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A Review on Minimization of Construction Time on Fused Deposition Modelling by Analyzing Process Parameters

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A B S T R A C T

AM is used in the automotive, aerospace, pharmaceutical, sports, construction, food industries and in all production units where production is faster and faces difficulties in producing extremely complex shapes. AM reduces the product cycle time from months to days and from days to hours. However, the cost of the product is higher due to the construction time. The transition from faster to faster is the urgent need to expand AM applications to the next level.The supports are not permanent parts of the final assembly. Therefore, a set wastes material when using too many media. In addition, adding media means that the product will take longer to print (more material = longer), and the media increases printing time by up to 100% in extreme cases, and the cleaning time required after removing media creates a big difference. in partial construction. Therefore, reducing or avoiding supports during the construction of a part becomes important in reducing the construction time. An experimental study would be essential to understand and control the complicated relationship between input process parameters and output response parameters. The developed algorithm reduces the construction time of the part in FDM. This would help increase the productivity of the manufacturing unit that produces components using FDM.

Keywords: Additive Manufacturing, Rapid prototyping, CAD,STL file, Deposition, Optimization

1. INTRODUCTION

Today, Industries has begun using RP systems to manufacture its components. In particular, the role of the AM is important in the design and production of products. However, it lacks design principles, production guidelines and process standards. To move to the next level of research in AM, it is essential to document the core questions, trends and associations.

Yong Huang et al. (2015) summarized the current trend of AM, the future sphere, research gaps and requirements, suggestions for associated technologies, industry-institute collaboration, knowledge transfer, teaching-learning and training process. They documented the information gathered in the workshop "Frontiers of research and education FA - 2013" held by the national scientific foundation.

Wei Gao et al. (2015) analyzed the events around AF, current difficulties, discoveries and future developments in AF. They also discussed the evolution of AM, the attributes of the process and the emerging areas of AM, such as profile design, materials processing and the teaching-learning process. In addition, they mentioned potential areas, such as a printed model, that are revolutionizing modern research and planting the seed for new exploration opportunities.

1.2 SLICING

Slicing is the process of cutting the CAD model and the 2S into different 2D transverse contours to facilitate the construction process. The cutting process requires cutting the STL file, 2S data, and layer thickness into thin layers.

1.3 Studies on Slicing

Suchada Rianmora & Pisut Koomsap (2010) applied an image processing method for adaptive direct cutting to find the layer thickness required for each cut. The method also suggests different appropriate positions for cutting a CAD model. To achieve this, the flat views of the model, taken at two different orthogonal angles, were converted to edge images. Cut positions were determined based on the complexity of the edge images and sent to the cutting software for cutting. Two different approaches were used for adaptive direct cutting, namely, uniform cusp height and uniform direct cutting. The implementation of the paper was done using LabVIEW. This approach would provide optimal construction time by reducing the number of layers without compromising the quality of construction. This cutting approach can be performed with any CAD software, as it only supports CAD model images, not real CAD models.

Topçu et al. (2011) proposed an STL file cutting algorithm that cuts the STL file and generates the G code as part of the process planning. They focused on developing open source software that is available online for free. The developed program was tested using many complicated 3D profiles in the computer's simulated numerical control software.

2..1.3 Summary of slicing studies

The problems found in the cutting studies are as follows: uniform surface finishing, scale error, longer cutting time, tolerance adjustment, insulation problem, dimensional accuracy, loss of complicated characteristics, etc. To overcome these problems, the researchers studied all available cutting strategies and developed different computerized algorithms, such as adaptive cutting based on regions, adaptive direct replacement technique, adaptive cutting strategy using rectangular edge layers, new cutting that applies unilateral tolerance of the whole part and the stratification algorithm that uses selective shading, adaptive cutting and direct strategies. In addition, they developed various techniques to calculate the volumetric error and the thickness of the layer, also to generate the G code.But the errors caused when creating an STL file, the problems in the rectangular edge layers, the increase of the execution time of the program due to the cut at each PDO, the requirement to change hardware while creating complex features and the change of tolerances were not discussed in detail.

