

Combination and Testing of Two Resins of 3D Printing Material: Comparison with ABS and PLA Materials

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ABSTRACT

3D printing is a modern fabrication method which builds components layer by layer from digital designs. It allows for the creation different shapes and multi-material structures that are difficult to produce using traditional techniques. In this study, Digital Light Processing (DLP) was selected for its high resolution and efficiency with photopolymer resins. Two materials, Pro-BLK for rigidity and Flex-BLK for flexibility were used to print test specimens. These include tensile samples designed to evaluate mechanical properties such as strength and elongation. Hybrid structures combining both resins were also produced to study the benefits of integrating flexible and rigid materials within a single print.

Keywords: 3D Printing, Digital Light Processing, Photopolymer Resins, Pro-BLK, Flex-BLK, Multi-material Printing, Hybrid Materials, Tensile Testing, Mechanical Characterization, Dimensional Accuracy, Functional Graded Structures, CAD Modeling, Resin Composite, DLP 3D Printer

I. INTRODUCTION

Digital Light Processing 3D printing is one of the most advanced and widely utilized resin-based additive manufacturing technologies. As a member of the vat photopolymerization family, DLP offers high precision, exceptional resolution, and rapid production capabilities, making it particularly suitable for intricate geometries and fine-detail components. Unlike traditional Stereolithography, which use a laser to cure photopolymer resin. DLP uses a digital projector to cure entire layers simultaneously. This key difference significantly reduces print time while maintaining excellent dimensional accuracy and surface finish.

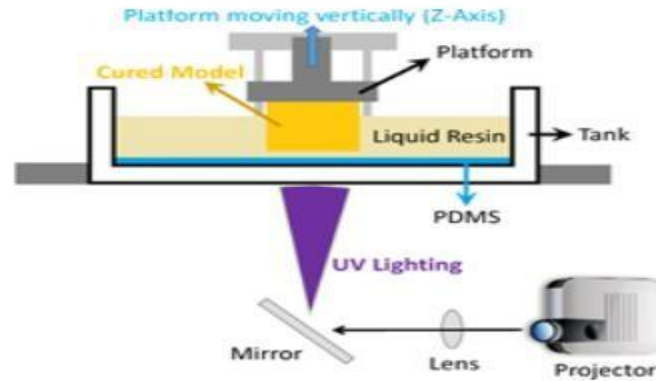


Figure No.1: DLP Working

Digital Light Processing (DLP) is an advanced 3D printing technique that uses a digital micromirror device to project UV light patterns, curing photopolymer resin layer by layer with high precision. This method enables the fabrication of parts with fine details, smooth surfaces, and excellent dimensional accuracy, making it suitable for applications like dental models, microfluidics, and precision components. In this study, tensile specimens were fabricated using Pro-BLK (rigid) and Flex-BLK (flexible) resins, individually and in composite blends, to investigate their mechanical behavior. The goal was to evaluate tensile strength and break strain of these hybrid materials, aiming to develop structures that combine both strength and flexibility. This research highlights the potential of multi-material DLP printing for producing high-performance, functionally versatile components.

NECESSITY OF WORK

In resin-based additive manufacturing, particularly in Digital Light Processing (DLP) 3D printing, material performance is a critical factor that determines the suitability of printed parts for functional applications. Most commercially available photopolymer resins are formulated with fixed mechanical characteristics either optimized for rigidity, toughness, or flexibility. However, in practical engineering applications, components often require a combination of these properties, such as stiffness for loadbearing capacity and flexibility for energy absorption or impact resistance.

Current research in multi-material DLP printing remains relatively limited, especially concerning custom material blends created by combining two or more base resins in varying proportions. While there has been progress in resin formulation and hardware compatibility, few studies have experimentally investigated how gradual changes in the ratio of rigid to flexible resin affect the resulting mechanical properties and print quality. This represents a significant knowledge gap in both academic research and industrial practice.

The necessity of this work is to study the need to understand the mechanical behavior and printability of composite resin blends made from different weight ratios of Pro-BLK (rigid, high-strength resin) and Flex-BLK (flexible, impact-resistant resin). By preparing and testing composite formulations such as 80:20, 70:30, 30:70, and 20:80 (Pro-BLK : Flex-BLK), neat Pro-blk and flex-blk, this research aims to systematically analyze how the blending ratio influences tensile strength, elongation at break, and dimensional accuracy. These insights are critical for engineers and designers seeking to tailor material

performance to specific functional requirements, particularly in applications that demand a balanced combination of strength and flexibility.

Furthermore, as industries increasingly adopt additive manufacturing for end-use parts, there is a growing demand for customizable material behavior without resorting to post-processing or hardware modifications. Developing tunable composite blends directly at the material level can offer a versatile and scalable approach to meeting diverse mechanical demands within a single platform. This study, therefore, provides foundational data for material selection, structural optimization, and future multimaterial strategies in resin-based 3D printing technologies.

APPLICATIONS

The Flex-Pro BLK composite material, developed by blending Flex BLK and Pro BLK in varying ratios, exhibits superior mechanical properties and printability compared to conventional 3D printing materials. Due to its high ductility, competitive tensile strength, and customizable performance, this material is suitable for various range of industrial and consumer applications.

1. Wearable Devices and Flexible Electronics: The enhanced flexibility and strength of the composite make it suitable for wearable devices such as smart bands, flexible casings for sensors, and soft enclosures for electronics.
2. Impact-Resistant Components: Applications such as drone parts, protective covers, phone cases, and shock-absorbing structures benefit from the composite's high elongation at break. It offers improved resistance to mechanical shock and repeated impact, making it a superior choice over brittle materials.
3. Automotive Interior Components: The composite material can be used in producing components like dashboard panels, clips, air vent parts, and cable organizers. Its strength and flexibility make it more reliable under mechanical stress, outperforming in terms of long-term performance and durability.
4. Robotics and Hinged Joints: The material is highly suitable for soft robotics, robotic grippers, finger joints, and other movable assemblies. Its ability to undergo repeated flexing without breaking offers a major advantage.
5. Tooling Jigs and Fixtures: In manufacturing environments, the composite can be used to produce durable jigs, clamps, and fixtures. These parts require both toughness and slight flexibility to withstand operational stresses.

FLEX-BLK

FLEX-BLK is a flexible photopolymer resin engineered for producing durable and impact-resistant 3D printed parts. It mimics the behavior of polypropylene and is ideal for applications where flexibility and toughness are essential. The material also demonstrates strong resistance to environmental aging, making it suitable for both short-term use and long-lasting prototypes.

PRO-BLK

PRO-BLK is a high-performance resin designed for applications requiring excellent dimensional accuracy, strength, and surface finish. It produces rigid parts with minimal post-processing and is ideal for functional components, especially where fine details and high fidelity are crucial.

Overview of Conventional 3D Printing Materials: ABS and PLA

1. Acrylonitrile Butadiene Styrene (ABS) Material : ABS is a widely used thermoplastic polymer known for its toughness and moderate strength. It is commonly used in engineering applications due to its resistance to impact, heat, and wear. ABS is a petroleum-based plastic and is often selected for parts that require durability and mechanical performance.

Key Properties:

- Tensile Strength: ~22 MPa
- Elongation at Break: ~6%
- Printability: Moderate to difficult – requires a heated bed, prone to warping, and emits fumes during printing.
- Applications: Automotive parts, enclosures, consumer products, mechanical components.

