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DESIGNANDDEFECTIVEANALYSISOFPLABASEDADDITIVEMANUFACTUREDROBOTICARM

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ABSTRACT

Manufacturing transforms raw materials into finished products through various processes, including machining, forming, and additive techniques. It plays a crucial role in producing goods for diverse industries, driving economic growth and technological innovation , additive manufacturing, particularly fused deposition modeling (FDM), has revolutionized the fabrication process of robots by enabling rapid prototyping and customization. In this study, we focus on the design and defective analysis of a robotic arm fabricated using polylactic acid (PLA) material via FDM technology. However, despite advancements in FDM technology, defects such as warping, layer misalignment, and voids may occur during fabrication, affecting the robot's overall quality andfunctionality. To address these challenges, a comprehensive defective analysis is conducted. This involves inspecting the fabricated robot for common defects using visual inspection, microscopy, and non-destructive testing techniques. Key design considerations include optimizingforPLA'smaterial properties,suchasitsstiffness,tensilestrength,densityandimpactstrength,toensurethe roboticarm's performance. The results of this study contribute to the advancement of additive manufacturing methodology in manufacturing robotics, facilitating the development of cost-effective, customizable, and high-performance robotic systems for various applications with less defects

Keywords: AdditiveManufacturing,FusedDepositionModeling,PolylacticAcid,RobotDesign,DefectiveAnalysis

INTRODUCTION

Additive manufacturing, commonly known as 3D printing, has emerged as a transformative technology with profound implications across various industries, including robotics. Among the numerous materials used in additive manufacturing, polylactic acid (PLA) has gained considerable attention due to its biodegradability, affordability, and ease of use. PLA-based additive manufacturing offers significant advantages, such as rapid prototyping, customization, and the ability to create complex geometries. This has led to its widespread adoption in the fabrication of robotic systems.The design and fabrication of robots using PLA-based additive manufacturing present unique challenges and opportunities. While the technology allows for the realization of intricate robotic designs with relative ease, ensuring structural integrity, functionality, and reliability remains paramount. Additionally, the additive manufacturing process itself introduces potential defects that can compromise the performance of the fabricated robot. This paper focuses on the design and defective analysis of a robot fabricated using PLA materialvia fused deposition modeling (FDM), a popular additive manufacturing technique. The design process involves conceptualizingtherobot'smorphology,locomotionmechanisms,andfunctionalrequirements,followedbytranslatingthese concepts into detailed digital models using computer-aided design (CAD) software. Once the design is finalized, the additive manufacturing process begins, wherein PLA filament is extruded layer by layer to build the physical robot structure. However, despite advancements in FDM technology, inherent defects such as warping, layer misalignment, and voids may occur during fabrication, necessitating thorough defect analysis and mitigation strategies.This study encompasses a comprehensive defective analysis methodology, including visual inspection, microscopy, and non-destructive testing techniques, to identify and characterize defects in the fabricated robot. Additionally, advanced computational tools like finite element analysis (FEA) are employed to simulate the mechanical behavior of the robot, aiding in defect detection and structural optimization.

LITERATUREREVIEW

*TensileTestingandEvaluationof3DPrintedPLASpecimensasperASTMD638Type-IVStandard***by**
GabrielGómezonDec08,2019(1)

Additive manufacturing offers an alternative to traditional processes but the strength of 3D-printed parts remains under research. Polylactic acid, a biodegradable material, is widely used in fused deposition modeling for 3D printing.

DesignandfabricationofpickandplaceroboticarmDr.T.Sunilkumar,K.sarath,Sd.Famil,A.V.S.Bhagyeshand Sk.Althaf 19 August 2020.(2)

The design and fabrication of an educational pick and place robotic arm using CATIA software, powered by servos for improved accuracy. Aluminum isselected for the components, with servo selection basedon detailed torquecalculations for each joint. The project aims to build a functional robotic arm for pick and place operations

OptimizationofCharpyImpactStrengthofToughPLASamplesProducedby3DPrintingOğuzTunçel7February 2024(3)

The Taguchi method and ANOVA to investigate and optimize the impact strength of tough PLA material produced via FDM, focusing on infilldensity,raster angle, layerheight,and printspeed.Theeffectof thesekeyprintingparameterson Charpy impact strength is explored.

