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PARAMETRIC STUDY OF EFFECT OF SOLID FREEFORM FABRICATION PROCESS PARAMETERS ON RESPONSE PARAMETERS: A REVIEW

Jaimin V Thakkar [1], Saurabh A Ban [2], Akash B Pandey [3]

P.G. Student[1], Assistant Professor[2], Assistant Professor[3]
Department of Mechanical
SVIT, Vasad, SVIT, Vasad, Faculty of Technology Engg, MSU, Vadodara.

Abstract: ***Solid Freeform Fabrication (SFF) is one of the most popular additive manufacturing technologies for various engineering applications. Now a days SFF is rapidly developed and widely used additive manufacturing technique. SFF is low cost and easy to used fused filament fabrication method. In this method thermoplastic materials used to build the object which is extracted from the nozzle orifice according to CAD model layer by layer manner. The purpose of this study to investigate the effect of various process parameters of SFF on response parameters by reviewing various research work done by the researchers in this field. Also this paper gives basic information about SFF process and how the individual output parameters affected by various input parameters***
In this paper, an extensive review is carried out for different methods used to optimize the input process parameters to get desired output results. This paper also covers the numerous techniques available for optimization of surface quality. There are several statically optimization techniques and microscopic observations are considered

Keywords: Solid Freeform Fabrication (SFF), Additive manufacturing, Process parameters, Mechanical properties, Part quality

I. INTRODUCTION

Additive manufacturing is newly developed advanced manufacturing technique in which rather than removing the material, material is added in layer by layer form for making the object. Additive manufacturing also called Rapid Prototyping Technique, solid freeform fabrication, and 3D printing. The AM found its huge usage and popularity in hobbyist and customer market. SFF was founded and patented by Scott Crumop in 1988. He is founder of Stratasys Company in 1989 in Minnesota. From the all methods of additive mfg. [1] SFF is most widely used low cost, easy to used manufacturing technique Using SFF process any complex shaped part which is possible to model in any of CAD software is easily printed layer by layer directly form that CAD model. It is done by Deposition of thermoplastic material extruded form the orifice of nozzle. SFF process was divided in to two parts 1) Virtual part 2) Physical part.
In First Part the CAD solid model of in any of modeling software is created. After that CAD model is saved as. STL format to make it in understandable by SFF machine software i.e., insight, ultimaker etc. After that this this. STL file inserted in to SFF machine for making slice into the desired direction, selecting the input parameters for generation of support material, providing build direction, temperature adjustment etc. This pre-processed file of model and supports called Stratasys machine language (SML) file or CMB file for SFF machine. After this process this file is send to the SFF for making modeled object. This part called pre- processing.
In second part of SFF process feed stock filament of thermoplastic material form spool enters in to SFF liquefier head by rollers, in this semi- liquid state filament extruded out in ultrathin bead from the nozzle orifice on machine build table. This table moves in X and Y directions and nozzle with extruder head moves in Z-direction the table movement is done according to parameter setting which is done in virtual part of process. Based on the complexity of part shape support structure is generated. Accept from the manufacturing and design application of SFF it found its place in research and development sectors. It may include part quality- quantity improvement, new material development, and biomedical engg. Tissue engg Textile engg etc[3],[6].

I-A Objective

This review paper gives information about individual output parameters like surface roughness, dimensional accuracy, mechanical properties etc. also gives information about input and output parameters to reader or new researcher in field of SFF for testing and measurement. The effect of particular input on individual process parameter was observed in this study.

I-B SFF process parameters [6]: -

To achieve superior part quality, avoiding undesirable waste, improving production time, production rate, safety, low cost mfg., satisfying the customer needs etc. using SFF process obtained by proper selection of process parameters. By doing this, we obtain better quality and required mechanical properties as per customer requirements. For selecting process parameters optimally there are several statical optimization techniques, mathematical models, and microscopic observations are used.