Limitations:

- Prone to warping and cracking during printing if not properly managed.
- Low flexibility compared to newer composite materials.

ii. Polylactic Acid (PLA) Material : Polylactic Acid (PLA) is an eco-friendly thermoplastic made from renewable resources such as corn starch or sugarcane. Known for its ease of use and low printing temperature, it is a popular choice in 3D printing for both novice and experienced users.

Key Properties:

- Tensile Strength: ~35.6 MPa
- Elongation at Break: ~4.2%
- Printability: Easy to moderate – low warping, low printing temperature, but brittle.

Limitations:

- Brittle, breaks easily under stress or impact.
- Poor heat resistance, deforms at relatively low temperatures (~60°C).
- Limited use in mechanical or load-bearing applications.

II. LITERATURE REVIEW

The literature review has been conducted to gain a comprehensive understanding of the key concepts, techniques, and challenges related to the combination of two resins in 3D printing and the corresponding analysis methods. This process serves as a foundation for identifying research gaps, refining the project scope, and developing a sound methodology. The primary focus of this review is to explore previous studies involving multi-material 3D printing, resin compatibility, mechanical testing of polymers, and the use of simulation tools such as ANSYS for validation purposes. Peer-reviewed journal articles, conference proceedings, and reputable academic sources were referred to during this review. These sources offer valuable insights into the mechanical behavior, printability, and performance analysis of various resins

used in additive manufacturing. By reviewing existing work, the aim was to extract relevant findings, methodologies, and experimental techniques that can guide the current study particularly in selecting materials, conducting tensile testing, and validating results through simulation.

Maros Eckert (2021) conducted a comparative study to evaluate the dimensional performance of various materials used in Fused Filament Fabrication (FFF) 3D printing. The materials analyzed included PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), PET-G (Polyethylene Terephthalate Glycol), Nylon, and FLEX filament. These were selected due to their widespread use and distinct mechanical behaviors. The study assessed each material's accuracy, print consistency, and surface quality by printing standardized test samples and measuring key dimensions. The results demonstrated that PLA and ABS offered superior dimensional accuracy and surface finish. PLA was particularly consistent due to its low shrinkage and user-friendly printability. ABS also showed strong performance, though it required controlled conditions such as a heated bed and enclosed environment to reduce warping. PETG provided a good balance between strength and print quality but needed optimized print settings to perform reliably. On the other hand, flexible filaments like FLEX and engineering-grade materials like Nylon posed challenges. Nylon's high moisture sensitivity led to dimensional inaccuracies unless properly dried and stored. FLEX, due to its elasticity, proved difficult to control during extrusion, resulting in less consistent geometries. This study underscores the importance of material selection in achieving dimensional precision in 3D printing, particularly when producing functional or mechanically loaded components.[1]

Liliane Guardia Olmos et. al (2017) conducted a study to evaluate the capabilities and accessibility of Digital Light Processing (DLP) 3D printing as an alternative to traditional additive manufacturing technologies. Their work emphasized the advantages of DLP in terms of precision and speed, particularly when compared to more common methods such as Fused Deposition Modeling (FDM). To validate the practical implementation of DLP, the research team developed a functional benchtop printer using easily accessible components, including a commercial video projector for layer-by-layer curing and a stepper motor for controlled Z-axis movement. The experimental setup allowed the team to test both Top-Down and Bottom-Up exposure configurations using two different acrylic-based resins (black and white). By printing mechanical components like gears, the researchers assessed the system's dimensional accuracy, surface finish, and structural fidelity. Additionally, the luminous energy density was analyzed to determine optimal exposure settings for each resin type. Results demonstrated that both resins yielded satisfactory performance under appropriate exposure conditions, though differences in formulation influenced overall print quality. The printed components exhibited strong visual and mechanical properties, suggesting that DLP printing can achieve reliable results even with a low-cost setup. The study highlighted DLP's potential for producing detailed prototypes quickly and affordably, promoting its use in applications ranging from education and small-scale production to mechanical design. This research supports the feasibility of deploying DLP systems in environments with limited resources while maintaining performance standards comparable to more expensive 3D printing technologies. It also lays the foundation for future improvements in printer scalability and material diversity, especially with the introduction of resin composites for enhanced mechanical properties. [2]

Giftymol Varghese et. al (2018) investigated an economical approach to ceramic component fabrication using Digital Light Processing (DLP)-based stereolithography, a subset of vat photopolymerization additive manufacturing. The research centered on developing a custom-built DLP 3D printer, which

utilized a standard digital projector as a UV light source to cure photosensitive resins loaded with ceramic powders, including alumina and yttria-stabilized zirconia (YSZ). The ceramic content in the formulations varied from 25% to 60% by weight, aiming to strike a balance between printability and mechanical integrity. The printed parts, known as green bodies, were subsequently sintered at elevated temperatures (ranging from 1200 °C to 1500 °C) to achieve densification and thermal stability. It was observed that increased ceramic loading led to higher post-sintering density, though a practical limit was identified near 60 wt%. Beyond this point, excess ceramic particles could not be effectively embedded within the resin matrix, leading to loose, non-adherent powder on the surface of the prints. This finding underscored the importance of maintaining optimal solid loading to preserve both structural integrity and dimensional accuracy. Dimensional deviations between the CAD models and printed parts, especially in the upper layers, were examined using photogrammetric analysis. These discrepancies were attributed to solvent evaporation during printing, which altered resin viscosity and curing behavior. To counteract this issue, the study recommended potential process refinements, such as controlling the vat temperature or using solvents with reduced volatility. The research successfully demonstrated that low-cost DLP stereolithography could be employed to fabricate complex ceramic geometries suitable for high-performance applications such as dental restorations, piezoelectric devices, and components in solid oxide fuel cells. This approach not only reduces the cost barrier associated with ceramic manufacturing but also opens avenues for tailored material properties through controlled resin-powder compositions. [3]

N. Shahrubudin et. al (2019) provided a broad and insightful analysis of additive manufacturing (AM), widely known as 3D printing, emphasizing its transformative impact across modern manufacturing domains. The study framed 3D printing as a digital fabrication process that builds physical objects layer by layer from digital CAD models, eliminating the need for traditional subtractive manufacturing or tooling. This technological paradigm shift allows for rapid, on-demand production of customized and geometrically complex parts, significantly reducing lead times and material wastage. The review categorized major 3D printing technologies such as Fused Deposition Modeling (FDM), Stereolithography (SLA), and Selective Laser Sintering (SLS), detailing their working principles and material compatibilities. It was noted that each method supports a diverse range of materials—from thermoplastics and photo-curable resins to metals and ceramics enabling application-specific fabrication across industries including automotive, aerospace, rail, healthcare, and agriculture. The paper highlighted the increasing relevance of 3D printing in both prototyping and low-volume end-use production, particularly where customization and complexity are key. The author emphasized how 3D printing promotes innovation by offering design freedom, material efficiency, and accelerated product development cycles. Ultimately, Shahrubudin's work pointed to the need for broader dissemination of technical knowledge and practical insights to support the continued integration of 3D printing into mainstream manufacturing. Future studies were encouraged to explore the performance of various printer-material combinations to optimize output quality and extend the range of feasible applications in industrial settings. [4]