1.3 PART ORIENTATION

Submitting the material to build a part in an RP system can be done in any desired orientation. This study addressed the influence of partial orientatio or partial submission orientation (PDO) on (i) several output responses (ii) construction time only and (iii) supporting structure.

1.3.1 Influence of PDO on Multiple Responses

Hambali et al. (2010) compared the properties of materials measured in parts built by the FDM system and analytical values using FEA for different PDOs. Due to the force applied to the parts produced in the MA, there were variations in the properties of the material. The deformation behavior of the sample pieces constructed in different orientations was also compared with the FEA results. The paper promoted additional research in design, analysis and manufacturing.

Paul and Anand (2011) analyzed the association between part orientation and cylindricality. They used the analytical method, the CAD model and the STL file to determine the cylindricality error. In addition, the authors used a graphical method to recognize the optimal regions of orientation of the parts for several cylindrical characteristics where the error of cylindricity is minimal. The relationship between PDO, cylindrical tolerance and a significant shape tolerance was investigated by an analytical method, simulating the CAD file and an STL file. Amar and Pande (2012) considered the weighted average factor of different performance measures for PDO optimization. The GA based methodology was developed in the optimization process after casting the CAD model and tested in SLS several times to obtain accurate results.

Mohammad Taufik and Prashant K Jain (2013) studied different methods used to identify the optimal PDO. The study was conducted taking into account the various relevant criteria and issues. The influence of PDO on built parts and quality improvement techniques were also discussed in the paper. Improving the accuracy of the part in the MA is very important, but the work done in this area has been minor. Sagar et al. (2014) studied the vital factors used in AM to produce wooden models and metal castings. Construction time, surface finishing, part accuracy and construction cost were the factors involved in this study. Commonly used sand molds, which consume more production time and installation costs to produce medium and small parts. The authors used RP techniques to overcome the problems mentioned above and to produce models with high precision and good finish. this was tested by comparing the results produced by RP techniques and conventional modeling methods.

Giovanni Moroni et al. (2015) worked to improve the accuracy of the parts. However, they treated all components together as a single set and the main focus was on the PDO; in particular, the connecting element, such as the universal coupling, was taken as a case study to validate the procedure developed by them. Sankara Narayanan G (2015) established a mathematical relationship for the process of processing electrical discharge of wires using an artificial neural network (ANN). The model described the relationship of the input parameters with the output responses of the samples. It was developed and trained by ANN and the Levenberg-Marquardt algorithm that is used to train a neural network before 3-7-11. The algorithms were tested on data and the predicted values were compared with the empirical values. The weights needed to improve the algorithm were included. The tests were performed repeatedly to reduce the average square error of the root until the target results were reached. Once the test phase was completed, the test data were analyzed with the errors produced.

Bastian Leutenecker-Twelsiek et al. (2016a) prepared design and manufacturing guidelines for the continuous production of parts. The designer made appropriate use of the design principles and the different features of the process with the help of the guidelines. Selecting PDOs at an earlier stage minimizes the number of iterations and post-processing. The structure of the guidelines clearly defines the process requirements, design rules and principles. Furthermore, the effect of the PDO on the guidelines was analyzed and its importance was discussed. A test piece was made according to the guidelines, and the guides proved to be very useful in design. Bastian Leutenecker Twelsiek et al. (2016b) addressed the influence of PDO on surface quality and design through design feature algorithm. The algorithm used ray tracing and convex body approaches to find a set of orientations after weaving the piece and identifying the outer surfaces of the piece. Helps the user reduce the structures in the console to limit the 2S requirement.

Yee Ling Yap et al. (2017) established an organized approach to examine the AM process of injecting material using special purpose devices. It is important to establish design and production guidelines for design, manufacture and assembly using AM. The capacity of the material injection process was characterized by three parts designed for various uses. The influence of the material injection parameters on the accuracy of the part size was determined by studying the metrological results using reference points. The unique design constraints of the features were framed and verified for different PDOs.