OBJECTIVES

Theobjectiveofourprojectis

- Tohelptheindustriestoincreaseproductivity
- Toreducetheworkersefforts&laborcosts.
- Toperformalloperationsatasingletime,henceincreasingproductionandsavingtime
- Tocompletelargeamountsofworkinlesstime.
- The usage of robotic arm Increases productivity by speeding up the assembly process, reducing errors, and ensuringconsistentquality.Italsoreducestheneedforhumanlaborinrepetitivetasks,freeingupworkersformorecomplex activities.

Picking components from one location and placing them in another, such as sorting products on a conveyor belt. Enhances speed and accuracy in sorting and arranging products, which is crucial in high-speed production environments. It also reduces labor costs and minimizes the risk of repetitive strain injuries for workers.

DESIGNOFROBOTICARM

ComponentModeling:

- **IndividualParts**:Modeleachpart(base,links,joints)individuallyinSolidWorks.
- **MaterialProperties**:SetthematerialpropertiestoPLAtoaccuratelysimulateweightandstrength.

Optimization:

- **WeightReduction**:Optimize thedesigntoreduceweightwhilemaintainingstrength,focusingonareasthatdonot compromise the structural integrity.
- **ComponentSizing**:Adjustthedimensionsofpartsforbetterperformanceandeaseofmanufacturing.

Prototyping:

- **3DPrinting**:Usea3Dprintertocreateprototypesoftheparts.Assembletheprototypestotestthefitandfunction.
- **IterativeDesign**:Basedonprototypetesting,refinethedesigntoaddressanyissuesdiscoveredduringtesting.

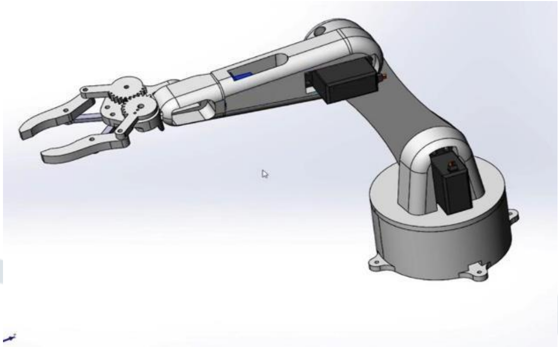


Fig:roboticarmdesigninsolid works

DESIGNPARAMETERS

Base:

- **Description**:Thebasesupportstheentireroboticarmandallowsforrotationaroundtheverticalaxis.
- **DesignParameters**:
  - **Material**:PLAforlightweightandeaseofmanufacturing.
  - **RotationRange**:0°to 360°.
  - **Dimensions**:Sufficientsizetoprovidestabilityandsupportfortheuppersections.
  - **MountingFeatures**:Holesorslotsforsecuringtoaworksurface.

ShoulderJoint:

- **Description**:Connectsthebasetotheupperarmandallowsforrotationaroundahorizontalaxis.
- **DesignParameters**:
  - **RotationRange**:Typically-90°to +90°.
  - **TorqueRequirements**:Sufficienttolifttheentirearmandpayload.
  - **ActuatorType**:Steppermotororservomotorwithappropriatetorquerating.

***ElbowJoint**:*

- **Description**:Providesasecondaryrotationaroundahorizontalaxis,enablingthearmtobendattheelbow.
- **DesignParameters**:
  - **RotationRange**:Typically0°to180°.
  - **TorqueRequirements**:Mustaccommodatetheweightoftheforearmandendeffector.

  - **ActuatorType**:servomotor.**WristPitch**:

- **Description**:Allowsthewristtopitchupand down.
- **DesignParameters**:
  - **RotationRange**:-90°to+90°.
  - **Precision**:Highprecisionfortasksrequiringfinecontrol.
  - **ActuatorType**:Servomotor.

WristYaw:

- **Description**:Enablesthewristtoyawleftandright.
- **DesignParameters**:
  - **RotationRange**:-90°to+90°.
  - **Precision**:Highprecisionforaccuratepositioning.
  - **ActuatorType**:Servomotor.