Parminder Singh et. al (2018) conducted a comprehensive review highlighting the accelerating role of 3D printing or additive manufacturing in transforming the medical industry. The study synthesizes existing scholarly research focused on the development and implementation of 3D printing technologies for medical applications, particularly in the fabrication of customized biomedical implants and patientspecific solutions. Unlike conventional manufacturing techniques, 3D printing enables the precise creation of

complex geometries tailored to individual patient anatomy, thereby improving both functional and aesthetic outcomes in clinical use. The review emphasized the versatility of additive manufacturing in producing anatomical models, surgical instruments, dental prosthetics, orthopedic implants, and scaffolds for tissue engineering. Singh noted that these advancements have led to shorter production timelines and improved operational efficiency within healthcare systems. Moreover, the ability to rapidly prototype and iterate designs allows for enhanced surgical planning and personalized treatment strategies. An important takeaway from Singh's analysis is the growing role of 3D printing in advancing personalized medicine and regenerative healthcare. Its application in biocompatible implants and tissue scaffolding represents a forward-looking approach to treating complex medical conditions. The review also acknowledged the cost-effectiveness of the technology, especially in producing low-volume, high-precision components for critical interventions. Overall, Singh's work underscores how 3D printing has emerged as a disruptive innovation in medicine, enhancing both the quality and accessibility of healthcare. The findings advocate for further interdisciplinary research to optimize the integration of this technology in clinical environments and to explore its full potential in future healthcare delivery systems. [5]

Daniel G. Anderson et. al (2016) study offers a comprehensive examination of polylactic acid (PLA), a biobased and biodegradable polymer that has garnered significant attention in both industrial and academic contexts. Derived primarily from renewable agricultural feedstocks such as corn starch and sugarcane, PLA stands out for its environmentally friendly lifecycle and favorable mechanical and biocompatible properties. As global emphasis intensifies on reducing plastic waste and carbon emissions, PLA has emerged as a viable alternative to petroleum-derived polymers like polyethylene and polypropylene. The synthesis of PLA is typically achieved through ring-opening polymerization or direct polycondensation, enabling the production of high-molecular-weight polymers suitable for a wide array of applications. One of the critical advantages of PLA lies in its low energy demand during manufacturing, consuming between 25% and 55% less energy compared to conventional plastic production. Future improvements in process efficiency suggest even lower energy footprints, further reinforcing PLA's role in sustainable materials development. PLA's classification as Generally Recognized as Safe (GRAS) by the U.S. FDA has expanded its use beyond conventional applications to include biomedical sectors. Notable implementations include drug delivery systems, bioresorbable implants, surgical sutures, and scaffolds for tissue engineering. Its biodegradability and non-toxic degradation products make it an especially attractive material for temporary medical applications. Despite these advantages, PLA exhibits certain limitations, particularly in terms of mechanical flexibility, impact resistance, and hydrolytic degradation rate. Its brittle nature and hydrophobic surface characteristics reduce its effectiveness in specific environments, especially those requiring long-term durability or enhanced flexibility. As a result, research has increasingly focused on enhancing PLA's performance through various modification strategies. These include blending with other polymers, the addition of plasticizers, copolymerization, and the development of PLA-based nanocomposites—all aimed at improving toughness, thermal resistance, and degradation behavior. [6]

Ignazio Blanco (2020) review provides a detailed examination of recent advancements in additive manufacturing (AM), particularly focusing on the evolution and diversification of materials used in fused deposition modeling (FDM). As one of the most accessible and cost-effective AM techniques, FDM has gained widespread adoption in industries and research settings. Its ability to fabricate parts directly from

digital models through layer-by-layer extrusion of thermoplastic filaments has made it a valuable tool for rapid prototyping and low-volume production. Initially, FDM relied heavily on standard thermoplastics such as polylactic acid (PLA) and acrylonitrile butadiene styrene (ABS). While these materials offered ease of processing and affordability, they also presented limitations in terms of mechanical strength, thermal stability, and durability. To address these shortcomings, the research community has increasingly explored polymer composites materials formed by embedding reinforcing agents like carbon fibers, glass fibers, or ceramic particles into the polymer matrix. These composite materials have shown significant promise in enhancing the performance characteristics of 3D-printed parts, including improved tensile strength, heat resistance, and dimensional stability. As a result, they are being actively considered for applications in sectors with demanding performance requirements, such as aerospace, automotive, and biomedical engineering. The integration of such materials into FDM processes opens up new possibilities for creating functional end-use components rather than just prototypes. [7]

Jose Maria Reverte et. al (2020) has explored the effects of incorporating short carbon fibers (CF) into polylactic acid (PLA) matrices for parts produced via Fused Filament Fabrication (FFF). The study offers valuable insights into how carbon fiber reinforcement influences both the mechanical and geometric attributes of 3D-printed PLA composites. This investigation included an extensive series of mechanical tests, including tensile, flexural, and interlaminar shear strength (ILSS) assessments, along with evaluations of surface quality and dimensional accuracy. The results demonstrated that integrating short carbon fibers into PLA significantly improves mechanical performance when compared to neat PLA. For instance, PLA-CF samples printed in a flat orientation showed an increase of approximately 47.1% in tensile strength and 179.9% in tensile stiffness. Similar enhancements were recorded in flexural characteristics, with flexural strength and stiffness improving by 89.75% and 230.95%, respectively. These improvements are attributed to the reinforcing nature of the carbon fibers, which provide better stress distribution and load-bearing capabilities within the composite structure. In addition to mechanical improvements, the study found that dimensional accuracy and surface finish were either maintained or enhanced in specific build orientations, notably flat and on-edge positions. This observation counters a common concern that fiber reinforcement might negatively impact print fidelity or surface smoothness. Scanning Electron Microscopy (SEM) imaging further supported the mechanical findings by revealing well-integrated fiber structures that contributed to load transfer and fracture resistance. However, the addition of carbon fibers did introduce some trade-offs. The reinforced composites exhibited a more brittle fracture behavior, as indicated by reduced strain at failure. Despite this limitation, the study confirms that the benefits of CF reinforcement—such as increased stiffness and strength outweigh the drawbacks in many structural applications. Overall, Reverte’s work highlights the considerable potential of carbon fiber-reinforced PLA composites in the additive manufacturing space. With optimized print parameters and orientation strategies, these materials offer an excellent balance between mechanical performance and geometric precision, paving the way for their expanded use in engineering applications that require both strength and dimensional stability. [8]

Huda Al Khawaja et. al (2020) conducted a comprehensive analysis on the impact of printing parameters on the mechanical performance of parts fabricated using Fused Deposition Modeling (FDM), one of the most prevalent additive manufacturing techniques. This method builds objects layer by layer by extruding thermoplastic materials, but the final mechanical properties of the printed parts depend on more than just

the base material. Key process variables including layer height, infill density, print temperature, build orientation, and printing speed play crucial roles in determining attributes such as tensile strength, elongation at break, and interlayer adhesion. The study emphasized that these parameters critically influence the quality, durability, and overall reliability of FDM-manufactured components. Variations in these factors can lead to significant changes in mechanical behavior, impacting the functional performance and safety of the parts in practical applications. To thoroughly investigate these effects, the research dissected the fundamentals of the FDM process, reviewed typical mechanical behaviors of thermoplastic prints, and examined how individual printing parameters affect the structural integrity and performance of the parts. In particular, the study focused on polylactic acid (PLA) specimens produced by FDM, conducting systematic compression tests to evaluate mechanical properties such as elastic modulus, compressive yield point, and compressive strength. These tests provided essential insights into the material's deformation response and load-bearing capacity. The findings contribute to a growing understanding of how to optimize FDM process settings to produce components with mechanical characteristics that meet or exceed the demands of their intended applications. This investigation highlights the importance of process parameter optimization in additive manufacturing, especially for replacing traditionally manufactured components with 3D-printed alternatives. By tailoring the printing settings, it is possible to enhance mechanical performance, thereby ensuring printed parts maintain required safety and functionality standards across diverse engineering fields. [9]