1.3.2 Influence of PDO on Build-Time

Mircea Ancau and Cristian Caizar (2010) developed an algorithm for RP processes that determines the profile of each layer and the corresponding construction time. They have obtained a mathematical expression for the calculation that helps the user to list a set of optimal guidelines for the part being built. They used LOM and SLS RP technologies to conduct case studies to validate the results. Waghchore et al. (2012) found the best rotation angle to obtain the construction time in FDM. Catalyst cutting software was used to layer the model and the test pieces were fabricated with a pitch angle of 15°. The orientation angles were graphically presented with the experimental results, such as construction time, number of layers and materials of parts and support.

Kuthe et al. (2012) demonstrated the reduction of waiting time in a rotor with disc rupture and an engine intake manifold. The above-mentioned components were manufactured by the investment foundry (block type) and RP trial. The quality of the prototypes produced and other features demonstrated that the PR process was economical in terms of cost and overall construction time. Jin et al. (2013) proposed a combinatorial adaptive method of tools to increase dimensional accuracy and AM manufacturing time. The proposed algorithm builds the layers using a NURBS curve along a zig-zag path to quickly complete the piece. The introduction of NURBS-based coating manufacturing has increased the accuracy of components. Also, the speed of the extruder was increased to obtain the shortest construction time. The approach was validated by performing experiments on five test pieces that have different geometries.

Zhang et al. (2016) developed a multi-material deposition technique using continuous fibers in the AM process. Handling several materials at a time minimizes construction time and costs without compromising product quality. Surface geometry contributes more to the part deposition technique. A set of rules was framed based on the characteristics of the materials and the limitations of the process. Several suitable PDOs were determined using the surface geometry feature. Of the selected PDOs, the best was identified based on the previous work configuration using the developed algorithm that manages numerous targets. The authors demonstrated their work with the help of a case study.

1. 3.4. Influence of PDO on Support Structure

Khairul Fauzi Karim et al. (2014) proposed a methodology to calculate the number of 2S and its total volume using externally accepted functions. The 2S generation depends mainly on the PDO. ANN was used to identify the optimal PDO to build 2S features and not 2S. The proposed approach has been implemented in the FDM system. Vanek et al. (2014) presented a new system called Packmerger to reduce 2S consumption and construction time in AM. Packmerger was used to convert the solid model in an empty model with a thin outer shell. The shell was then broken into several segments. Each segment volume decides the division positions. When the number of segments is smaller, the 2S volume and the boundary box volume are also smaller. Tight end segments of an empty part reduce time and another 2S. Based on tests performed on three 3D printers, it was found that the reduction in construction time was up to 30% and the reduction in 2S was up to 65%. After printing the segments, you need to assemble them.

The use of metals in AM is limited due to several problems, including scale errors and sizing and geometric tolerance errors (GD&T), power consumption, etc. Paramita Das (2015) presented a method to determine the optimal PDO that reduces the 2S volume and meets the defined GD&T conditions of the prototype. The GD&T features and other related geometric data in the model were extracted through the programming interface of the Siemens Product Lifecycle Management application on a direct sintering RP system with a metal laser. Quadtree decomposition was used to determine the 2S volume for regions requiring 2S. The relationship between GD&T and PDO was described mathematically to calculate the analytical results.

Ratnadeep Paul and Sam Anand (2015) studied the flatness and cylindricality of shape errors to measure the influence of PDO. They developed a methodology to determine the best PDO to reduce flatness error and cylindricality error using two specimens. It is observed that smaller shape errors lead to a larger 2S volume and therefore the flatness factor must be eliminated. Volume 2S was calculated using a voxel-based method that is part of the algorithm.

To reduce the volume of 2S, Rohan Vaidya and Sam Anand (2016) used cell-like space filling structures. A shorter Dijkstra path algorithm has been added to optimize 2S and remove constraints to the algorithm for the sake of easy removal of the supports from the part built after manufacture. The strength of the support was tested by FEA analysis to verify the performance capacity of the support. Two parts of the sample were used to validate the media and one part of the sample was used to validate the removal restrictions.

