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Review Article

Challenges and Opportunities in Additive Manufacturing Polymer Technology: A Review Based on Optimization Perspective

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In the emerging modern technology of additive manufacturing, the need for optimization can be found in literature in many places. Additive manufacturing (AM) is making an object layer by layer directly from digital data. Previous works of literature have classified additive manufacturing processes into seven types. However, there is a lack of comprehensive review describing the optimization challenges and opportunities in the material extrusion process (polymer technology) and also the need for FDM polymer materials application in impeller making. In this review paper, a specific optimization method called multicriteria decision-making (MCDM) from the mathematical programming technique used in additive manufacturing polymer technology (AMPT) is discussed. The other topics such as different types of optimization techniques, applications of different MCDM tools and their applications in different fields including AM, and the optimization challenges and opportunities in AMPT particularly impeller application are discussed.

1. Introduction

Additive manufacturing (AM) has been used everywhere in the manufacturing industry in recent decades [1]. AM has many advantages such as less waste during production, lower production cost, and direct production from design data. In this, material extrusion process polymer technology is attracting more attention due to many features such as raw material availability, low cost of raw material, and low cost of production machinery [2]. The polymer raw materials are used to produce end products for many applications like automobile, medical, and civil engineering. A lot of research is being done to improve this technology, and one of the most important is operational research [3]. Operation research is a subject from the scientific mathematical technique used to make decisions in difficult situations [4]. It is divided into three categories and can be seen in Figure 1. Vijay et al. used optimization approaches to investigate the thermal conditions of several polymer composites and then ranked the composites as a result [5]. Jothibasu et al. explored the different polymer composite mechanical properties using optimization techniques, and the result selected the best composite for making an L-framed flower stand application [6].

Using the MCDM optimization technique, Singaravelu et al. performed the research on various polymer composite brake frictions. Their findings showed that the boron graphite composition is the best among the various compositions [7]. The natural fibre polymer composite was investigated by Manoharan et al. using the Taguchi optimization approach, with the goal of identifying the ideal process parameter for natural fibre [8]. With the aid of the Taguchi optimization approach, Binoj et al. examined the areca fruit natural polymer composite fibre process parameter optimization and determined the ideal process parameter [9]. Mannan et al. did research on natural polymer composite for

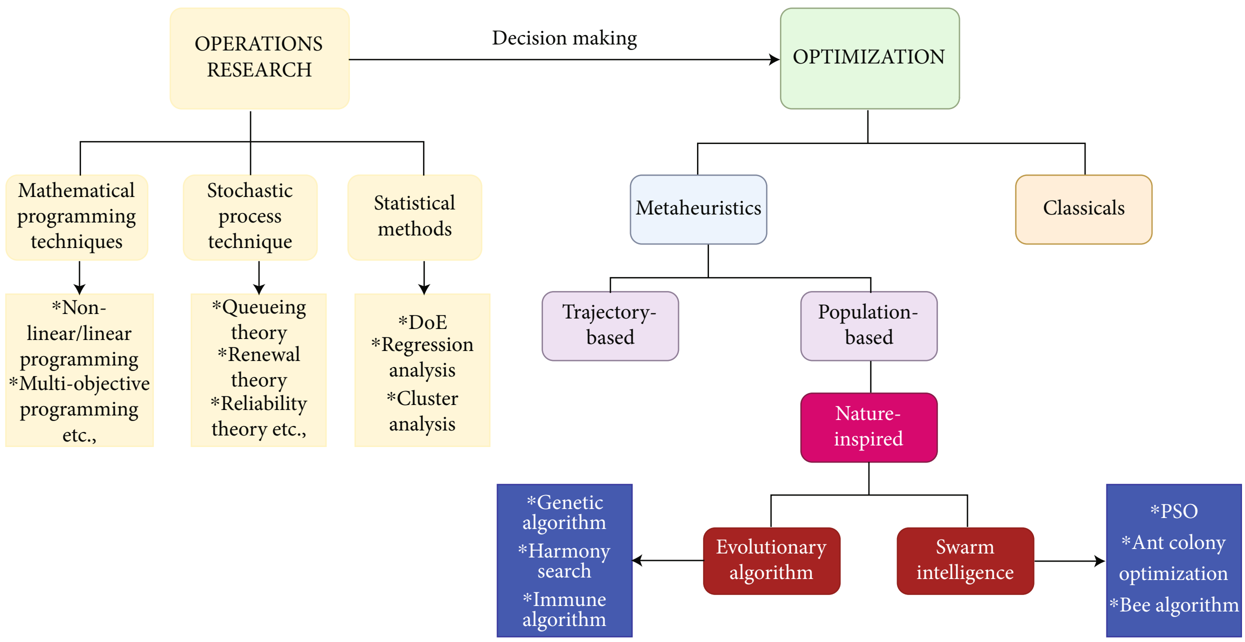

Figure 1: Classification of optimization techniques [13].

construction applications, and their findings produced a composition that was suitable for achieving a high level of mechanical strength [10, 11]. Natrayan et.al investigated the soybean oil-reinforced polymer composite shear strength with different compositions using an optimization method and their result ranked the high-strength composition [12]. Based on the literatures, optimization is the method of choosing the best and is a part of our daily life. There are several steps involved in optimization such as describing a system mathematically, finding the variables and conditions that are satisfying, describing the properties of the system, and finding the state of the system.

1.1. Optimization Techniques in Operation Research. De Leon-Aldaco et.al [13] reviewed the power converters' meta-heuristic optimization methods and classified the operation research optimization techniques as follows.

1.1.1. Mathematical Programming Techniques. In this method, the decision maker's opinions are converted into numerical values and solved with a decision matrix, for example, MCDM (multicriteria decision-making) and linear and nonlinear programming.

1.1.2. Stochastic Process Techniques. This method application is known by previous researchers to give an approximate solution, for example, queuing theory and renewal theory.

1.1.3. Statistical Method. This method is used to evaluate the experimental results and select the appropriate one, for example, DOE and the Taguchi method.

From this, the application of MCDM methods in additive manufacturing' material extrusion process (polymer technology) has very less research only carried out. Therefore an extensive review of MCDM and also a few DOE methods are proposed to optimize problems in the additive manufacturing material extrusion process. In the first step, MCDM and DOE optimization methods, additive manufacturing, and, especially, the material extrusion process can be seen. Then, the optimization challenges and opportunities in additive manufacturing polymer technology are explained in detail. More specifically, the novelty of this research is focusing on optimization in additive manufacturing polymer technology in impeller applications. Finally, the summary and conclusion show how well the research purpose was accomplished.