Weiping Deng et. al (2022) provide a detailed examination of Digital Light Processing (DLP) technology, emphasizing its role as a precise and efficient method within the additive manufacturing landscape. Positioned alongside other common 3D printing techniques, DLP distinguishes itself by curing photopolymer resins layer-by-layer through projected light, enabling faster build speeds and higher resolution compared to methods like Fused Deposition Modeling (FDM) and Stereolithography (SLA). The study notably investigates the fabrication of highly detailed tooth models, a demanding application that necessitates exceptional dimensional accuracy. DLP printing was integrated with embedded microprocessor systems that actively monitor and adjust the printing parameters in real-time, enhancing process control and reliability. Furthermore, the implementation of advanced algorithms for optimizing slicing and layer generation contributes to minimizing dimensional deviations. Results from this comparative study show that parts produced by DLP with microprocessor-based control exhibited a 15.6% reduction in dimensional deviation relative to samples fabricated through alternative 3D printing methods. This outcome highlights DLP's superior capability in producing detailed and dimensionally accurate components, making it especially suitable for industries where precision is critical, such as dental prosthetics, biomedical devices, and microfabrication. Overall, the research underscores the significance of combining sophisticated hardware innovations with intelligent control systems to improve the performance and consistency of DLP-based additive manufacturing. These advancements reinforce DLP's potential as a leading technology for automated precision manufacturing applications that demand tight tolerances and complex geometries. [10]

LITERATURE GAP

Despite notable progress in additive manufacturing, particularly with FDM and DLP technologies, several research gaps persist. Most studies focus on individual materials like PLA, ABS, or resins such as PRO-BLK and FLEX-BLK, with limited attention to blending rigid and flexible DLP resins. Key aspects like



compatibility, curing behavior, and combined mechanical properties remain insufficiently explored. Additionally, the integration of simulation tools like ANSYS to support experimental findings is minimal. There is a lack of practical case studies on multi-material or functionally graded resins, along with limited research on their durability and industrial scalability. This highlights the need for comprehensive studies combining material development, mechanical testing, simulation, and real-world application.

AIM OF THE STUDY

To blend Pro-blk and Flex-blk material in different Percentage and experimental tensile testing done along with ANSYS Workbench results for Validation and compare this results with ABS and PLA 3D printing materials mechanical properties to see composite shows better results than the ABS and PLA materials.

OBJECTIVE OF THE STUDY

The primary objective of this research is to investigate the feasibility of combining two different 3D printing resins to create new materials with superior properties. Specific objectives include:

- i. To print and study the mechanical behavior (maximum stress and break strain) of Neat Pro-BLK, Neat Flex-BLK and Composites of Pro-BLK and Flex-BLK in varying weight ratios.
- ii. To analyse the Experimental vs. Numerical Stress Analysis.
- iii. To study the influence of Composition on Tensile Strength and Ductility.
- iv. To compare the mechanical performance with FDM printed ABS and PLA.
- v. To evaluate the printability of composite materials using standard 3D printing processes.

III. METHODOLOGY

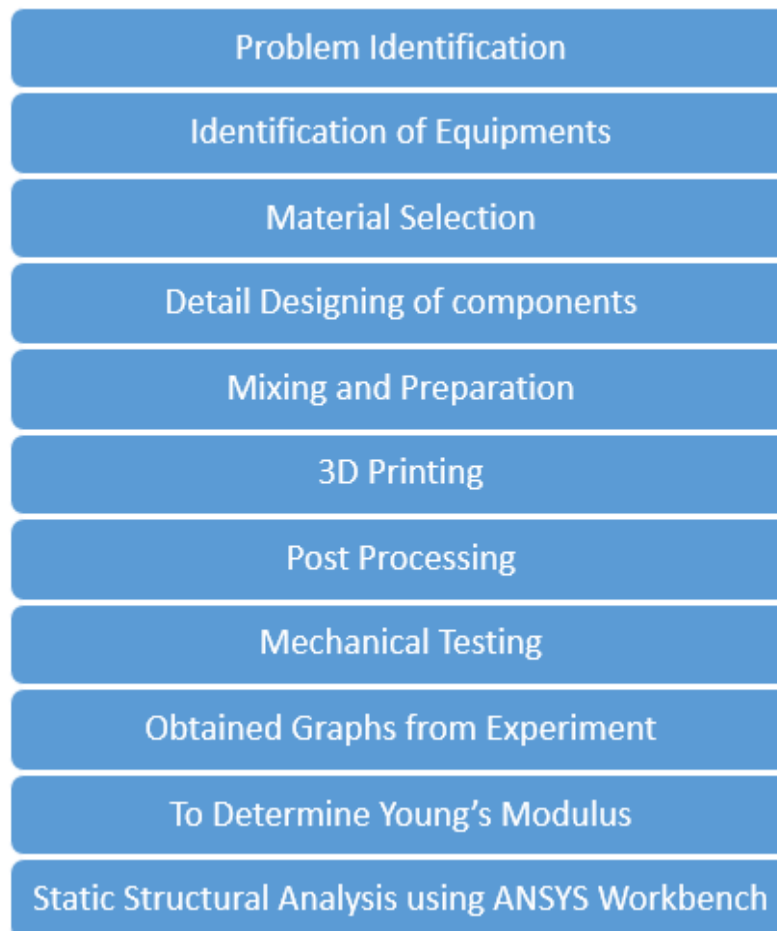


Figure 2: Methodology

1. Problem identification: In this stage first we identify the problem which are occurs in this identification the root cause of a problem. Developing a detail problem statement, that includes the problem effect of stiffness, maximum elongation at break while combining two materials in 3D printing to give the future scope in Manufacturing Industry.
2. Identification of equipments: After discussion and final the project. In this stage different equipments require for the project's completion this are discussed and final. Different tool are identify with discussion. In this Standalone DLP is used to print the specimens.
3. Material Selection: Select two compatible resins, Flex-BLK and Pro-BLK, considering their properties and potential for blending.
4. Detail designing of components 2D and 3D: In this stage, design of the components in the Creo PTC software version 8.0.4.0 is to print the dumbbell shaped specimen as per the standard dimensions. This Creo PTC file is converted into .stl format for the 3D Printing.