WristRoll:

- **Description**:Allowsthewristtoroll,providingrotationalmovementoftheendeffector.
- **DesignParameters**:
  - **RotationRange**:0°to 360°.
  - **Precision**:Crucialforapplicationsrequiringrotationaladjustments.
  - **ActuatorType**:Servomotor

Componentsandspecification's

SL.NO	COMPONENTNAME	SPECIPICATION	QUANTITY
01	NODE MCU	ESP8266	**1**
02	BUCKCONTROLLER	ACTODC CONVERTER	**1**
03	POWERCONVERTER	VOLTAGE CONVERTER	**1**
04	BREADBOARD		**1**
05	SERVOMOTOR	MG996R	**2**
06	SERVOMOTOR	SG90	**4**

METHODOLOGY

The robotic arm operates by receiving commands from the microcontroller, which instructs the servo motors to articulate each of the arm's six degrees of freedom. These motions enable precise positioning and manipulation of objects within the arm's reach, facilitating tasks such as picking, placing, and assembly in industrial settings. The impact of the robotic arm is significant, streamlining production processes, reducing manual labor, and increasing efficiency. To ensure reliability, components are subjected to rigorous testing, including density checks to verify material integrity, tensile tests toassess strength and durability, and impact tests to evaluate resistance to external forces. These measures ensure that the robotic arm meets quality standards and can withstand the demands of industrial operations.

Impact Test and density test is performed at CIPET Hyderabad and the tensile test is performed in Narayana Engineering college, Nellore

Fig:TensileTestatNECN

Fig:TestingatCIPET(Hyd)

RESULTANDDISCUSSION

Thematerialundergoesdifferenttestingmethodstodetermineitscharacteristicsafterprintingandbeforeprinting

S.NO	TEST	TESTMETHOD	RESULT OBTAINED	UNIT	STANDARD VALUES ASPERBIS
1	Impactstrength	ASTMD256	49.50	j/m	42.50
2	Density	ASTMD792	1.193	g/cc	1.24
3	TensileTest	UTM	49	mpa	45 -60

TENSILESTRENGTHOFPLAMATERIAL

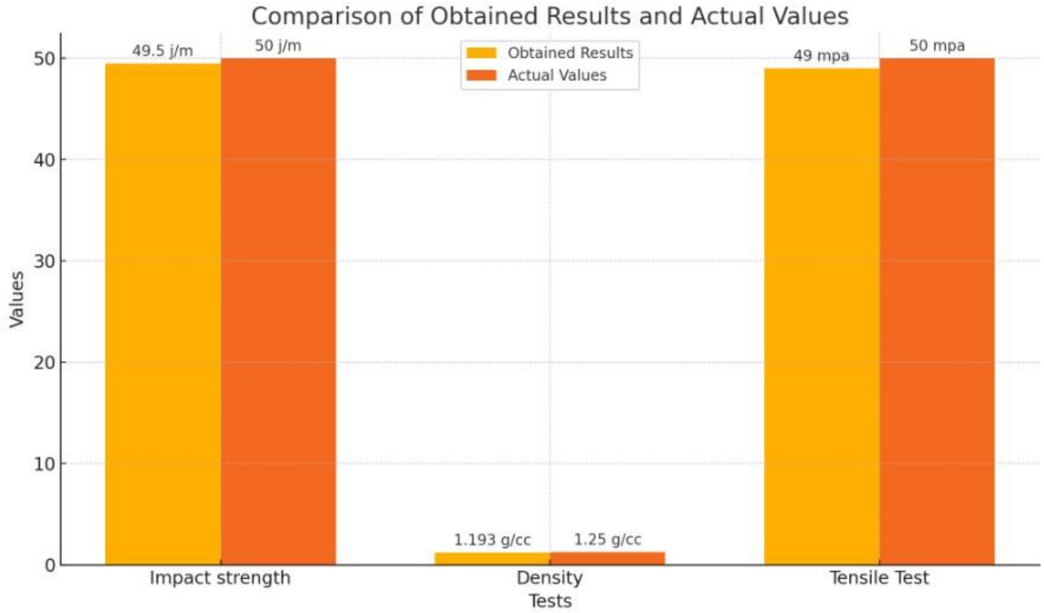
PLA (Polylactic Acid) typically has a tensile strength of 45 to 60 MPa, influenced by its molecular weight, processing conditions, and additives. Derived from renewable resources like corn starch or sugarcane, PLA is biodegradable and environmentally friendly. Its tensile strength and other mechanical properties make it suitable for 3D printing, packaging, and biomedical devices. Manufacturers can modify PLA formulations or use post-processing techniques to enhance its properties for specific applications. Researchers also explore additives and polymer blends to improve PLA's mechanical characteristics.