1.2. MCDM (Multicriteria Decision-Making). MCDM is a method of selecting a suitable alternative from more than one alternative [14]. Previous researchers have applied this method to complex decision-making situations in many fields. The MCDM technique has been used in many names in previous literature such as multicriteria decision analysis (MCDA) [15], multiobjective decision analysis (MODA) [16], and multiattribute decision-making (MADM) [17]. Stojcic et al.'s [18] review explored how the MCDM method has been widely used in two ways, like qualitative and quantitative research, by previous literature. Figure 2 describes the hierarchy of the MCDM method and more details are given in Section 3. MCDM tools are AHP (analytical hierarchy process) [19], TOPSIS (technique for order of preference by similarity to ideal solution) [20], ANP (analytical network process) [21], BWM (best worst method) [22], FAHP (fuzzy analytical hierarchy process) [23], COPRAS (complex proportional assessment) [24], and PROMETHEE (preference ranking organization method for enrichment of evaluations) [25]. In this, a pairwise matrix is created based on the opinions of the decision maker, and it is converted into numerical values from 0 to 9 (based on the MCDM tool/technique) [26]. Then, the created pairwise matrix is evaluated by basic steps like criteria weight, consistency ratio, and random

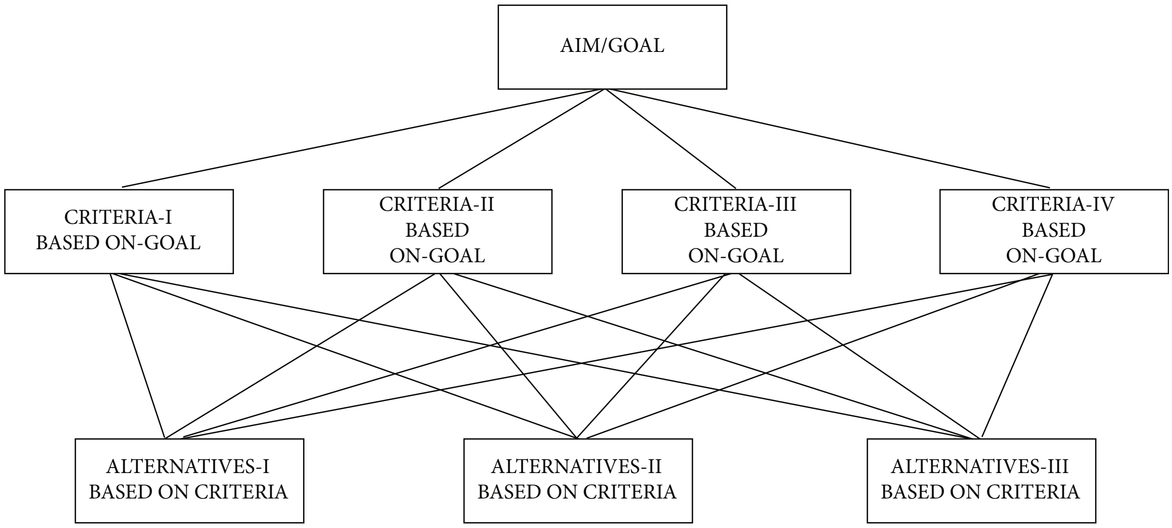

Figure 2: Hierarchy structure of multicriteria decision-making technique.

index [27]. Finally, the alternatives are ranked based on the decision matrix and priority values. On the basis of ranking, the necessary alternative is selected by the decision-maker.

1.3. DOE (Design of Experiment). The design of the experiment is considered as an optimization technique that helps to analyze the data by conducting an experiment easily through knowledge and techniques and to find its correlation [28]. DOE is a structured technique used to find the relationship between input and output variables [29]. Also, it is used to find which parameter most influenced the result. DOE is used in many fields like agriculture [30], engineering [31], and defense [32]. Three such DOE strategies have been used by previous researchers like examining multiple factors simultaneously [33] and examining multiple factors together [34], and one factor is examined at a time [35]. Anderson and McLean [36] have classified the DOE as the factorial design (finding main effects on prices), response surface design (finding the maximum and minimum response of various factors), mixture design (finding ideal proportion in mixture processes), and optimal design (used to find sufficient details).

Factorial design is divided into two categories such as full factorial design (experiment conducted for all factors and levels) and fractional factorial design (experiment conducted only for certain combination levels), and the Taguchi design is also a type of factorial design. It is also believed that sustainability can be achieved through the use of optimization techniques in many fields. Additive manufacturing is considered to be a growing field in the current manufacturing industry, and also, the optimization needs to find a lot of processes [37].

1.4. Additive Manufacturing. The contribution of additive manufacturing in the manufacturing sector has attracted a bit more attention in recent times as compared to conventional manufacturing [38]. The main reason for this is many advantages such as lightweight, low material wastage of material, low cost, less lead time, low emission, and facilities that can easily produce hard material [39]. As proof of this, the use of additive manufacturing in forming, castings, etc. industries has increased gradually [40]. It consists of seven methods as shown in Figure 3 with its modern technology and raw materials. Liquid polymer, discrete particle, molten material, and solid shield systems are several types of AM technology. In this binder jetting, 3D printing, ink jetting, S-print, and M-print technology are used in which metal polymer and ceramic raw materials are used. The vat photopolymerization process uses stereolithography and digital light processing technologies and uses photo polymer and ceramics raw materials. The sheet lamination method uses ultrasonic consolidation and laminated object manufacture technology and hybrid metallic ceramic raw material. The material extrusion process uses FDM technology and polymer raw material. Material jetting uses polyjet, ink jetting, thermojet technology, and wax raw material. The powder bed fusion process uses SLS, SLM, EBM, and DMLS technologies and raw materials like polymer, ceramic powders, metal powders, and ceramic. Finally, in direct energy deposition, technologies such as LP-DED, LW-DED, AW-DED, and EB-DED and metal, metal alloy, wire, powder, ceramic, and polymer raw materials are used. However, the material extrusion method only has the lowest technical cost and raw material costs. Although many researchers have conducted many researches on the material extrusion method, some research gaps can be seen in the optimization area. In particular, this review article describes current problems such as the selection of production machinery and supplier selection.

1.4.1. Material Extrusion Process (Polymer Technology). In the material extrusion process, the filament (polymers) is passed through a hot extruder to form a final product layer by layer according to the given (.STL) design [42]. Material extrusion is a method with very low-cost raw material and machine costs compared to all other AM processes. The lower cost of raw materials and machinery gets more