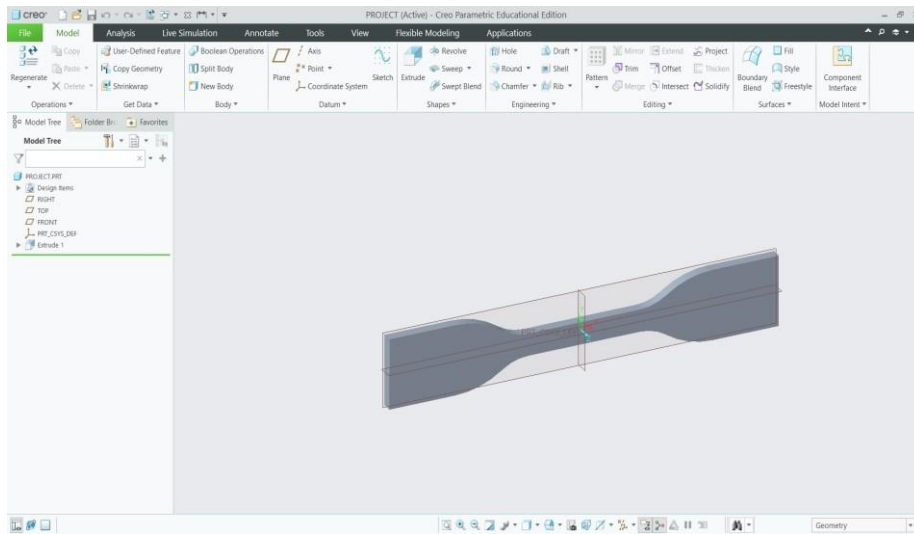


Figure 3: Three Dimensional Model

5. Mixing and Preparation:

- a) Firstly, neat Pro-blk and Flex-blk separately taken.
- b) Mixed the two resins in different proportions to create homogeneous blends.
 - Mixing Ratios: Prepare blends of Flex-BLK and Pro-BLK in the following ratios:
 1. 20% Flex-BLK : 80% Pro-BLK
 2. 30% Flex-BLK : 70% Pro-BLK



Figure 4: Material in DLP

- Mixing Techniques: Utilize mechanical Standalone ultrasonic Machine mix to ensure homogeneous blends.

6. **3D Printing:** In this study, a Digital Light Processing (DLP) 3D printer was employed to fabricate the test specimens. DLP is a resin-based additive manufacturing technique that utilizes a digital light projector to selectively cure photopolymer resin layer by layer. The printer provides high resolution and precision, making it ideal for producing small and detailed parts, especially for mechanical testing. A total of seven individual specimens were fabricated using this technique. Each specimen was printed separately to ensure consistency in the printing conditions and to eliminate any potential variables that could arise from batch printing. This approach ensures better control over the mechanical properties and dimensional accuracy of each sample, which is critical for reliable comparative analysis.

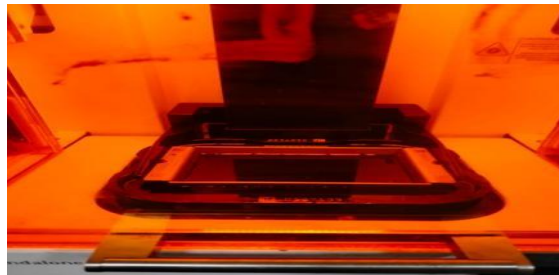


Figure 5: Printing of a 3D model



Figure 6: Specimen Printed

7. **Post Processing:** Post-processing is a crucial step in DLP 3D printing to ensure the final product meets desired quality standards. Immediately after printing, remove the part from the build platform and soak it in a cleaning solution, such as isopropyl alcohol (IPA) or a specialized cleaning solution provided by the resin manufacturer and heat treatment is done.

8. **Mechanical Testing:** The mechanical performance of the 3D-printed specimens, tensile testing was conducted using a Universal Testing Machine (UTM). Tensile testing is a fundamental method for determining the strength and ductility of materials. During this test, a gradually increasing uniaxial load is applied to the specimen until failure occurs. The Universal Testing Machine records the applied force and the corresponding elongation of the specimen throughout the test. From this data, a force versus stroke (displacement) graph is generated of individual specimen, which provides valuable insights into the material's behavior under tensile stress. Key mechanical properties such as maximum stress, elongation at break and Young's modulus can be derived from the graph. This testing method is essential for comparing the mechanical characteristics of different material compositions and for validating the suitability of 3D-printed parts in structural applications.

UNIVERSAL TESTING MACHINE DETAILS:

EQUIPMENT CODE: CIPET/ABD/PTC/EQUIP/MECH/22

TEST METHOD: ASTM D638

EQUIPMENT SPECIFICATION: RANGE/ACCURACY-0-500N, 0-5KN, 0-10KN,0-100KN

MODEL: AUTOGRAPH

MAKE: SHIMADZU-JAPAN

OBJECTIVE: To determine the Tensile, Flexural and Compressive, shear strength.

ACCESSORIES REQUIRED: Load cell, Different types of gauges, grips, wedges, support beams, etc.



Figure 7: Universal Testing Machine

9. Obtained Graphs from Experiment: The Graphical Representation shows the Force vs. Stroke graph clearly shows the elastic and plastic deformation zones.

a) Graph - 01 (Specimen no. 26220325 i.e. Neat Pro-blk):

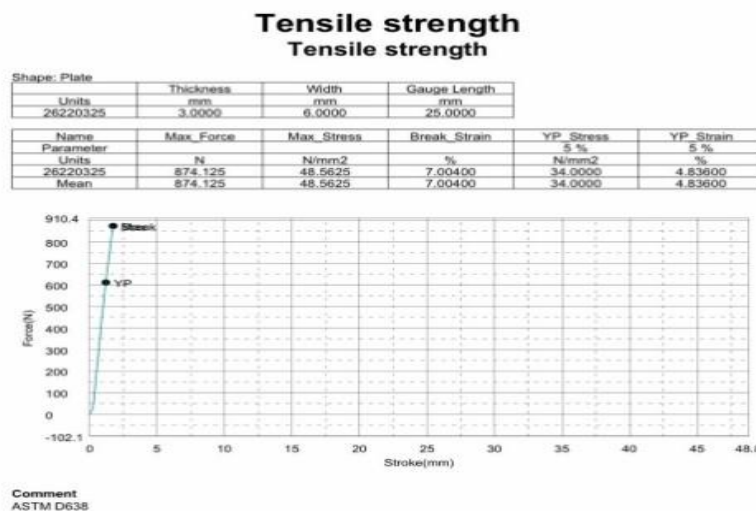


Figure 8: Graph of Neat Pro-Blk

The graph suggests that the material has a good balance of strength and ductility, capable of absorbing significant stress while still allowing some elongation before fracture.

b) Graph - 02 (Specimen no. 26280325 i.e. Neat Flex-blk):