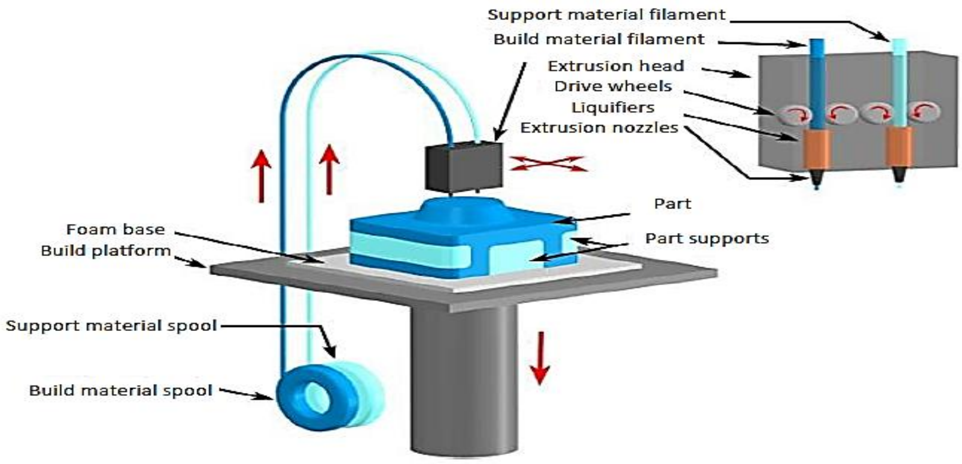


Fig. 1 Principle of SFF Process [6]

There are following some main process parameters are described below. The fig 2 shows the actual process parameter.

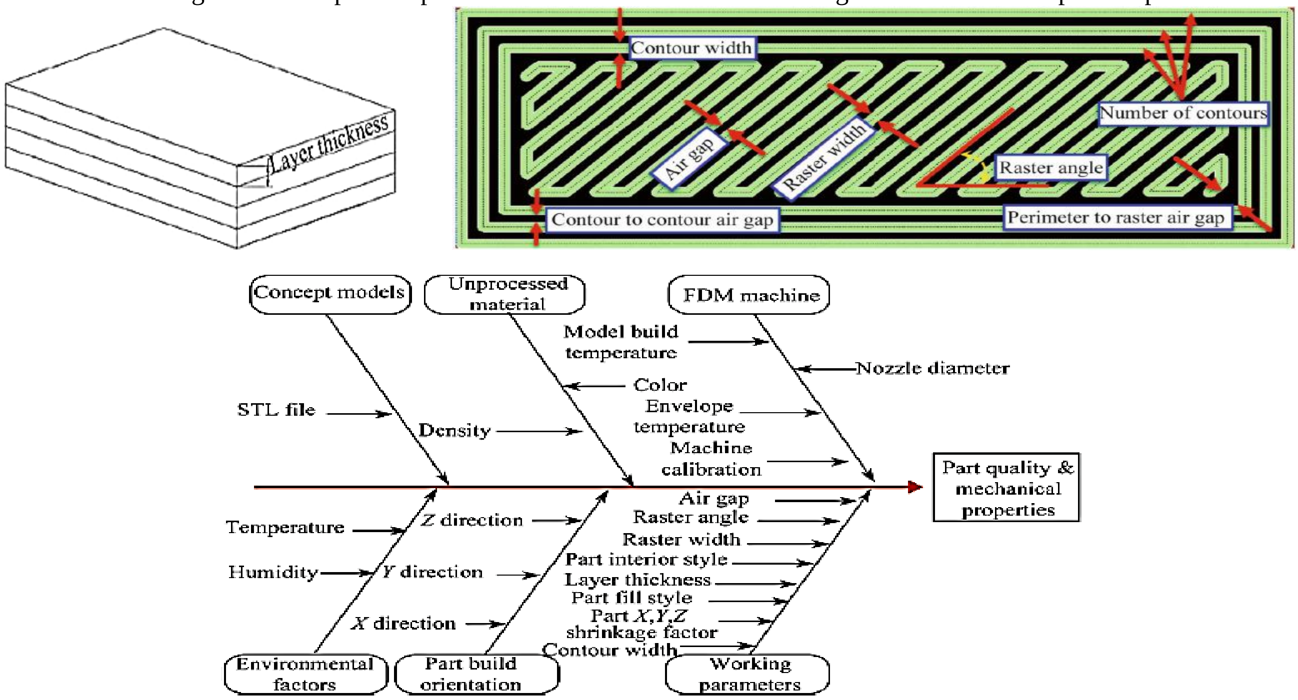


Fig. 2 a) layer thickness, and b) SFF tool path parameters c) Fishbone diagram [3] [6]

1) Build orientation [BO]: It is the direction in which part is oriented on build platform with reference to X, Y and Z axis.
2) Layer thickness [LT]: It is the thickness of material deposited from the orifice of nozzle.
3) Air gap [AG]: It is a gap between two adjacent a raster in same layer on bead.
4) Raster Angle [RA]: - It is an angle made by a raster with reference to X- axis from the bottom of part layer.
5) Contour width [CW]: It is width of a raster which makes outer shape of object which is seen in fig.
6) Number of contours: It refers to quantity of contours that makes all outer and inner curves of part.
7) Perimeter to raster air gap: It is a gap between outer most raster and inner most contours which makes part inner curves.
8) Contour to contour air gap: It is a gap between contours two adjacent when multi-layer fill styles is set in machine.