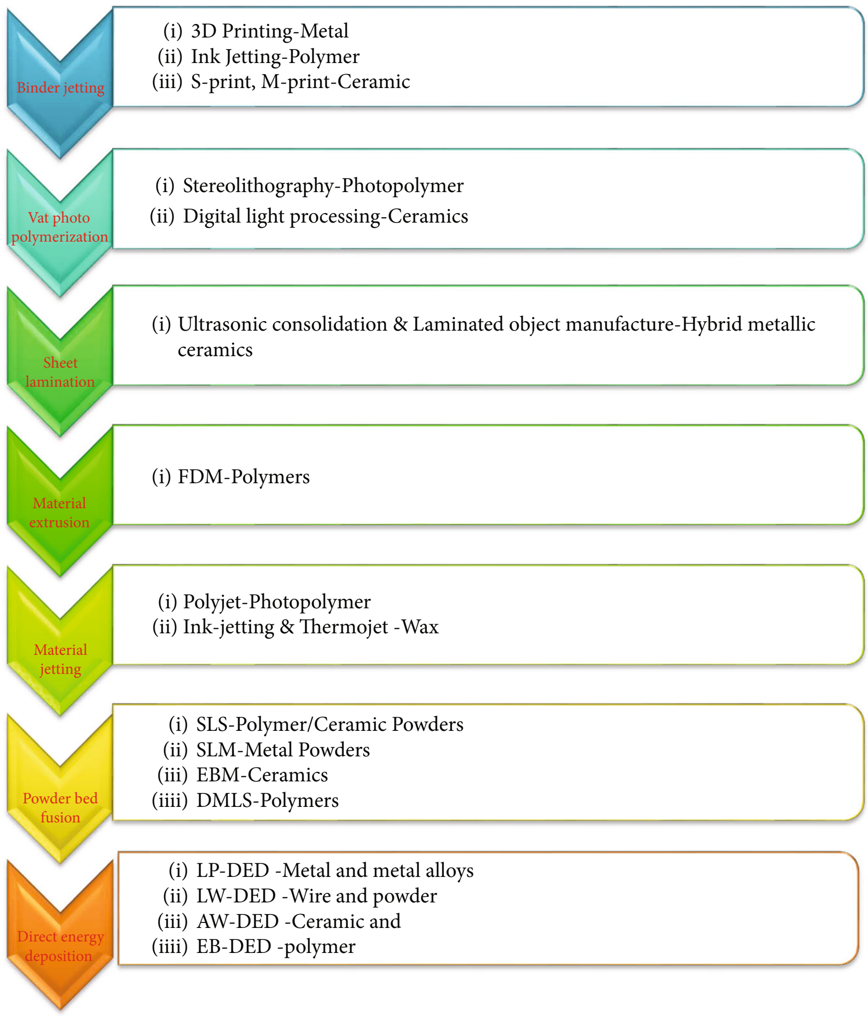

Figure 3: Different processes/technologies/materials in additive manufacturing [38–41].

attention in the market for increased producers and users of AM. Thermoplastic polymers like PLA (polylactic acid) and ABS (acrylonitrile butadiene styrene) are used as raw materials in the form of filament and the standard filament wire diameter used as 1.75 mm [43]. FDM machine and their important components such as filament spoof, filament, extruder, melting zones, molten filament, and object in the build platform are shown in Figure 4. Each polymer raw material has its unique properties, for example, PLA is a biodegradable material [44], and ABS is a toxic material [45]. So, it is used in many applications like medical [46], pipe making [47], and impeller making [48] based on the raw material properties. A previous literature review revealed that the FDM-fabricated impeller of the rotodynamic hydraulic pump performed similarly to the original impeller.

Filament spoof is the roll of polymer filament in the wire format, and it is connected with extruders. The extruders have heated with the melting zone when the wire filament passes through the melting zone.

Printing parameters play an important role in the material extrusion 3D printing process. One of the most important printing parameters is the infill pattern such as

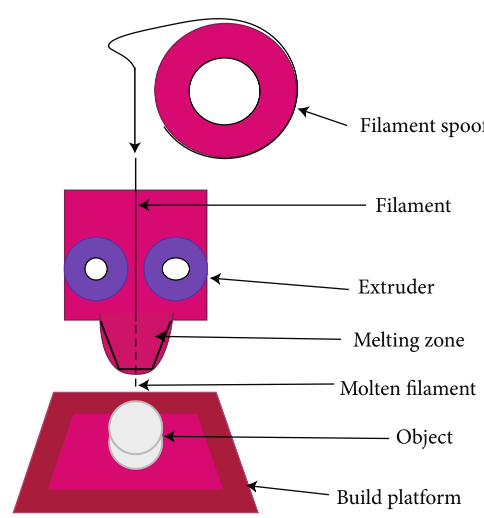

Figure 4: Material extrusion process (software: draw.io-online free software).

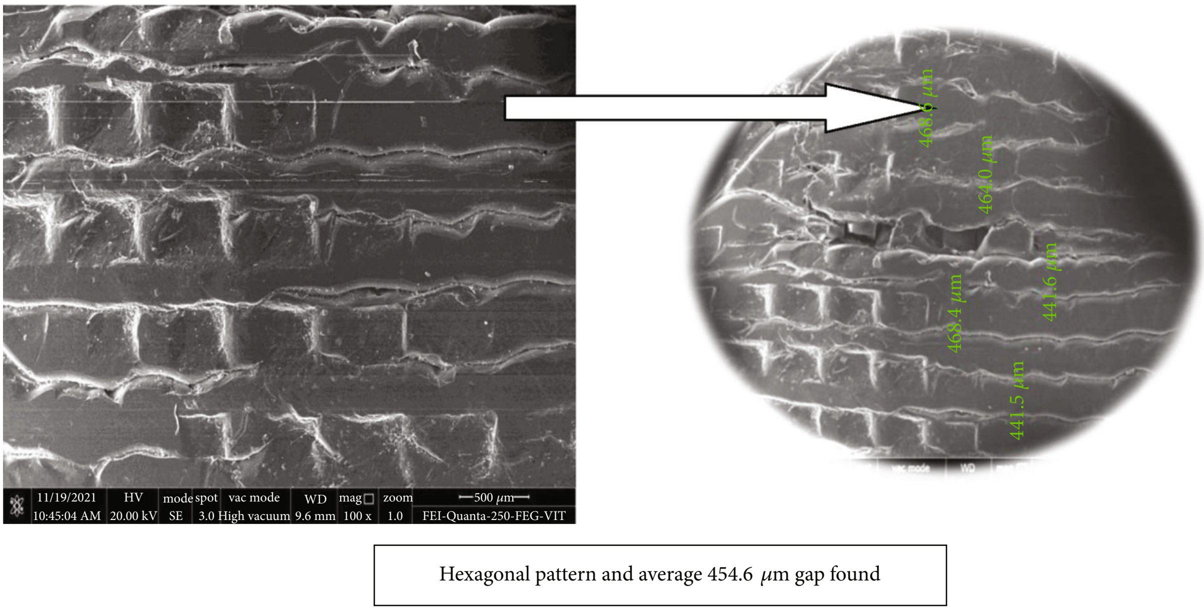

Figure 5: Hexagonal pattern morphology.