Jun Wu et al. (2016) demonstrated the design of the internal volume appearance of a one-piece CAD model to be constructed to meet the application requirements compared to the material properties. But adding and subtracting inner 2S is a major problem in commonly used AM processes. A new approach was presented to generate application-based specific filling structures using rhombic cells. The resulting structures meet the construction needs for the thickness of the coating and the angle in the console. The developed structure does not need additional 2S. Surface models were used to fabricate the structure using an adaptive rhombic network. The objective equation has been improved by introducing a rare set of rhombic cells and various numerical techniques. It subdivides the rhombic grid adaptively and enlarges the cell walls. The effectiveness of the proposed method was demonstrated by generating internal structure projects to increase the static stability and rigidity of the part.

Morgan et al. (2016) used a unique goal enhancement technique to reduce 2S while constructing the track to determine the best PDO. The proposed technique is a reliable and efficient method of minimizing waste, especially for new users. The unrestricted gradient-based algorithm was used to develop the code using MATLAB which uses many starting positions to find a minimum global volume. Three test samples with different complexities were used to test the validity of the algorithm by comparing the experimental data with the results of the algorithm. Optimal solutions were obtained in two out of three case studies for 2S volume optimization. It was found that the manual selection of the PDO is not superior to the automatic selection.

1.3.5 Summary of part orientation studies

DOP influences the different input construction parameters, such as the construction height, the number of layers, the volume of the part or construction, the volume of the support structure, the number of support structures, etc. In addition, PDO makes changes to different output responses, such as surface finish, strength, size accuracy, payment time, part cost, etc.

The optimal PDO was determined by certain criteria. The researchers used various criteria, such as volumetric error, cutting thickness, weighted average surface roughness, cusp height, scale error, curved layer, etc. From this study, it was clear that the importance that researchers attached to reducing construction time was less. With the exception of a few, all studies used a standard optimization algorithm, such as GA, particle swarm optimization algorithm, ANN, etc. Also, to determine the best PDO, only volume 2S is used. The volume of the model was used only once.

1.4 STUDIES ON OPTIMISATION OF PROCESS PARAMETERS

1.4.1 Multiple and Single Response Optimisation

Kumar and Regalla (2012) analyzed the influence of various FDM construction parameters such as part hatch angle, hatch width, cut thickness, contour width and PDO The 200mc RP FDM system was used to produce components with specified construction parameters and have system responses such as 2S volume and build time were recorded. Design Expert® was used to analyze production data collected from experiments performed based on DoE (Design of Experiments) - complete factorial design. Based on the production parameters of the production, the relationship model was developed by ANOVA. The authors discussed the importance, model and effects of individual parameters and their interaction.

Rao and Rai (2016) used algorithmic approaches to establish the process parameters of the FDM optimum. For unique objective problems, an algorithm based on teaching-learning, GA and quantum swarm particle algorithms was used, and their results were compared and recorded. The proposed teaching-based approach ranks first among the three based on results. For multiobjective problems, extended versions of the teaching-learning and GA-based method have been used. that is, the algorithm based on teaching the non-dominant classification and the non dominant GA classification were used to find the set of results that helps the user to make decisions in difficult situations.

Manu Srivastava and Sandeep Rathee (2018) customized the properties by adjusting the construction parameters in the MA. The CAD model was created by conical primitives using solid constructive geometry and the part was produced in FDM 250mc. The Taguchi method established four control factors with three levels, namely, contour width, air space, cutting height and weft width. The optimal construction parameters were found by analyzing the S / N ratio, and their individual percentage contributions were calculated by ANOVA. The effect of the air gap proved to be maximum, followed by the width of the contour and the height of the layer. But, the interaction effects of the parameters were less important than the effects of the individual parameters.

Making a realistic part has been an eternal necessity since the beginning of engineering. Establishing a correct PDO would meet the need mentioned above. Chaudhari et al. (2018) optimized the parameters of the FDM process by performing several experimental runs. Good surface quality was obtained by setting the filling density to 100%, the slice thickness to 0.30 mm and the PDO along YZ0. The surface quality was further improved by polishing the surface with a sand blade. The construction speed was increased when the filling density was set to 20%, the slice thickness to 0.30 mm and the PDO along XY0. Zakariaa et al. (2015) highlighted the significant factors that must be taken into account in the processing of a metal (hybrid material-FeCuSn) through a process of electric discharge processing (EDM) with wire. The material was produced using the indirect SLS process for building network-shaped components. Recent research has focused more on the production of hybrid metal materials by AM, especially indirect SLS. Matching the EDM processing parameters on the wire, such as peak current, voltage, on and off pulse time to respond to the output is a difficult task because it depends on the skill of the operator. The DoE was used to reset the parameters to determine the influence of the sample surface hardness.