II. SFF PROCESS PRONS & CONS [2]

II-A Advantages [4], [3]

1) Complex parts can be produced with good accuracy and with low cost when compared to conventional manufacturing process.
2) No need for special tooling.
3) As simple as printing of copy from normal inkjet printer.

4) No material waste.
5) Potential for new materials

II-B Disadvantages [4], [3]

1) SFF is a costlier process.
2) The size of the output product is limited to a very small size.
3) Raw material limitations. (No metal based filaments can be used due to requirement of high temperatures).
4) Build speed.
5) Anisotropic properties.

Sr. No.	Ref. No.	Auth. Name	Year	Material	Method	I/P Parameters	O/P Parameters	Most Affecting
1	[32]	Hafsa et al	2018	PLA	Taguchi	Orientation Build Pattern	Surface Roughness	Orientation
2	[48]	Perez et al	2018	PLA	ANOVA, 2^3 Full Factorial	Layer Thickness Print Speed Wall Thickness	Surface Quality	LT, Print Speed
3	[55]	Shubham et al	2018	ABS	experimental	Layer Thickness, Nozzle Temperature, Infill Percentage	Storage And Loss Modulus, Mechanical Damping	Infill And LT
4	[35]	Das et al	2017	ABS	Factrography	Build Orientation	Strength And Cost	BO
5	[10]	Jayanath et al	2018	ABS	Measurement	Different Chemicals	Tensile Strength	-
6	[36]	Garge et al	2015	ABS	Chemical Treatment	Orientation, Different Chemical	Dimensional Accuracy, Surface Roughness	All
9	[37]	Ahn et al	2002	ABS	L16 Taguchi Method	Raster Angle, Air Gap, Bead Width, Temp.	Tensile And Compressive Strength	RA And AG
10	[38]	Clever et al	2018	ABs , PLA	Taguchi	Layer Thickness, Infill %, Orientation	Tensile Strength, Strain, Modulus Of Elasticity	All
11	[18]	Heechang et al	2017	PLA , ABS	2^3 Full Factorial	Orientation, Infill, Material	Tensile Strength	All
12	[43]	Santhakum et al	2016	ABS	ANOVA, L9 Taguchi	Road Width, Layer Thickness, Orientation, Raster Angle	Impact Strength	All
13	[53]	Faharaz et al	2014	ABS	L18 Taguchi, ANOVA	Slice Height, Road Width, Air Gap, Raster Angle, No. Contours	Material Consumption, Roughness	RW,RA,AG
14	[49]	Kumar et al	2015	ABS	2^5 Full Factorial ANOVA, RSM	Layer Thickness, Raster Angle, Orientation, Road Width	Build Time , Volume	All

III. REVIEW ON RESEARCH IN SFF PROCESS OPTIMIZATION

SFF process provides competition in resent advanced manufacturing market because of its improved surface roughness, dimensional accuracy, manufacturing time, building time, etc. Several critical input process parameters the characteristics of SFF processed part. Most of researchers are focusing to do research on improving roughness, dimensional accuracy and mechanical properties of part processed from ABS. They give optimized parameters using appropriate Statical designs, no. of experimental results, and optimization techniques. Research on each quality characteristics is reviewed in detail in following subsections.

III-A Dimensional accuracy: -

Stephen O Akande et al [7] accuracy of parts greatly affected by various process parameters of SFF. The dimensional accuracy was tested with help of micrometre and average of percentage change is considered. Also tip calibration and measurement taken in X, Y and Z direction. They selected I – optimality because it is related to para estimation which is important build factor. It is newly developed method which may helpful to build RSM design when need is optimized parameter setting and greater accuracy of part. Statical analysis was done by ANOVA procedure and Fisher p and f value test. Also regression model for normal, predicted and adjusted was considered. For validation normal probability graph plotted are used for percentage change in l, w, t. used multiple runs at different points, reduced gradient algorithm with sequential repetition.