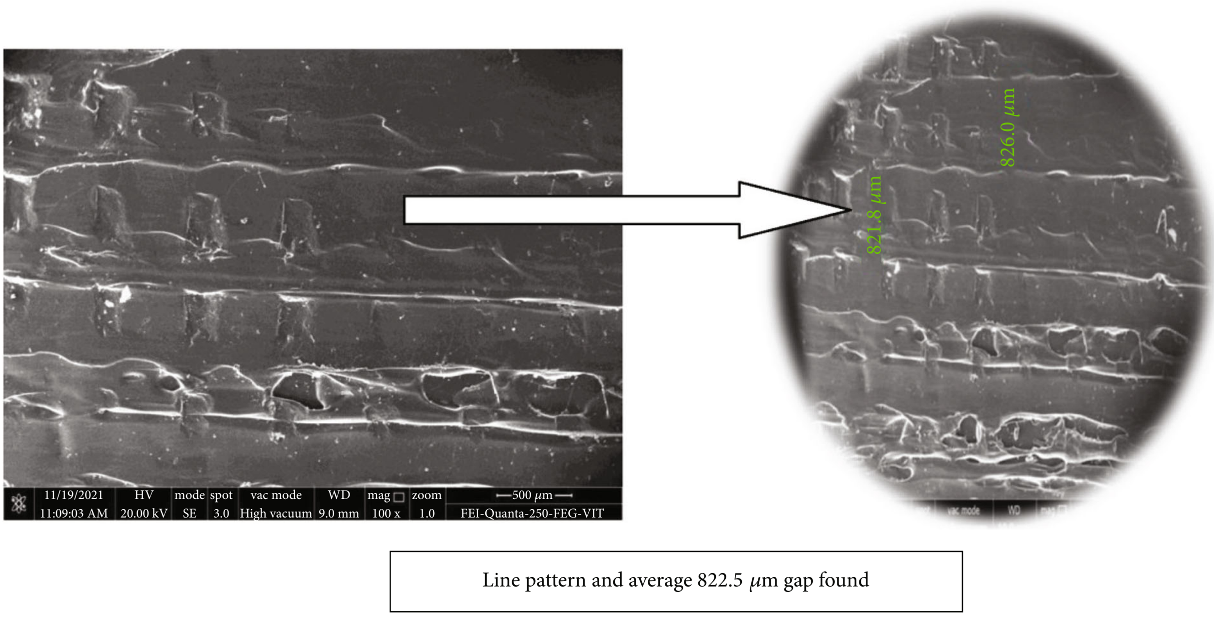

Figure 6: Line pattern morphology.

hexagonal, line, and triangle printing in which Figure 5 shows the microstructure of the hexagonal pattern. In this, the printing shape and distance of the hexagonal pattern and the average gap between the two layers are calculated as 454.6 μm.

Figure 6 illustrates the microstructure of the line pattern and the 822.5 μm average spacing for two adjacent lines.

Finally, Figure 7 describes the microstructure of the triangle pattern and the 612.7 μm average spacing between the two layers. These three remarkable patterns were produced by an FDM printer using PLA filament and described with the help of a FESEM image for this research. Based on this result, the hexagonal pattern is recommended for production in the material extrusion method because it is observed only for a low construction gap between two layers. Also, the solid infill pattern is having more conductivity after the spatter coating. Therefore, the microstructure of the solid infill pattern is unable to find with spatter coating. However, the remaining patterns can be selected according to the infill percentage, user's application, etc.

Figure 8 illustrates the entire additive manufacturing process and some important material extrusion raw materials and their applications.

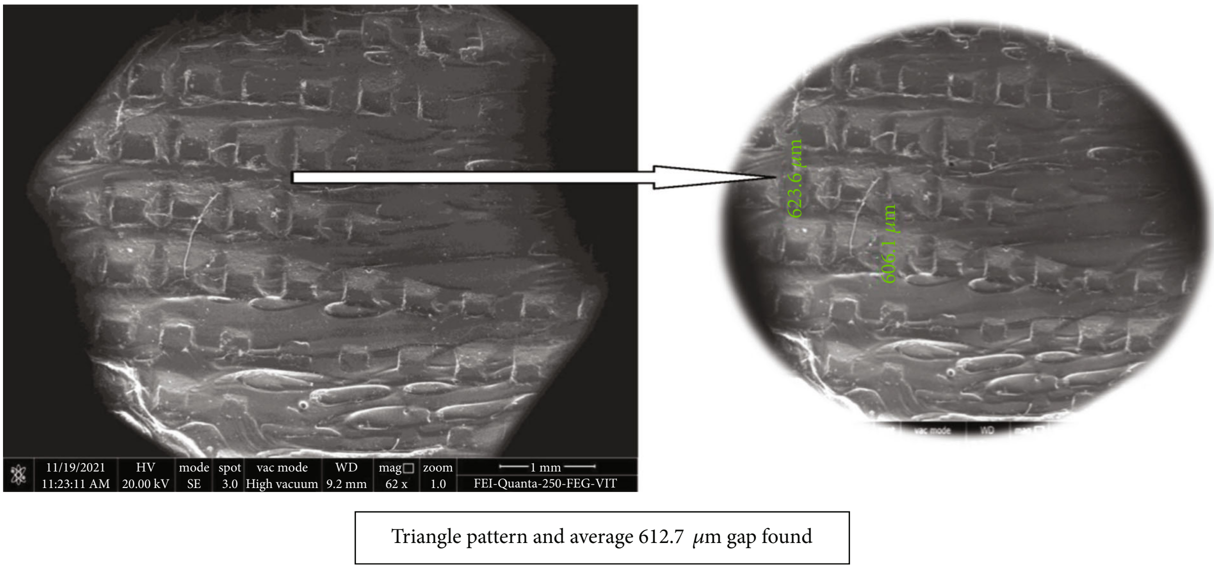

Figure 7: Triangle pattern morphology.