The physical properties of the materials can be improved by adopting a network structure in the design. AM makes it easier to use complicated network structures in manufacturing, but needs improvements. Guoying Dong et al. (2018) used the Taguchi method to examine the effect of FDM process parameters. The construction quality was improved when the manufacturing was performed using optimal parameters that were found by the S / N ratio. The classification of the optimal construction parameters based on their importance was performed using ANOVA. Research has shown that horizontal and inclined rods have several variations in the level and importance of their construction parameters. In addition, the effect of the construction parameters on the mechanical properties was evaluated by performing compression tests and an improvement of the youth modulus and the maximum strength of the network structures was found.

Mei-Ling Huang et al. (2016) applied the Taguchi design technique, the response surface methodology and a composite GA method and back propagation neural networks to improve the quality in piston fabrication. The Taguchi method applies the "nominal is the best" condition to the inside diameters of the ditch ring and the piston, in addition to the outer diameter of the ditch ring. The orthogonal matrix (OA) L27 was chosen for perform experiments for various construction parameters, such as the applied chuck pressure, rotation speed, cutting depth and type of carbon steel and type of cutting fluid. Experiments were performed for each technique and the results were compared and discussed in improving the quality of piston fabrication.

Powder bed melting is a fashionable AM process in recent days to produce usable products. Ivanna Baturynska et al. (2018) applied machine learning and finite element methods to evaluate and improve the construction parameters used in MA. A hybrid method of the two methods mentioned above has been proposed and the three methods have been revised in terms of the quality of the parts produced by the powder bed fusion process. The authors demonstrated that a large amount of data is needed for machine learning and statistical research to obtain accurate results. Rather, detailed information is needed for numerical modeling in the physical sciences. The proposed approach can face all kinds of challenges and therefore the same type of data and their combination can be used without any increase in costs.

1.4.2 Multiple Responses as Single Response

Optimisation The Taguchi method can be used effectively to solve single-answer problems so far and cannot be applied to optimize problems that have multiple answers. In today's scenarios, customer satisfaction requires more product quality features. Therefore, many techniques are developed to improve the required qualities of the products right at the design stage. Gray theory was introduced by Deng in 1989. It was established to effectively solve problems involving discrete data with incomplete and uncertain information (Huang and Liao 2003).

Gray Relational Analysis (GRA) can be implemented regardless of sample size or probabilistic assumptions. It has simple and robust mathematical calculations because it is established with progressive data trends (Tong & Wang 2003). Goyal & Grover (2012) proposed a multi-attribute decision-making method, fuzzy gray relational analysis, to select the advanced manufacturing system from different alternatives. The qualitative characteristics were transformed into quantitative using a fuzzy transformation scale. Subsequently, the transformed data were normalized using fuzzy which facilitates the data for comparison of alternatives. Then, the gray relational coefficient was calculated between all comparability sequences. Finally, an alternative that has the highest relational degree of gray was chosen as the best option.

RP systems were selected and the footprint was compared in terms of dimensional accuracy, part cost, construction time, surface quality and material properties. The GRA and fuzzy-TOPSIS results were compared and the selective laser sintering process (SLS 2500) was selected as the most suitable process for better 3D printing of the parts (Mahapatra & Panda 2013). Raju et al. (2014) demonstrated the optimization of the multiple quality characteristics of the stereolithography process (SLA) of the epoxy material SL5530 using Taguchi-based gray analysis. GRA was used to obtain the ideal parameter settings for the SLA process.3D printing properties a part such as tensile strength and crystallographic orientation - density analyzes to be maximized were considered as quality attributes of ALS. Layer thickness, DOP and weft spacing were considered parameters. GRA has been used to convert several quality features into a single feature and derives the optimal parameters needed for the process.

The composite casting process is used for the manufacture of 3D scaffolding in tissue engineering. A major concern in printing a complex biological composite is the difficulty you face in providing the best quality composite scaffolding, as well as the instability in the processing environment.