Y. Y. Aw et al [8], focus on dimensional accuracy and raster angle value of component made by SFF. For measurement of da Mitutoyo digital calliper with accuracy 0.01mm used against design CAD model. Also the Pareto chart is used for finding relationship between size of effect and the Statical evolution which is done in MINITAB software with $\alpha = 0.05$. Multi response Durability Function Analysis (DFA) was used to calculate their durability function for each output para. For optimization using DFA different weight values given to each para whose values varies form 0 to1. Form the experimental results graphs are plotted. From the plot seen that fill density and speed of deposition affects dimensional accuracy value the obtained durability function is 0.927 for dimensional accuracy which validate DFA model

A. Bagsik et al [9], they study focus on three response para mfg time, Ultimate Tensile Strength, and dimensional accuracy. For obtaining para combinations for performing no. of experiments Taguchi L9 orthogonal array was used. Cure Ultimaker software was gives simulated results of actual manufacturing and also para information obtained from it. The ANOVA was used to found significantly affecting para and their proportion combination for output para required. From the experimental results main effect plots and pie chart generated in Minitab. Form that plots and seen that dimensional accuracy is mostly affected by layer thickness.

TABLE 1 SUMMARY OF PUBLISHED WORK ON SFF PROCESS OPTIMIZATION

Jaynath et al [10] investigate the effect of cold vapour treatment on dimensional accuracy of part made SFF with ABS. For cold chemical treatment first Diethsylketon used but it has aggressive reaction so that acetone is used because it is less hazardous, low cost and easy to use. Nikon V10A profile projector with least count 0.001 mm used fir dimensional accuracy measurement and their average value was considered and compare against dimension of CAD model. The test specimen in next step is exposed to cold vapour in diethylketon. After the performing tests seen that improvement in dimensional accuracy due to chemical treatment. But no change in percentage error same as that of untreated component at different orientation angle.

Nitiskumar Dixita et al [60] in this study two different RPT systems based on dimensional performance using Grey relational analysis method considered. Step by step procedure for developing GRA model was performed for both resultant. In this study 23 full factorial method was used for parameter combinations form experimental results mean effect plots are developed for the both dimensions along L1 and L2 is decreased due to shrinkage of deposition material form experimental and numerical analysis revels that approximate control of machine process will open source printer.

Ngoc-hien Tran et al [11], studied that the effect of deposition parameters on printed part qualities first they explained or analgised individual i/p parameter extrusion head temperature, nozzle which analysed using ANSYS. Nozzle diameter considered for calculating extrusion time. Also for developing slice for each components various slice algorithm are used by considering various input parameters and build parameters. There are two materials was used PLA and ABS from that various sized gears are manufactured to compare build quality and dimensional accuracy. Special new structure was developed for SFF in this research. The printed gear are used in toy's gear box which was work very accurately. This research work was developed for inheriting the research for training in universities

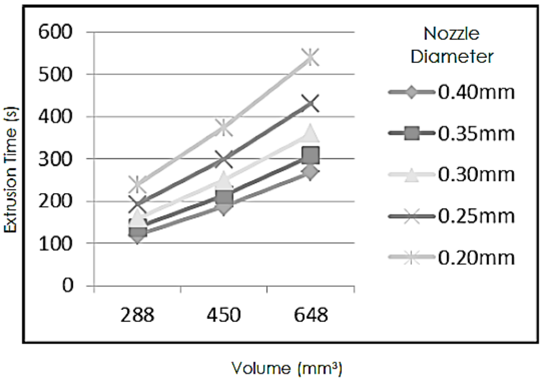
III-B Surface Roughness: -

Tejendrasinh S. Rual et al [45], Focus son investigation on build parameter on SR using RSM for consider the experiment there are three input para layer thickness, dimensional accuracy, raster angle also Minitab used for development of experiment plan for RSM. In RSM CCD was selected for performing the experiments total 20 experiments are performed. Form measurement of raster angle reading SURFEST SJ- 210 instrument form that average taken for all 20 test specimens. Regression model was used for compression with RSM model for raster angle value. Using full quadratic response surface models to determine effect of input parameter on experimental results using Minitab. Form the calculation of co-relation coefficient gives 97.44% confidence level which is obtained from the RSM predicted results. Also 3D response pot was generated using RSM and from that it is seen that as for orientation angle& layer thickness increases raster angle increase up to certain limit then after decreases. raster angle shows slow behaviour to affecting raster angle value.