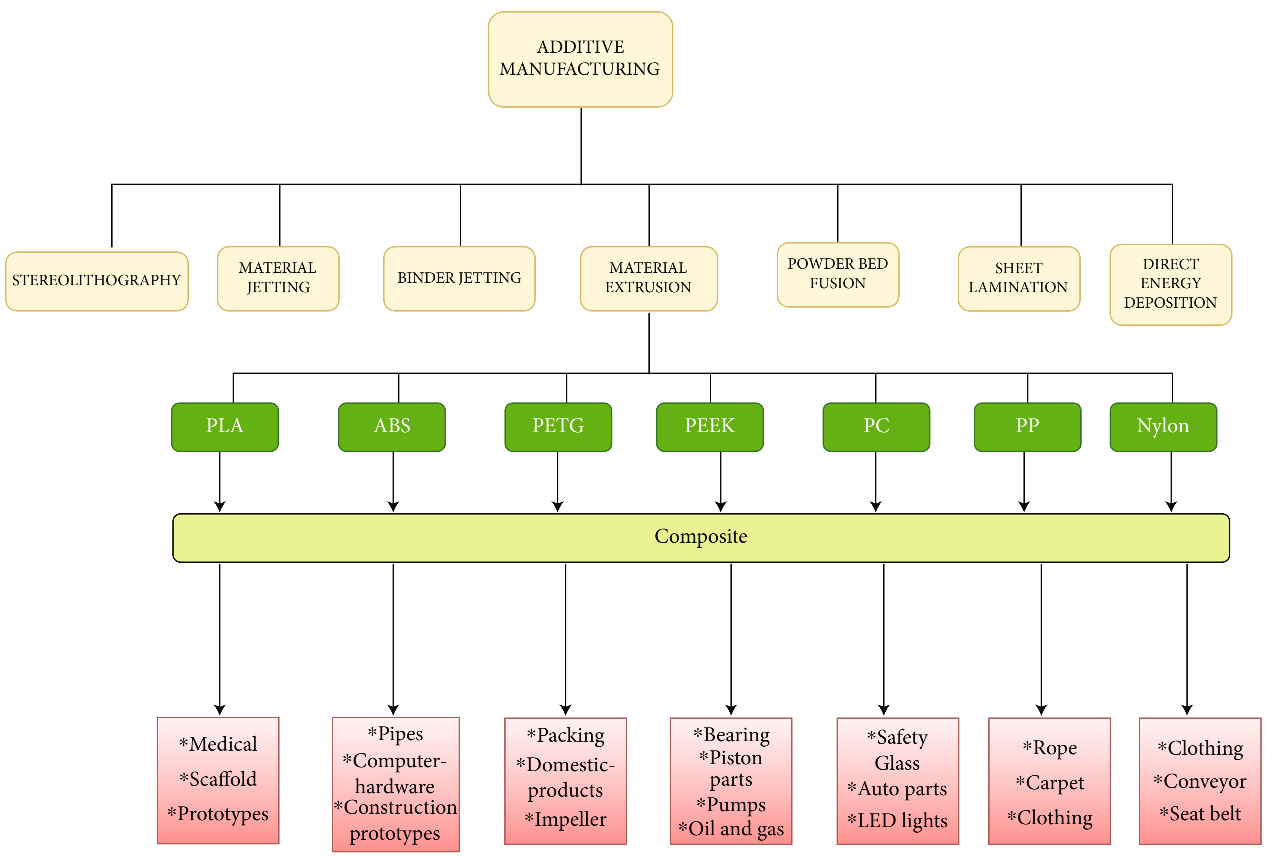

Figure 8: Additive manufacturing process and material extrusion's raw material with the application.

2. Optimization Challenges in Additive Manufacturing Polymer Technology

Optimization is the process of selecting the desired or suitable one from among several alternatives [49]. As illustrated in Figure 9, resource, weight, cost, and process are chosen for the optimization ways. The current optimization problem identified in the material extrusion process is as follows.

2.1. Machine Selection. The sales of similar FDM machines with slightly different features are increasing day by day in the market [10, 16, 50, 51]. Also, choosing the most suitable

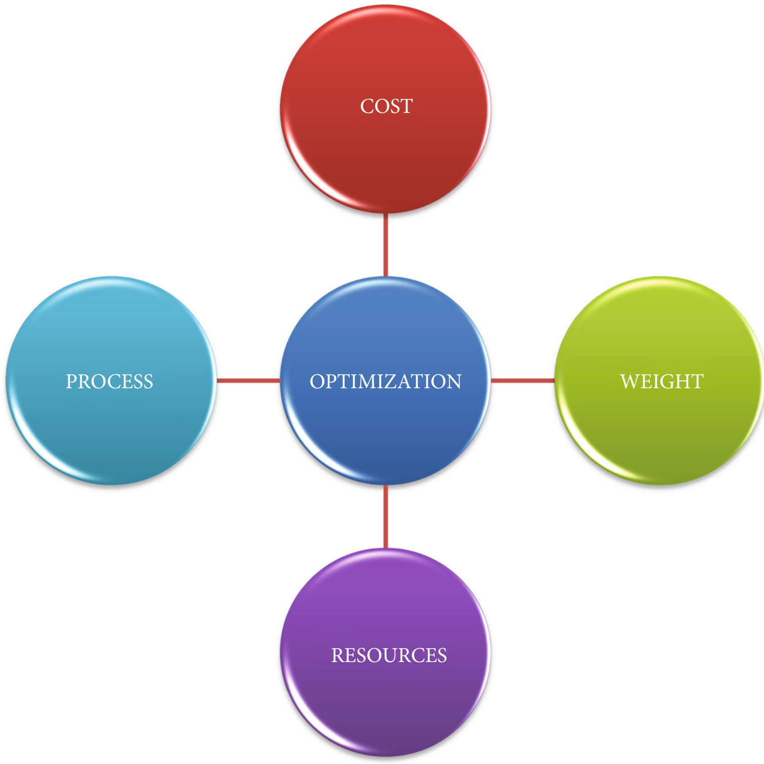

Figure 9: Different applications of optimization.

machine for the users from the various machines that have got the same sales rating on the online platforms is considered to be the current challenge so commercial companies can use optimization techniques to reduce investment and end product costs. Figure 10 described the optimization problems in the material extrusion process and proposed optimization tools.

2.2. Supplier Selection. FDM machine users suffer a lot because after purchasing a machine, services such as repair or replacement of parts are not available properly from suppliers. Therefore, it is considered very important for wholesalers to choose distributors [10, 17, 52, 53] who provide proper sales and service. Solving this using any suitable MCDM method would be a novelty.

2.3. Logistic Selections. 3D printing manufacturers are largely independent of production. So, logistics is a bit more expensive and takes delivery time [54–58]. Additive manufacturing can solve logistics problems when manufacturers combine production. Especially in India, known as small industries development corporations (SIDCO), governments adopt policies to consolidate clusters of similar industries. This makes logistics continuous and cost-effective. Therefore, integrating FDM commercial manufacturers is considered very important in choosing the right logistic partners.

2.4. Raw Material Selections. Large numbers of smaller molecules or repeating units, known as monomers, are joined together chemically to form polymers, which are referred to as macromolecules.

Within a single polymer molecule, the degree of order, the relative orientation, and the kind of monomer can all vary. The benefits of polymers, including their low price, flexibility of manufacture, water resistance, and suppleness, have led to their use such as industry. Depending on the manufacture, various types of polymers can be found as powders, granolas, filaments, and resins. Polymers called thermoplastic are used in the material extrusion. It is fusible when heated [59]. This review article describes the most important polymers and their properties and applications. It is a novelty to use MCDM methods to select the most suitable polymer for the user among polymers with similar uses. The various types of polymers and their applications are shown in Table 1.

2.4.1. PLA (Polylactic Acid). PLA is made from organic source sugarcane or corn starch. Its molecules are renewable so it can also be known as biodegradable material. It is often used to make medical, scaffolds, and prototypes as shown in Figure 8. Also, its melting point is calculated to be 195°C to 220°C. It is priced from INR 869 onwards in the Indian market. Moreover, PLA is not ideal for high-temperature applications. According to results from tests on creep behaviour, PLA's behaviour resembled that of a weakly cross-linked elastomer the most, which caused the creep curve to be held to a constant limit under light loads. Previous literature presented PLA as a material to consider when looking for long-term use based on their findings. Comparing this polymer to other polymers, its fair price, eco-friendly biocompatibility, and suitable physicomechanical characteristics have made it an excellent choice. [60–65].