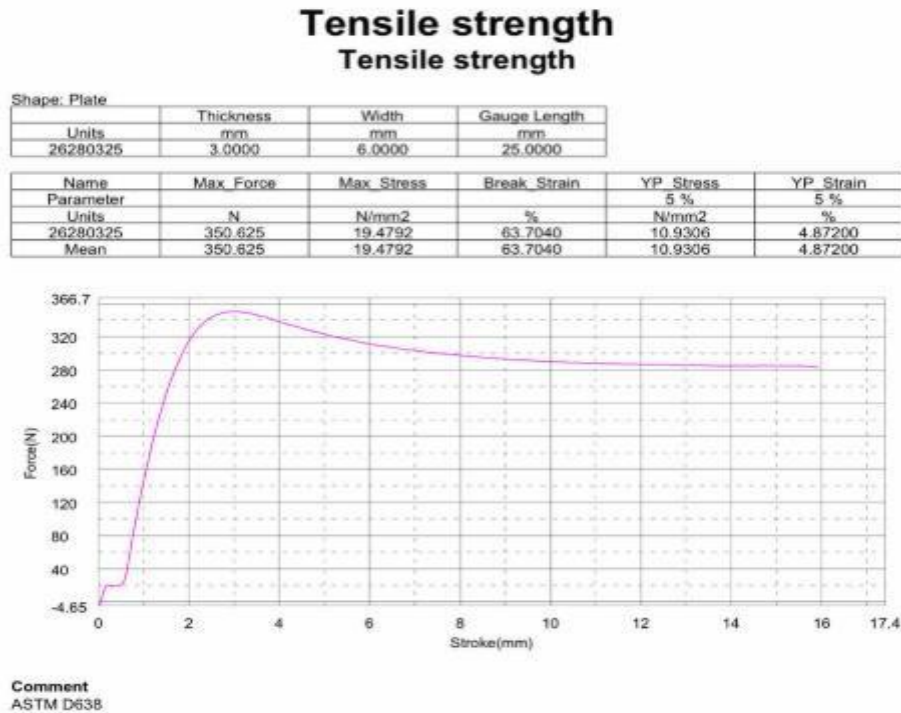


Figure 9: Graph of Neat Flex-Blk

The curve shows that while the material has moderate tensile strength compared to more rigid polymers, it excels in elongation capacity, making it suitable for applications that demand flexibility and stretchability rather than load-bearing capacity.

c) Graph - 03 (Specimen no. 26230325 i.e. 80% Pro-blk + 20% Flex-blk):

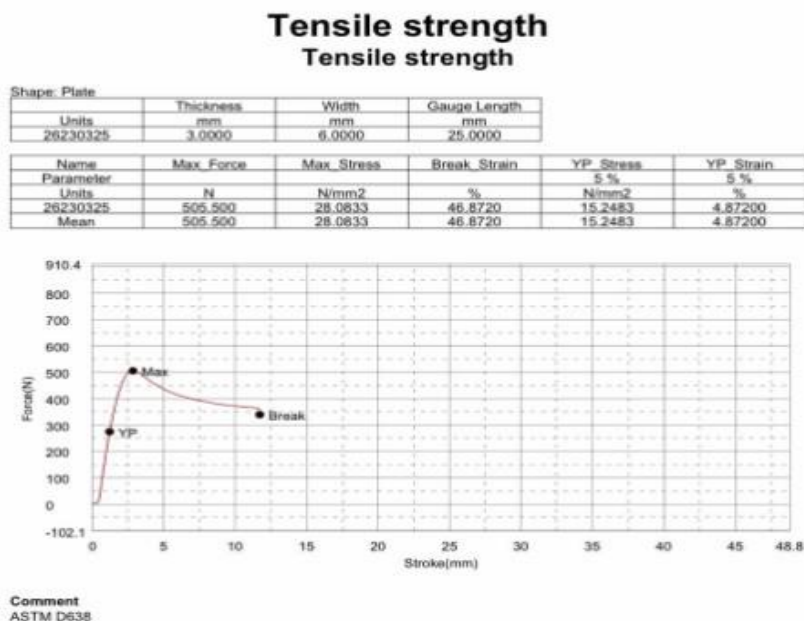


Figure 10: Graph of 80% Pro-Blk + 20% Flex-Blk

The specimen fractures at a break strain of 46.8720%, which reflects its ductility. This behavior demonstrates that the material possesses a good balance between strength and flexibility, making it suitable for semi-structural applications where moderate strength and considerable elongation are desired.

d) Graph - 04 (Specimen no. 26240325 i.e. 70% Pro-blk + 30%Flex-blk):

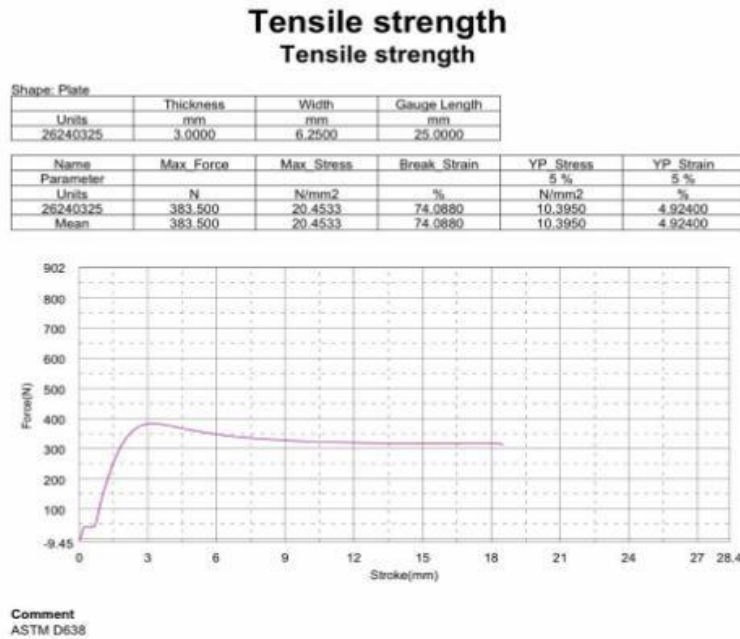


Figure 11: Graph of 70% Pro-Blk + 30% Flex-Blk

This specimen displays moderate tensile strength with very high ductility, making it suitable for applications where flexibility and energy absorption are prioritized over stiffness or high strength.

10. Mathematical Calculation: Analyze the experimental Graph data to determine the Young's Modulus of each specimen.

a. Neat Pro-blk:

- i. Force= 616 N
- ii. Area= 3*6= 18 mm²
- iii. Stroke= 1.25 mm
- iv. Gauge Length= 25 mm

$$\text{Young's Modulus [E]} = \text{Stress/Strain}$$

As we know, Stress= Force/ Area and Strain= Stroke/ Gauge Length

$$\text{Therefore, Young's Modulus} = (\text{Force/Area}) / (\text{Stroke/ Gauge Length}) \quad E = (616/ 18) / (1.25/ 25) = 684.4 \text{ MPa}$$

b. Neat Flex-blk:

- i. Force= 140 N
- ii. Area= 3*6= 18 mm²
- iii. Stroke= 1 mm

iv. Gauge Length = 25 mm

Young's Modulus [E] = Stress/Strain

As we know, Stress = Force / Area and Strain = Stroke / Gauge Length

Therefore, Young's Modulus = (Force/Area) / (Stroke / Gauge Length) $E = (140 / 18) / (1 / 25) = 195$ MPa

c. 80% Pro-Blk + 20% Flex-Blk:

i. Force = 256 N

ii. Area = $3 \times 6 = 18 \text{ mm}^2$

iii. Stroke = 1.25 mm

iv. Gauge Length = 25 mm

Young's Modulus [E] = Stress/Strain

As we know, Stress = Force / Area and Strain = Stroke / Gauge Length

Therefore, Young's Modulus = (Force/Area) / (Stroke / Gauge Length) $E = (256 / 18) / (1.25 / 25) = 285$ MPa

d. 70% Pro-Blk + 30% Flex-Blk:

i. Force = 250 N

ii. Area = $3 \times 6 = 18 \text{ mm}^2$

iii. Stroke = 1.5 mm

iv. Gauge Length = 25 mm

Young's Modulus [E] = Stress/Strain

As we know, Stress = Force / Area and Strain = Stroke / Gauge Length

Therefore, Young's Modulus = (Force/Area) / (Stroke / Gauge Length) $E = (250 / 18) / (1.5 / 25) = 231.33$ MPa