Min Kyung Kim et al [15], focus on effect of fabrication para on raster angle values of parameter made with PLA by SFF process also more focusing on gap between the nozzle and substrate because it affects layer thickness and raster width. If distance between nozzle and substance is less, then certain critical value deposited material was spread more than diameter of nozzle and vice versa. This effect was observing cross sectional area by optical microscope and image processing. From measurement and microscopic observations, it was concluded that at 0.35 mm fabrication distance best raster angle value was obtained which is 2-micron deviation. Also as line width decreases as inflow speed and nozzle speed increases. Based on experimental results empirical formula was derived for response.

Nora Amin Sukinder et al [16], focus on raster angle for newly developed open source 3D printing machine using PLA material. For design of CAD model Autodesk Inventer used. Taguchi's 35 DOE method with L27 orthogonal array was implemented in Minitab software for fabrication of parameter combination for experiment. raster angle value measured by Perthometer S2 PGK surface analyzer. ANOVA was used to generate normal probability plot and residual versus fits plot. Also S/N ratio was calculated for each parameter level form that main effect plots are generated. Form that plots it was concluded that extruder temperature and layer thickness are most affecting parameter to raster angle value. Using

SEM, micro structure of each component at various temperatures observed after finishing and most accurate results are obtained at 2100 to 2500 c using RSM optimization method.



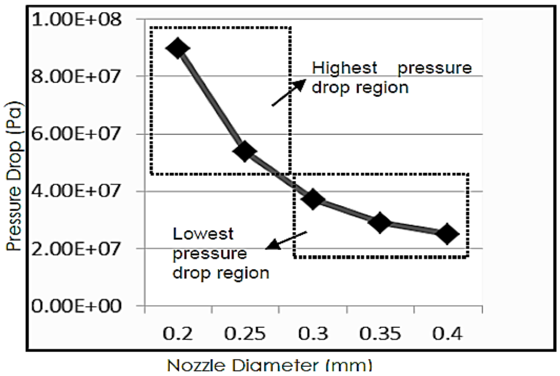


Fig. 3 Comparison of time taken between different nozzle diameters to extrude square parts for pressure drop

Rafiq Noorani et al [11], Studied that improvement of raster angle of part made by SFF with ABS 400 material using DOE. For finding optimized process parameter two separate methodologies are used, first is two level with three factors and other one is three level with two factors. Surtronic plus for raster angle value measurement used. If the line interacts in plot, then only one para is most affecting and lines are not interacting then no more effect of input parameter on response factors. The simplest mathematical form selected for model form table of two factor significantly effect of layer thickness was founded mean line intersection is very strong. From the both method it was founded that layer thickness has greatest effect on raster angle then other input parameter.

Gurpal Singh Bual et al [40], in this study improving the surface roughness of parts produced by SFF. There are various methods for improving Ra of fused part reviewed in this paper which are namely 1) optimization of build orientation and 2) fabrication parameters optimization 3) slicing strategy 4) post treatment. From that literature review it is seen that SF is improved by choosing suitable build orientation of part it can increased by reducing larger thickness but it may increase by reducing layer thickness but it may increase build time. It is concluded that SF also improved by post processing of parts made by SFF.

Grezegar Krolczyle et al [44], in this studied experimental analysis of surface roughness and surface texture done for both machined part and fused part. The taste specimens are made according to the ASTM standards for both conventional and fused part after that comparison of micro structure of both SFF and turning process compared also plots for load capacity after turning and SFF plotted and its strength also compared. Also surface integrity analysis done for both parts using Infinite Focus measurement machine. IFM allow to capture image with resolution of lateral down 400 nm and vertical down 20 nm from that plots observed that turned component has uniform roughness and SFF printed part has uneven roughness and also it has higher Ra then tuned parts. Auto correlation and gradient distribution primary model developed for both turned fused part.

III-C Mechanical Properties: -

We know that SFF made components may have affected by many of process parameters as well as machine component design. There was huge research work done for understanding behaviour of material under varying process parameters. So that research papers are reviewed below,

J. M. Brock et al [20] in this paper the effect of various process parameter on mechanical properties of part made with SFF in all three direction X, Y and Z. in this study Polyetherimide (PEI) with. The test specimen is made at different tool path parameter. Form the test it is seen that maximum strength is obtained in X direction before braking and elongation. Also lowest strength in Z direction. Also it is seen that thin filament has low lower tensile strength compared in study to thick parameter setting considered in study. Best results obtained for all direction with – ve air gap.