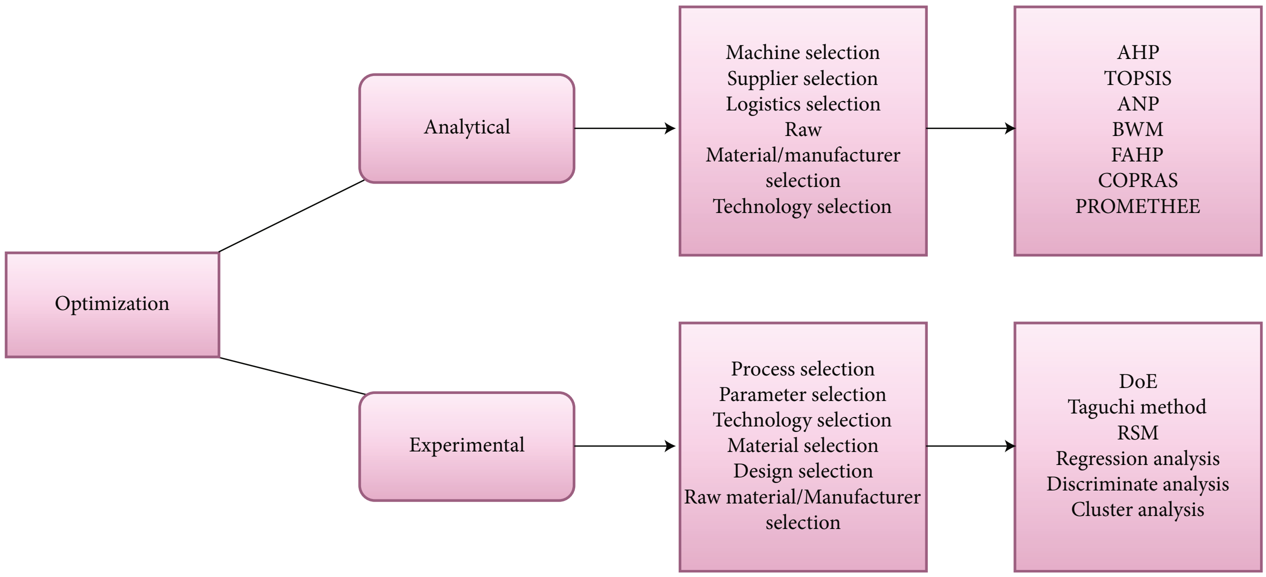

Figure 10: General optimization problems and methodology in the material extrusion process.

Table 1: Different types of polymers [84–87].

Type of polymer	Structure	Different polymer
High-performance polymers	Semicrystalline	Polyether ether ketone, liquid crystal polymer, polyphthalamide, polyphenylene sulfide, polycyclohexylenedimethylene terephthalate, and polyimide
	Amorphous	Polyethersulfone, polyethylenimine, and polyphenylsulfone
Engineering polymers	Semicrystalline	Polybutylene terephthalate, polyvinylidene difluoride, nylon, polyamide, and polyethylene terephthalate
	Amorphous	Poly(ADP-ribose), polycarbonate (PC), polysulfone, and modified polyphenylene oxide
General use polymers	Semicrystalline	Polylactic acid, polypropylene, and low-density polyethylene
	Amorphous	Polyethylene terephthalate glycol, acrylonitrile styrene acrylate, acrylonitrile butadiene styrene, poly(methyl methacrylate), polyvinyl chloride, high-impact polystyrene

2.4.2. ABS (Acrylonitrile Butadiene Styrene). ABS filament is styrene and acrylonitrile derived from polybutadiene. It is a toxic filament and is used for external use only and is also considered more suitable for higher temperature applications than PLA. As mentioned in Figure 8, computer hardware, prototypes, and pipe-making purpose ABS are used. The ABS melting point is calculated to be 210°C to 240°C. Previous research on ABS's mechanical characteristics in the manufacture of impeller pumps demonstrated that ABS can be thought of as a good choice for the manufacture of impellers [65–67].

2.4.3. PETG (Polyethylene Terephthalate Glycol). Chemical impact resistance hardness, ductility, and transparency are considered the main properties of PETG. As mentioned in Figure 5, it is used to make packing, domestic products, impellers, etc. PETG melting point is used between 220°C and 240°C. Previous research examined the use of PTEG impellers in pump-jet modules (PJM). A PTEG impeller exhibited the necessary characteristics while operating for this application, taking into account the 1200 rpm rotational speed that produced a thrust of 14 N. [68–71].

2.4.4. PEEK (Polyether Ether Ketone). PEEK is a colourless organic thermoplastic with excellent fire performance and excellent mechanical strength. As mentioned in Figure 8, PEEK is used for bearing, piston parts, pumps, oil, gas, etc. Moreover, its melting point is calculated at 230°C to 250°C. Extensive researches have focused on the use of PEEK impellers in centrifugal pumps for medical applications because of the enhanced strength and durability they provide [72–76].

2.4.5. PC (Polycarbonate). Bisphenol A is a toxic substance in polycarbonate, so it is used for external use only. However, PC has slightly higher strength and stiffness than other polymer filaments. As mentioned in Figure 8, it is used for safety glass production, auto parts, and led light production. PC melting point is used between 250°C and 285°C in the FDM printers [2, 77–80].

2.4.6. PP (Polypropylene). PP is lightweight, flexible, chemical resistant, and tough. Therefore, as mentioned in Figure 8, it is mostly used for rope, carpet, clothing, and packing, and its extruder melt temperature is calculated from 220°C to 250°C. Also, PP is slightly more flexible than PLA [81–83].

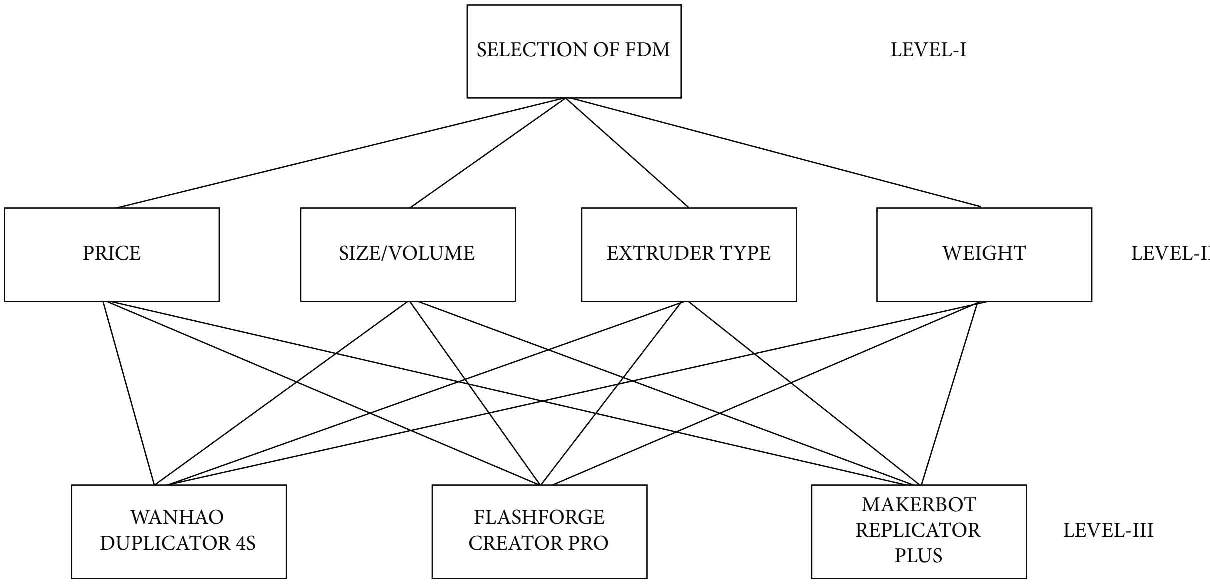

Figure 11: Hierarchy structure of machine selection problem [18].