DENSITYOFPLAMATERIAL

The density of PLA (Polylactic Acid) generally ranges from 1.24 to 1.27 g/cm³, but it can vary slightly based on manufacturing processes, specific grades, and additives. Densities below 1.24 g/cm³ suggest modifications, such as changes in molecular weight or blending with other polymers, which can alter its mechanical strength, thermal stability, andbiodegradability. Understanding PLA's density is vital for accurately calculating material usage, determining part weight, and predicting its behavior in applications like 3D printing.

IMPACTSTRENGTHOFPLAMATERIAL

The impact strength of PLA (Polylactic Acid) material can vary depending on factors such as its molecular weight, crystallinity,processing conditions,and any additivesor modifiersincorporated into thematerial.Generally,PLA exhibits impact strength values ranging from 5 kJ/m² to 15 kJ/m². If the impact strength of PLA material is greater than 42.50 J/m, it would suggest that the PLA has been significantly modified or enhanced beyond typical properties associated with standard



Conclusion:

The design and defect analysis of a PLA-based additive manufactured robotic arm demonstrate the potential and challenges of using PLA in robotics. The FDM process enabled the creation of complex, customized components, but also introduced defects such as warping, layer misalignment, and voids. Comprehensive defect analysis, including visual inspection, microscopy, and non-destructive testing proved essential in identifying and mitigating these issues. FEA simulations provided insights into the mechanical behavior, aiding in design optimization. While PLA offers significant advantages, ensuring structural reliability and functionality requires meticulous defect management. Ongoing research and technological advancements arecrucial for enhancing the quality and performance of PLA-based robotic systems, ensuring they meet the necessary performance criteria.

TensileTestRemedies

- OptimizePolymerization**:**Ensureconsistentpolymerizationconditionstomaintainuniformmolecularweightand improve tensile strength.
- AddReinforcements**:**Incorporatereinforcingagentslikeglassfibersorcarbonnanotubestoenhancetensilestrength.
- ControlCoolingRates**:**Adjustcoolingratesduringprocessingtoimprovecrystallinityandtensileproperties.
- UseHigh-GradePLA**:**Selecthigher-gradePLAknownforbettertensilepropertiessuitableforspecificapplications.

ImpactStrengthRemedies

- AddImpactModifiers**:**Incorporateimpactmodifiersortougheningagentssuchasrubberparticlestoincreasethe material's impact strength.
- BlendingwithOtherPolymers**:**BlendPLAwithtougherpolymerslikePBAT(polybutyleneadipateterephthalate)to improve impact resistance.
- OptimizeProcessingConditions**:**Fine-tuneprocessingparametersliketemperatureandextrusionspeedtoenhance impact strength.
- Annealing**:**Post-processthematerialbyannealingtoimproveitstoughnessandimpactresistance.

DensityTestRemedies

- StandardizeManufacturing**:**Implementcontrolledmanufacturingprocessestoensureconsistentdensity.
- CarefulSelectionofAdditives**:**Chooseadditivesandfillersthatdonotsignificantlyalterthedesireddensity.
- RegularTesting**:**Performregulardensityteststoensurebatch-to-batchconsistency.
- BlendingandCompounding**:**BlendPLAwithotherpolymersorcompoundsthatcanachievethedesireddensitywithout compromising other properties

ImplementingthesestrategiescanoptimizePLA'smechanicalproperties,ensuringitmeetsspecificapplicationrequirements. Regular testing and quality control measures are essential to maintain consistency and performance.

Byfocusingontheseremedies,PLA'stensilestrength,impactresistance,anddensitycanbeeffectivelymanagedandenhanced for various applications, including 3D printing, packaging, and biomedical devices.

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