Jiang et al. (2015) presented an orthogonal experiment and an analytical technique based on the signal / noise ratio. The gray correlation theory was used to transform the optimization of the multi-objective parameter into the optimization of a single objective. The best possible construction parameters were predicted using the proposed technique that produces a good quality scaffolding.

Dixit et al. (2016) used the GRA method to determine the consequence of the process parameters together with their interactions on the dimensional accuracy of the printed part using two different RP systems; an industrial FDM 3D printer and a low-cost open source 3D printer. The most important parameters of the 3D printing process, such as raster width, layer height and path speed, are identified and contribute to the dimensional accuracy of open source 3D. The dimensional accuracy of the specimens was taken into account as a result of the process. The gray relational method was used to obtain an optimal level of each dimensional factor and characteristic simultaneously. From the GRA results, it was concluded that a low-cost 3D printer produced adequate part accuracy compared to industry based FDM.

Liu et al. (2017) identified the process parameters that influence the FDM process on the mechanical properties of a product using the Gray Taguchi technique. Process factors, namely PDO, layer thickness, weft width, deposition style and weft space were important factors that contributed to the different strength values, such as the stretch, impact and also flexion of an FDM product. The concept of experiment design was used for the design of the experiments and the orthogonal matrix L27 was used for the experiment. The effects of the five factors at the three levels were analyzed by constructing ANOVA on the responses. As a last point, the optimal process parameter for improving the mechanical properties of FDM parts was achieved using GRA.

Srivastava et al. They recommended a hybrid optimization method. (2017), to reduce the partial printing time and volume of the model in the FDM process. A collective approach to the response surface methodology and the GRA was used to optimize the operational parameters of the FDM process. The contour width, spatial orientation, airspace and screen angle were considered the parameters that most influence the responses, such as the partial print time and the volume of the model.

Rahman et al. (2018) implemented GRA to predict the most favorable state of the FDM process. Six construction parameters, such as work table temperature, printing speed, nozzle temperature, layer thickness, filling and number of loops were identified as important factors and varied on three levels until experimentation. Dimensional accuracy and surface roughness of the part were considered answers. L27 OA was selected for experimental studies. The experimental results showed that the measured dimensions are always larger than the CAD dimension in the Z direction, but the dimensions in the X and Y directions are smaller than the CAD dimension shown.

1.4.3 Summary of process parameters optimisation studies

In order to optimize the process parameters, experiments were performed with different 3D printers, such as SLA, SLS, FDM, etc. The influence of various FDM construction parameters, such as part weft angle, weft width, air space, cutting thickness, contour width and PDO was investigated to test system performance in terms of surface quality, part accuracy, lead time. manufacturing and strength of parts. To decide the number of experiments, the Taguchi method was universally applied using an orthogonal matrix. The fill density construction parameter was used once, but the fill pattern was never used. In the output responses, surface quality was found predominantly. The need and type of support structure were not discussed.

1.5 CONCLUSION

Based on the literature survey, it was found that researchers have added their contribution to the field of MA. The problems they have faced in recent years as the MA has developed rapidly are fewer material options, scale errors that reduce part accuracy, residual stress, improper duplication and uniformity of manufactured parts and unauthorized and non-standardized procedures. A lot of research work has been done on rapid prototypes to increase the surface finish by orienting the piece, so far.The initial and operating cost of this 3D printer is high because there are many parameters to consider. Using the support structure adds more time to build a part in FDM. To facilitate the next industrial revolution with fully equipped AM, components must be produced quickly at low cost without compromising quality. To date, the construction time is reduced by varying the thickness of the cut, mainly and, in some cases, the volume 2S. The genetic algorithm has been widely used as an optimization tool for rapid prototyping process. Despite this, a new generic algorithm is proposed, optimizing DOP, to build the parts in FDM from the perspective of reducing costs and materials.

In addition, for the operation of the 3D printer, optimizing the process parameters is an important step in printing. The parameters of the FDM process and their optimization have been managed by many researchers. A new set of process parameters such as layer thickness, PDO, fill density and fill pattern are used in partial construction to minimize construction time and partial cost.

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