2.4.7. Nylon. Nylon filament has high flexibility and high toughness. Its extruder melting point is calculated at 250°C, and also, nylon is used in clothing, seat belt, and conveyor applications as mentioned in Figure 8 [88–90].

In all polymer filament materials, composite filaments are available in the market with 90% parent polymer and 10% another polymer according to the application, for example, ABS+, ABS Premium, PLA Pro, PLA+, PLA carbon fibre, and PETG carbon fibre [91–94].

2.5. Raw Material Manufacturer Selection. The same polymer raw material or filaments are prepared by many manufacturers of different qualities in the Indian market. It is considered difficult to choose the best polymer raw material based on online ratings alone. Therefore, it is considered a novelty to investigate a polymer raw material using the optimization MCDM method based on the experimental result for different manufacturers same filament [95–97].

3. Opportunities of Optimization Techniques in AMPT

The purpose of this review article is how to solve all the optimization problems mentioned above using MCDM and the statistical method which is a common mathematical programming technique. Accordingly, Figure 2 illustrates the general hierarchy of the MCDM method, and the aim/goal means the problem to be solved. It is considered the first step in MCDM methods.

Then, the second step is to identify common criteria for alternatives depending on the objective. Finally, priority values are determined using any of the MCDM methods for the alternatives based on each criterion. Through this ranking, the alternative with the highest value is recommended to the decision-makers. This process is known as multicriteria decision-making [98–103].

For example, the hierarchy is illustrated in Figure 11, considering the machine selection problem. In which the selection of a suitable FDM machine is the aim/objective. The price of the machine, extruder type, build platform, safety guards, etc. is common criteria for alternatives. Finally, alternatives are FDM machines, namely, X (Wanhao Duplicator 4S), Y (Flashforge Creator Pro), and Z (MakerBot Replicator Plus). Moreover, if the MCDM tool called AHP is used to calculate the priority value for the alternatives, then the criteria weight, consistency ratio, random index, and pairwise matrix are found through the Saaty scale.

Then, it is confirmed whether the nature of the pairwise matrix is correct. Then, depending on each criterion, separate priority values are found through another pairwise matrix for alternatives with the help of the Saaty scale. Finally, by summing all the identified priority values, the final priority values are obtained for the alternatives. A high-value alternative is recommended to the decision maker.

Various important and significant MCDM methods and their uses in different fields can be seen in Table 2, and this method can also be done analytically (data collection—collect the opinions based on a numerical scale and solved). Therefore, in similar problem situations in the material extrusion process, the decision-maker can ease the use of the appropriate MCDM tool.

According to the statistical method, based on the experimental result, any optimization tool is applied, and a suitable solution is given to the end user. For example, taking the machine selection problem, innovative research can be carried out by producing a product on more than one machine and depending on the results, using an appropriate statistical tool. What is necessary to use the statistical tool in this is that the results obtained have distinct characteristics from each other. Statistical tools are used to make the decision-makers choose the appropriate option easily. It is worth noting that experimental optimization has been

Table 2: Different MCDM tools and their application.

Field	Purpose	Problem solved by previous literature	Applied MCDM	Reference
Transport and logistics	Selection	(i) Sustainable transport plan selection (ii) Transport infrastructure contractor selection (iii) Transport terminal location selection (iv) City logistics centre selection (v) Multimodal logistic selection	(i) WSM (ii) AHP and FAHP (iii) Fuzzy Delphi, fuzzy Delphi ANP, and fuzzy Delphi VIKOR (iv) Fuzzy MAGDM (v) DEMATEL-MAIRCA	[104–108]
	Evaluation	(i) Urban section roads evaluation (ii) Uncertain environment sustainable transport selection (iii) Logistics third-party evaluation	(i) AHP (ii) Fuzzy TOPSIS (iii) Fuzzy SWARA and fuzzy MOORA	[109–111]
	Others	(i) The sustainable urban transport project screening purpose (ii) The best-used component collection identification purpose	(i) AHP (ii) AHP-EW and MABAC	[112, 113]
Civil engineering and infrastructure	Selection	(i) Optimum solution selection for RC building and existing masonry construction (ii) Material selection projects (iii) Method selection for highway selection (iv) Location selection (v) Effective delivery system selection in power plants	(i) TOPSIS, ELECTRE, and VIKOR (ii) FEAHP (iii) ANP (iv) Rough BWM and rough WASPAS (v) SMART	[114–118]
	Evaluation	(i) Urban drainage plan evaluation (ii) Sewer pipe materials evaluation comparison and evaluation (iii) Green building construction evaluation	(i) Adaptive AHP, entropy, and TOPSIS (ii) AHP (iii) DEMATEL, ANP, and ZOGP	[119–121]
	Others	(i) Sewerage pipes sustainability analysis (ii) Worst passenger car parking indication	(i) AHP and MIVES (ii) SAW, TOPSIS, COPRAS, and AHP	[122, 123]
Energy	Selection	(i) Power generation selection (ii) Wind farm location selection (iii) PV project location selection	(i) LNN PW-CODAS (ii) Rough BWM and rough MAIRCA (iii) AHP	[124–126]
	Evaluation	(i) Wind farm sites evaluation (ii) Renewable energy source evaluation	(i) FAHP and fuzzy TOPSIS (ii) AHP and TOPSIS	[127, 128]
	Others	(i) Estimate thermal power plant quality	(i) ASPID	[129]
Supply chain Management	Selection	(i) Sustainable supplier selection (ii) Thermal power plant equipment supplier selection	(i) FPP and fuzzy TOPSIS (ii) Fuzzy entropy-TOPSIS	[130, 131]
	Evaluation	(i) Supplier performance evaluation (ii) Sustainable supplier selection evaluation	(i) Fuzzy Delphi, DEMATEL, and DEMATEL ANP-VIKOR (ii) AHP, VIKOR	[132, 133]
	Others	(i) Oil and gas industry sustainability classification	(i) ELECTRE TRI	[134]
Additive manufacturing	Selection	(i) Machine selection (3D printers) (ii) Technology selection (SLM, SLS, and FDM) (iii) Material selection (appropriate raw material from a similar property material)	(i) Analytical hierarchy process (AHP) (ii) Best worst method (BWM) (iii) Fuzzy technique for order of preference by similarity to ideal solution (TOPSIS)	[10, 16, 41, 135]

Table 2: Continued.