K. J. Christiyan et al [21] investigate that impact of process parameter on Ultimate Tensile Strength of SFF printed in crisscross pattern using PLA. In this case PLA is selected because it has good printing capability and semi Crestline in nature raster width, layer thickness, and raster angle are selected as input parameter. Also full factorial experimental design with L27 orthogonal experimental combination was used and effect of individual parameter is observed. From Ultimate Tensile Strength results for each 27 experiments S/N ratio calculated for tensile strength was developed from plot it was seen that raster is most affecting parameter. For 400 to 500-micron raster width it gives maximum tensile stress for 300-micron layer thickness maximum and with 200-micron minimum tensile strength and maximum strain or elongation at 300 microns. from that concluded that layer thickness is most affecting parameter to Ultimate Tensile Strength and elongation.

M. Dawoud et al [22] focus on the effect of six SFF process parameter on flexural strength of part made with SFF using ABS. for optimization Firefly Algorithm was used which is proposed by X in- She- Yang. Also regression model equation for flexural strength developed in ANOVA for each level values of combination put into it and compared with reference to RSM and experimental results. From the experimental results three dimensional response plots for effect on flexural strength by input parameter individually represented. It is seen form the plots that number of contours increase then flexural strength by also decreases up to certain limit and after that increases. Also air gap and orientation angle increase flexural strength increases linearly. As layer thickness increased flexural decrease.

D. Horvath et al [23] focus on effect of process parameter on various mechanical properties for comparison between parts made with CABS and ABS material. There are following properties tested in this research. First is tensile strength, in which the test specimen made with two infill pattern liner and rectilinear. The Ultimate Tensile Strength for both material increase with increase in infill density. But from the experimental results seen that ABS has higher Ultimate Tensile Strength value then CABS. This is because of presence of carbon black which is brittle in nature. Optimum stiffness value obtained at [00, 900] raster angle for linear pattern and for rectilinear at [450/-450] at 100% infill density. Second is electrical conductivity, it is seen from the measurements in experiments electrical conductivity increase with increase in infill density for both linear and rectilinear but higher value in linear then rectilinear. Also CABS has higher conductivity then ABS because of carbon black. Third is thermal properties form the experiments and measurements seen that higher value of thermal conductivity obtained with rectilinear pattern in CABS and for ABS with linear pattern. The materials for thermal conductivity test specimen are blended with ZnO. In CABS/Zno higher value of see back co-efficient in linear pattern is obtained then ABS for same parameter settings.

Agnes Bagsik[9] et al consider the study on investigation on effect of variation of process parameter of SFF was considered for ABS + hydrous magnesium silicate composite was conducted. The print speed, layer thickness is considered as input parameter. There are nine samples for each property test made using SFF process. It is seen from the experimental results with increase in both individually print speed and layer thickness tensile strength decreases. The highest value of Ultimate Tensile Strength 28.5 MPa obtained at 0.2-layer thickness and 30 mm/sec print speed.

Krishna M. otaparti[24] et al was studied that the effect of various process parameter of SFF on the mechanical properties of Ultem 9085 parts. The anisotropic properties and anisotropy were observed in part not due to martial but due to fabrication process which are tested in flexural and compression test. For coupon fabrication solid and sparse build styles are used and from that effect of individual and combined process parameter are tested. It is seen from chart made from experimental results maximum values of yield and compression strength, stress/mass and modulus/ mas ratios are obtained for solid at 240 C temperature in flexural testing. For compression test yield strength yield strength and stress/mass ratio at solid coupon with horizontal build style with zig zag pattern. Microscopic examination of fractured part was founded using statically analysis software JMP11 for determining main effects and interactions. For horizontal build direction max yield strength obtained at 450/-450 orientation angle and for vertical direction it was observed at 00/90.

Swayam Bikash Mishra et al [26] focus on the effect of five parameters on flexural force in SFF specimen. The definitive screening design method (DSD) which is novel approach for statical analysis and extrusion of maximum information from relatively less number of experiment with advantage of minimum aliasing. DSD is accepted following advantage that has number of runs are 2m + 1 and main effect are independent to interaction between other factors. Also the ANOVA and regression model involved for optimization for that R2 and RMSE values are calculated for each variable. The graphs are plotted from the above experimental results and optimization techniques. From that seen that flexural force increases with increase in layer thickness after certain limit it decreases. As extrusion speed and infill optimization density increase individually then flexural force also increases. Also for increasing in raster angle flexural force decreases, which seen from 3D response plots.