11. Static Structural Analysis Using ANSYS Workbench: To evaluate the mechanical performance of seven different material specimens, static structural analyses were performed using ANSYS Workbench. Each specimen, corresponding to a unique material composition was modeled and simulated individually.

a. Neat Pro-Blk:

- Maximum Stress-

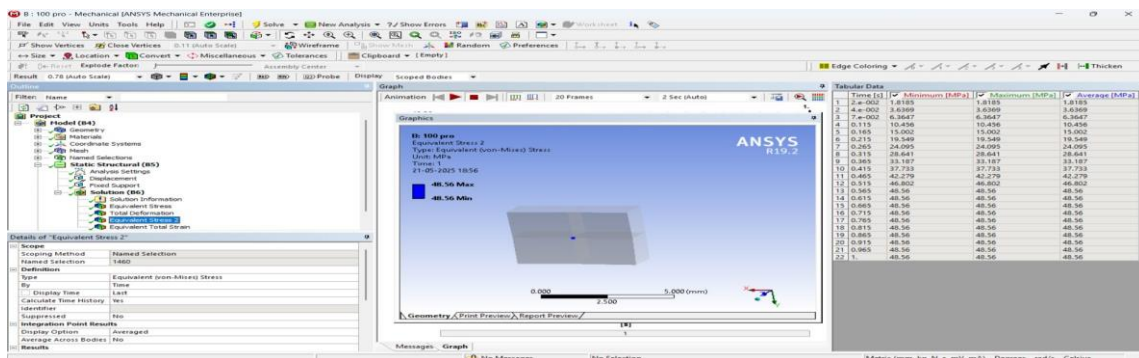


Figure 12: Maximum Stress of Neat Pro-Blk

b. Neat Flex-Blk:

- Maximum Stress-

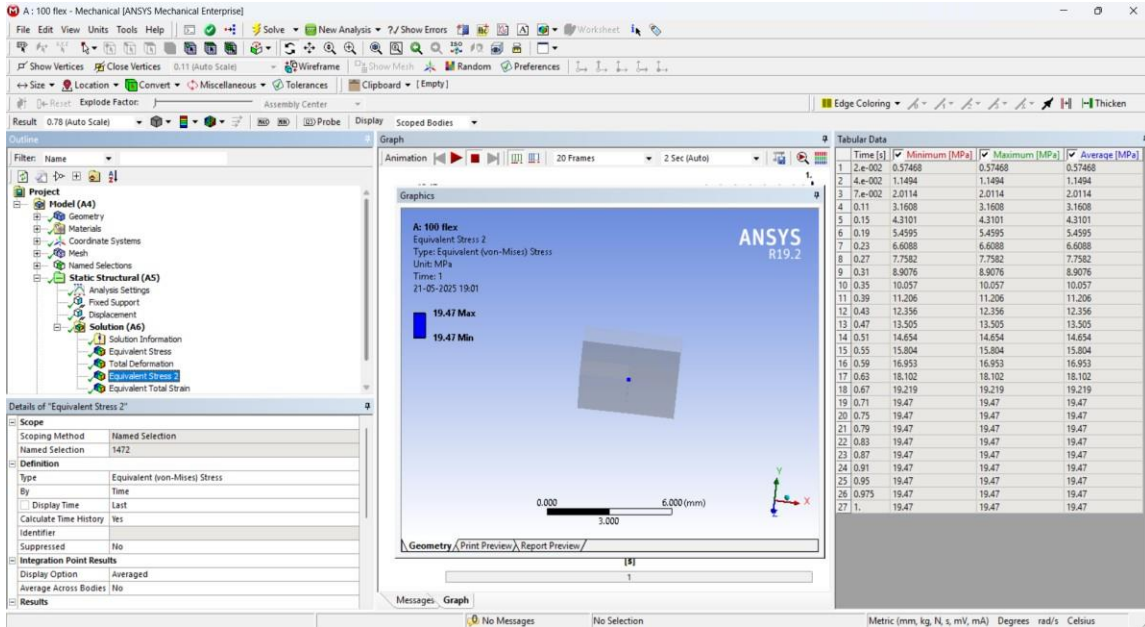


Figure 13: Maximum Stress of Neat Flex-Blk

c. 80% Pro-Blk + 20% Flex-Blk:

- Maximum Stress-

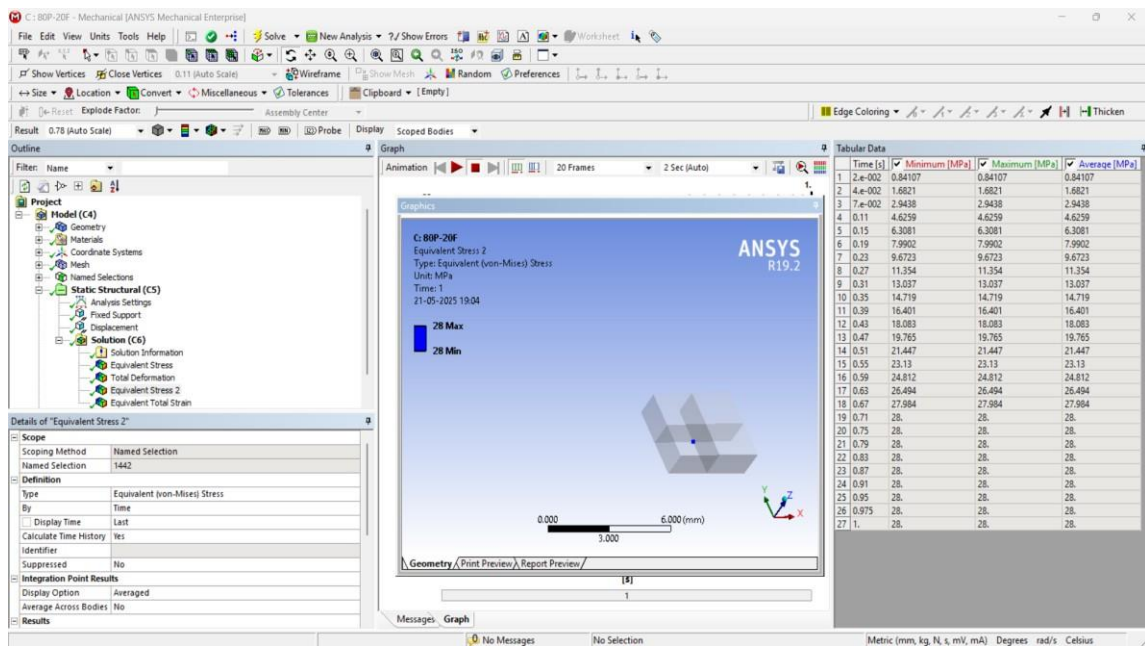


Figure 14: Maximum Stress of 80% Pro-Blk + 20% Flex-Blk

d. 70% Pro-Blk + 30% Flex-Blk:

- Maximum Stress-

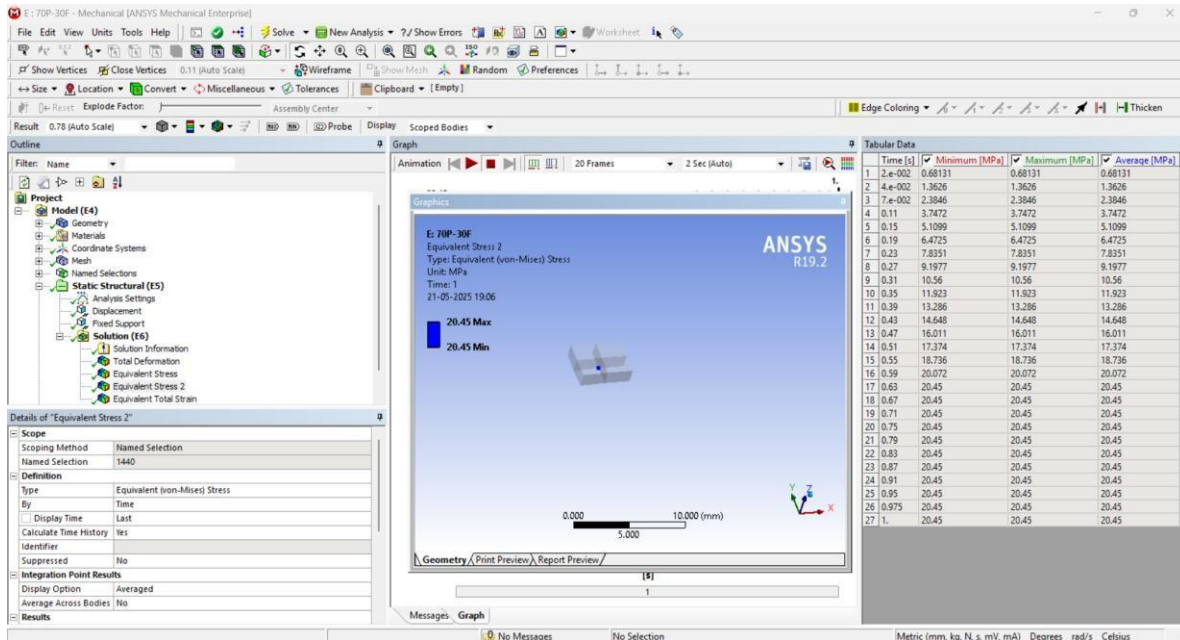


Figure 15: Maximum Stress of 70% Pro-Blk + 30% Flex-Blk

III. RESULTS AND DISCUSSION

This section presents the mechanical properties maximum tensile stress and break strain of 3D printed specimens composed of neat Pro-BLK, neat Flex-BLK, and various weight percentage composites of both materials. The performance of these Digital Light Processing (DLP) printed materials is further compared with standard thermoplastics, ABS and PLA.

1. Experimental vs. Numerical Stress Analysis:

The experimental results demonstrate excellent agreement with the numerical results obtained from ANSYS simulations. For all tested compositions, the deviation between experimental and simulated maximum stress values is minimal, validating the reliability of the finite element analysis model.

SR. NO.	Material Composition	Max. Stress (Experimental) [MPa]	Max. Stress (ANSYS Simulation) [MPa]
1.	100% Flex-BLK	19.48	19.40
2.	100% Pro-BLK	48.56	48.56
3.	80% Pro-BLK + 20% Flex-BLK	28.08	28

4.	70% Pro-BLK + 30% Flex-BLK	20.45	20.45
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Figure 16: Comparison of various Specimen

This close correlation confirms the validity of the simulation for further predictive modeling and optimization of mechanical properties in DLP-printed composite materials.

2. Influence of Composition on Tensile Strength and Ductility:

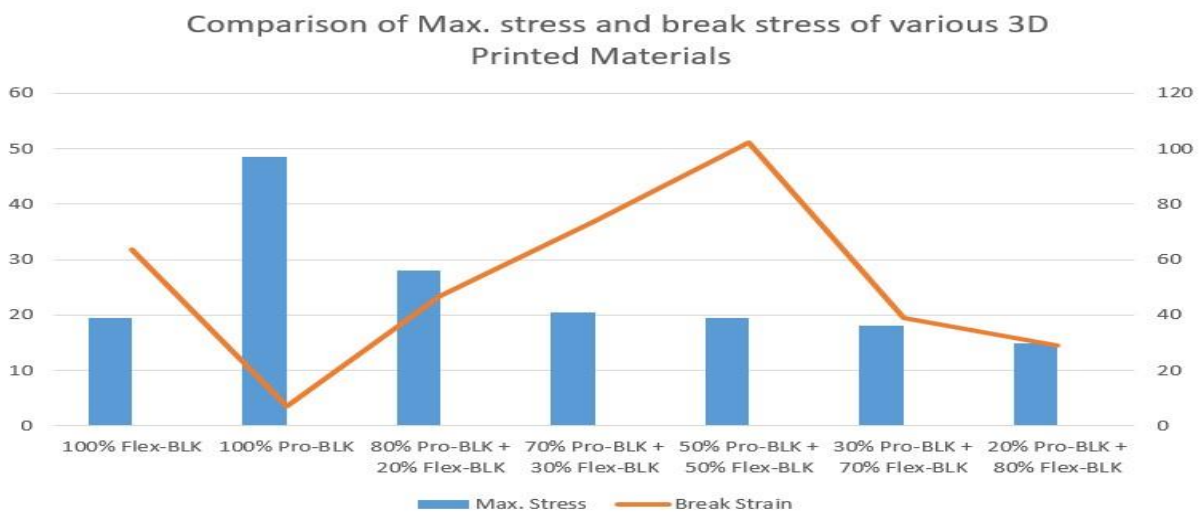


Figure 17: Graph of Maximum Stress and Break Strain

- The blue bars represent maximum stress (MPa).
- The orange line shows break strain (%).

The variation in Pro-BLK and Flex-BLK ratios significantly influences both strength and ductility:

- Pro-BLK (100%) shows the highest tensile strength at 48.56 MPa, but the lowest break strain (7.0%), indicating a stiff and brittle behavior.
- Flex-BLK (100%), conversely, displays lower strength (19.48 MPa) but far greater elongation (63.70%), revealing a flexible and ductile nature.

Blending the two materials leads to intermediate properties:

- The 80% Pro-BLK + 20% Flex-BLK composition presents a well-balanced profile, combining relatively high strength (28.08 MPa) with good ductility (46.87%). This blend can be considered optimal when both mechanical durability and flexibility are required.
- Compositions with more than 30% Flex-BLK start to lose strength significantly, while their strain performance does not proportionally improve, as seen in the 30% Pro-BLK + 70% Flex-BLK sample (18.17 MPa, 38.87% strain).

3. Comparison with ABS and PLA (FDM Printed) :

Material	Max Stress (MPa)	Break Strain (%)
ABS	22	6
PLA	35.6	4.2

Figure 18: ABS and PLA Mechanical Properties

- Compared to ABS, most Pro-Flex composites provide higher ductility and comparable or better strength, making them suitable alternatives where flexibility and impact resistance are critical.
- This highlights the potential of DLP-printed composites as customizable alternatives to conventional thermoplastics, especially in applications requiring tailored mechanical responses.

IV. CONCLUSION

This study demonstrates the potential of combining Pro-BLK and Flex-BLK resins to create DLP-based composite materials with customizable mechanical properties. Experimental analysis showed that blending these resins in different ratios allows for tuning between strength and flexibility where Pro-BLK provides higher tensile strength and Flex-BLK offers greater ductility. The 80:20 blends emerged as optimal for balancing durability and elongation. Numerical validation using ANSYS closely matched the experimental results, confirming the reliability of simulation models. When compared to traditional FDM-printed ABS and PLA, these composites exhibited superior ductility and competitive strength, making them suitable for applications requiring both resilience and adaptability.

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