Field	Purpose	Problem solved by previous literature	Applied MCDM	Reference
	Evaluation	(i) Printing parameter optimization	(i) Fuzzy AHP-TOPSIS	[24, 25, 40]
	Others	(i) Comparison of different manufacturing processes	(i) AHP	[19]
Other engineering disciplines	Selection	(i) IC engine optimum biodiesel blend selection (ii) Agriculture product strategy selection (iii) Particulate matter sensor selection	(i) Fuzzy AHP-TOPSIS, fuzzy AHP-VIKOR, and fuzzy AHP-ELECTRE (ii) DEMATEL and MABAC (iii) DEMATEL and VIKOR	[136–138]
	Evaluation	(i) Evaluating the level of sustainability (ii) Site evaluations	(i) AHP (ii) WASPAS-SVNS	[139, 140]
	Others	(i) Sustainable environment design proposal	(i) ELECTRE III	[141]

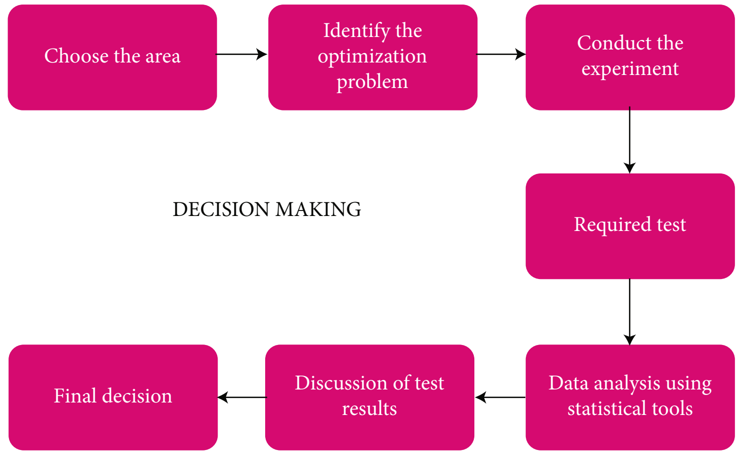

FIGURE 12: Steps of an experimental optimization tool.

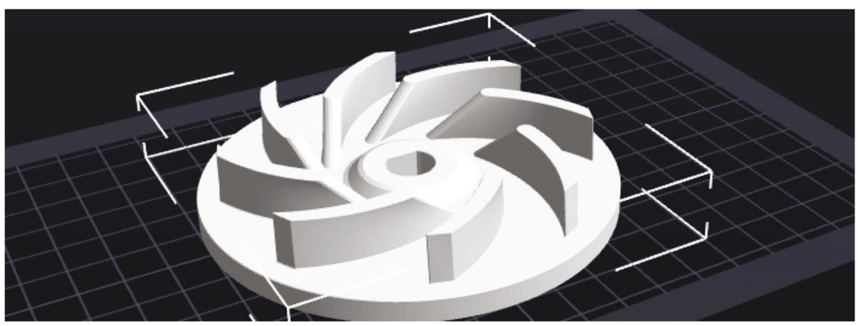

FIGURE 13: Polymer impeller CAD design into slicing softer image (online free software: Flashforge 5.0).

extensively explored by previous researchers [142–148]. Figure 12 explores the experimental optimization procedure.

4. Material Extrusion Polymers in Impeller Application

An impeller is considered the main part of turbomachinery. The work of the impeller is to convert the velocity of the working fluid into pressure due to the very fast rotation [149]. Impeller application also plays an important role in many fields, for example, pumps [150], medical [151], automobile [152], and aerospace [153]. In injection moulding and other traditional impeller production techniques, raw materials such as polymeric, metal glass, stainless steel, titanium, aluminium, and nickel alloy are frequently utilized. Metal impellers achieve only slightly lower efficiency due to their heavy weight. Efficiency can be increased when using thermoplastic polymer impellers with low weight and high strength. The main kinds of thermoplastics are amorphous and semicrystalline. Different thermoplastic polymer forms like powders, granules, and filaments. The benefits of this class of polymer include its capacity to be recycled, high ductility, and impact resistance when compared to thermosets. The modulus of the thermoplastic item is typically less than 5 GPa, though this might vary based on the object's chemical constitution and production process. At present, the AMPT method is used to produce the final product directly from the given design in less time and more accurately. Polymer impellers were first used in the heating ventilation and air conditioning (HVAC) and microorganic ranking cycle (mORC) and refrigeration systems. Polymers like PEEK, PLA, and ABS have been used for the first time for impeller application. The ABS impeller met the anticipated operating condition taking into consideration the working environment and safety factor (FoS), which is the ratio of elastic modulus to the maximum equivalent stress. One of the key benefits of employing this polymer was the ability to manufacture the impeller at a lower cost by using ABS, which enables the mass production of mORC. It is also noteworthy that only PEEK-GF30 [154] has been used in the composite rotary component. Impellers are manufactured using a minimal amount of polymers when using an additive manufacturing process.

PLA has been utilized in the manufacturing of impellers for pumps and marine applications. However, since PLA and ABS are both easily accessible, these two categories of thermoplastic have been investigated in various experiments as pump impellers. Pump and compressor applications for a variety of industries, including the automotive, aerospace, and medical sectors, place a high value on PEEK impellers. Pump and mORC applications have both utilized PETG impellers. For the production of pump blades, this polymer was chosen because of its excellent water resistance and biodegradability. Metals have been replaced by carbon fibre polymer-matrix composites, one of the most effective families of materials. These kinds of composites can be divided into categories based on the type of fibre condition, such as short or continuous. Epoxy, which has been frequently utilized as a matrix for these composites, is a thermoset, and PPS, PEEK, PI, and PEI are thermoplastics. In the case of a microturbine generator, a PEEK carbon-reinforced impeller was suggested as a suitable material to replace an aluminium impeller. However, the time required to make an impeller using many polymers (directly or compositely blended like PLACF and PETG-CF) in the market, changing the printing parameters, making changes in the manufacturing geometry, etc. will be an optimization challenge and opportunity in AMPT for impeller application.

Figure 13 shows the flash forge software for slicing the impeller design. Choosing optimal process parameters using the MCDM method will be a novelty for future researchers because each polymer filament has different process parameters like different melting temperatures, printing speed, and infill.

5. Summary and Conclusions

In this review article, mathematical programming MCDM and statistical method optimization problems in additive manufacturing material extrusion are presented. In more than 147 AM material extrusion-related 3D printing selection, supplier selection, logistic selection, raw material selection, main properties of raw material (polymers), and raw material manufacturer selection, interesting new novel problems through this conclusion provide useful information to the researchers. This review article also describes the optimization challenges and opportunities in the use of polymers, especially in impeller applications. Although material extrusion polymers have many sectoral applications, only significant research has been done on impeller applications. Likewise, optimization challenges such as selecting the appropriate FDM and selecting the appropriate raw material have been highlighted. Moreover, the optimization opportunity is described with an example based on mathematical programming techniques and statistical techniques. Many fields like transport, logistics, energy, civil engineering, and other engineering disciplines have achieved sustainability by using optimization methods. It describes several applications of MCDMs so that future researchers can easily find the appropriate technique to suit their application. Finally, today's increasing use of optimization in all fields reflects its importance and nature of sustainable decision-making.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

There is no conflict of interest.

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