Eunj park et al, [18] in this article consider study on mechanical properties of single and dual material using SFF fabrication method. For single material experiment both material individual used for parts of PLA and ABS parts are nothing but test specimens which are printed in three different directions X, Y and at 45 angle. In this research work two level 23 full factorial orthogonal array used for single material. Result from this array optimized by using ANOVA method for O/P parts tensile strength for both material and compared results for both materials at different process parameters optical image of part made also considered to observe the microstructure. In case of dual material two material in combination used to make test specimen and verging the process parameters to see the effect on response parameters. There are three different combinations 20-80%, 40-60% and 50-50 for both PLA and ABS and form that seven test are performed with 100% infill density in X- direction gives maximum mechanical properties.

Rupinder singh et al, [42] this study focus on the effect on shore hardness by barrel finishing. There are six i/p parameters which shows that for performing experiment for shore hardness with barrel finishing and optimizing process parameters. Also in this study Taguchi's orthogonal array used. there are various geometries for bench marks used like cubical, conical and spherical behind this is complex geometries may consist of curves, lines and angles which can approximately considered in present study form the Taguchi results mean effect plots seen that layer density is most affecting parameter. Also seen there is no effect in change in shape of barrel finishing media and lower effect seen increase of part orientation and barrel finish cycle time. After that ANOVA was performed for final cross check for % improvement in shore hardness. Also SEM images at varying conditions observed from that it was concluded that barrel finishing can be adopted as efficient method for improvement in surface finishing of parts made by SFF with the optimized parameters it is seen that 13.09% in shore hardness obtained.

Kyle Raney et al [52] studied that experimental characterization of tensile strength of SFF part made of ABS considered effect of varying process parameters on tensile strength was experimental observed. Also Ultimate Tensile Strength et al studied that experimental characterization of tensile strength of SFF part made of ABS considered effect of varying process parameters on tensile strength was experimentally observed. Also Ultimate Tensile Strength, YS and strain and young modulus values also considered at different values of infill density a build orientation as shown that data sets and ANOVA values considered optimization of parameters for better result of response parameter. Parts were tasted in tension and compared its strength with respect to strength of ABS materials strength from this study it is observe that position of the layers and internal channel to axial load was material to result differently. The strength of simple has 74 to 79 % then the samples along layer. This strength difference due to weaker bond between layers.

Sung- har –Ahn et al, [37] was investigated that anisotropic material properties of SFF for ABS material. Series of samples are built on SFF by modifying tool path in quick slice software. Also SML file showing. There are five i/p para meters considered. In this study L16 orthogonal array was used for performing experiment. From that experiment seen that airgap and raster orientation are largely affects to yield strength of material while parameter has no significant effect on response parameters. It is seen from experiment part with orientation angle observed. It is also concluded from experiment that axial build part has maximum and very near to injection holding parts.

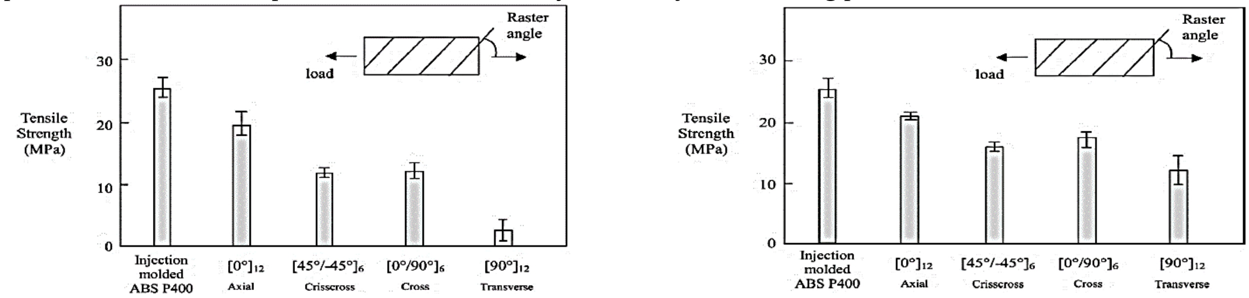


Fig. 4 Comparison of tensile strength for Zero and – ve Air gap

Thoms hostaette et al, [56] studied that simulation of downsized nozzle for SFF and fluid flow simulation of nozzle has been considered this simulation results are compared with experimental results were depends on material properties with temp and pressure dependency. In fluid flow analysis laminar flow of ABS material through nozzle orifice was considered. In thermal analysis nozzle at 6000 analysed software. Also plots for velocity field plotted from the analyzed the it is observed that velocity very w.r.t pressure difference quadraticaly.

