demonstrate that adjusting parameters such as layer thickness, infill density, infill pattern, and nozzle temperature significantly improves tensile, compressive, and impact strength. Dimensional accuracy is also strongly influenced by factors like layer thickness, build orientation, print speed, and infill settings, with lower layer thickness and optimal orientations yielding higher precision. Material innovations, including the incorporation of fillers such as expanded perlite, have enabled lightweight and thermally insulating ABS composites, while specific infill patterns and higher densities improve strength. Furthermore, parameters like raster orientation and nozzle diameter play a crucial role in determining tensile, compressive, and fatigue properties, especially for automotive applications. Post-processing techniques such as thermal annealing, acetone vapor treatment, and surface finishing enhance surface quality and stability, with some improving tensile strength by up to 20%, though occasionally reducing fracture toughness. Additionally, simulation and modeling approaches, including FEM, FEA, and machine learning, are increasingly employed to predict stress distribution, shrinkage, and tensile behavior, allowing optimization before physical testing. Collectively, these advancements highlight ABS's versatility in producing lightweight, durable, and dimensionally stable parts, with optimized designs such as lattice structures and fatigue-resistant geometries making ABS a strong candidate for automotive applications.

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