Luzanin et al, [31] aims at identifying compressive evolution of optimization algorithm for tensile strength prediction of SFF processed part. In this study GA used to optimize process parameters of SFF for obtaining best Ultimate Tensile Strength. DPDotNet, METLAB Toolbox, JGAP etc., simulation software is used for GA process. There are 4 different parts was taken at 3 different levels for performing experiments L27 orthogonal array was used for 27 combination of i/p parameters are used. After applying various GA operator’s values of tensile strength is 22.484 obtained by optimum parameters setting form experiment results and GA results are compared w.r.t each other. Form plots it is seen that most all GA results are near to each other.

Omar Ahammed Mohanad et al [29] studied that identifying process parameters optimization of viscoelastic properties of SFF manufactured Part using RSM was used for case of optimization. There are six i/p parameters considered with six different levels and their effect of variation observed on complex modulus and dynamic viscosity. To analyzed this property are measured by dynamic mechanical analyzer was used. For performing optimization using RSM there are sixty experiments with various combinations of process parameters used. Experiment optimal design matrix is done using Matlab 17 and second order polynomial equation for both response parameter was developed from that calculated that results at different levels are plotted. From the plot seen that AIR gap and no. of contours are largely affected in both response parameters. Also SEM images of each optimum parameter observed.

Y zhang et al, [57] was investigated that parametric study of part distortion in SFF using 3D finite element analysis. In this FEM method considered coupled thermal and mechanical phenomenon and incorporating an element parametric study with 3 factor at 3 different levels is performed, to evaluate effect of deposing model with larger size are fabricated, measured and compared with simulated results. For FEA analysis rectangular element for meshing used. Boundary condition in this analysis were obtained by forced convection with ambient temperature of 74 0c and heat co-efficient of 84 w/m2 k. the mechanical analysis with static used element where activated according to filament deposition sequence. After that FEA and ANOVA analysis performed. It is concluded that road width alone not affected residual stress and part distribution.

L.M. Galantucci et al, [59] studied that compression properties of topologically optimized SFF made structural parts. The topologically optimized part has been created with internal geometric, using narrow wasted structure that avoid need for supports. After that bar charts developed for individual parameters with respect material volume. Specimen have been compressive tasted with Instrone 4485 universal testing machine. From this approach reduce consumption of material time and cost for layered manufacturing. This approach is applicable to all types of RPTs on the other hand internal angle and shell width are very important compressive strength aspects. The study has demonstrated validity of approach to achieve cost time and material reduction, contributing to lower economic and environment effect.

TABLE 2 FINDINGS FROM LITERATURE

No	Characteristics	Variation
1	Infill Speed	15-35 mm/S
2	Layer Thickness	0.1- 0.35 mm
3	Infill Pattern	Rectilinear, Grid, Zigzag, Cubic, Cross 3d

4	Raster Angle	0, 45 , 90
5	Infill Density	0-100%
6	Nozzle Diameter	0.2 - 1 Mm
7	Nozzle Exit Geometry	Circular
8	Nozzle Angle	60^{c}, 90^{0}, 120^{0}
9	Nozzle Temperature	200^{0} - 300^{0} C
10	Bead Temperature	60^{0} - 80^{0} C
11	Environment Temperature	80^{0} - 120^{0} C
12	Input Parameters	Layer Thickness, Raster Angle, Orientation Angle
13	Out Parameters	Material Strength, Surface Quality, SEM
14	Material	ABS, PLA, Nylon
15	Build Orientation	0^{0}, 45^{0}, 90^{0}

IV. CONCLUSION

This article represent various research work was carried out in order to determination, selection of input parameters for better output and optimization the Stratasys was developed new technology which if SFF. It has prominent position in Additive Manufacturing this will increased interception from last 2-3 decades. The larger no of units installed in plastic based AM because this technology attained market leadership. This article studies the various areas of SFF process and it give understanding about future research work. The lots of research work done in the area of varying process parameters for testing mechanical properties and surface qualities of components made by SFF process for PC, ABS, PLA etc. materials but very few work done with ABS+, PLA+, PPSF, PC- ABS etc. Form overall literature survey it was observed that layer thickness, raster angle, build orientation, and air gap are most affecting parameters.

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