PAPER NAME

A Design Consideration of Heated Bed's Rapid Levelling Tool Based on Von Misses Stress Using FEA Si

AUTHOR

Rudi Kurniawan Arief

WORD COUNT

2608 Words

CHARACTER COUNT

12930 Characters

PAGE COUNT

5 Pages

FILE SIZE

470.4KB

SUBMISSION DATE

Apr 3, 2023 12:08 AM GMT+7

REPORT DATE

Apr 3, 2023 12:08 AM GMT+7

20% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 19% Internet database
- 16% Publications database
- Crossref database
- Crossref Posted Content database
- 0% Submitted Works database

Excluded from Similarity Report

- Manually excluded sources

A Design Consideration of Heated Bed's Rapid Levelling Tool Based on Von Misses Stress Using FEA Simulation

Rudi Kurniawan Arief
Department of Mechanical Engineering
Universitas Muhammadiyah Sumatera Barat
Bukittinggi, Indonesia
rudikarief@umsb.ac.id

Erry Yulian T. Adesta
Department of Materials and Manufacture Engineering
International Islamic University Malaysia
Gombak, Malaysia
eadesta@iium.edu.my

Riyadh Ali Abdullah Hannaf
Department of Materials and Manufacture Engineering
International Islamic University Malaysia
Gombak, Malaysia
Riyadh14hannaf@gmail.com

*Irfan Hilmy
Faculty of Mechanical Engineering
Higher Colleges of Technology
Fujairah, UAE
ihilmy@hct.ac.ae
*Corresponding Author

***Abstract*— Currently, heated bed levelling method used in low cost FDM 3D printer is using spring and screw adjustment system that requires more effort and time. This is a part of ongoing research to design a novel leveling system for FDM 3D by introducing a new system to replace the screw system. Previous research has introduced a new concept design to quick and easy levelling of FDM 3D printer's heated bed using staggered pin design. This paper is to analyze the staggered pin system by simulating various dimensions and materials using Finite Element Analysis (FEA) simulation software. Best configuration was analyzed by comparing the VMS value obtained from the simulation. Using FEA, 18 design configurations have been simulated and analyzed. All configurations are strong and safe to apply and can be carried on for further research but Polyethylene (PE) material obtained lowest VMS value and suggested to be chosen. PE material also good for mass production because it can be manufactured by using plastic injection molding and can be sold in relatively lower price.**

Keywords—FDM, FEA, VSM, 3D printer, leveling tool

I. Introduction

Nowadays, Fused Deposition Modelling (FDM) 3D printer has been introduced as the most common used Rapid Prototyping Machine for home use and educational purposes, invented by Scot Crump in 1989 [1] [2] [3]. It has been made famous by Prof. Adrian Bowyer by the invention of his open sourced Replicating Rapid Prototyper (RepRap) system where everybody could build and modify it them self [4] [5]. Creative people can make use this 3D printer to produce their own creative products, almost any kind of products from toys, home appliances, fashion accessories to complicated medical and technical equipment. This type of printer has also been chosen by some researchers for its low cost and user friendliness.

Research topic in the development of FDM 3D printer has been growing from year to year. Since 2016 hardware development topic has become the most interesting topic, 30% of FDM 3D printer related research has contributed to hardware development. Research sub topics have been addressing the development of the Extrusion head by 41%, followed by development of frames and modification printer's function by 28% and 25%, then the topic of heated bed development by 3% [6] .

Many failures still occurred due to lack of bed levelness, misalignment, shrinkage, etc. [2] [7]. These failures might lead to machine destruction beside product quality, time and material waste [8] [9]. Despite of those detrimental effects, very limited scientific research addressed the failures in FDM 3D printer. A research by Agile and Sustainable Manufacturing Research Unit (ASMARU-IIUM) in 2018 shown that 12% of failures happened in the operation of 3D printer process was caused by the lack of bed levelness and 26% of bed's problems complaints by the users are caused by lack of bed levelness (Fig.1) [6].

Failures caused by the lack of bed levelness has created some problems and difficulties, but very limited if any, research covers this problem. One of the problems found is the difficulties of the users to perform bed levelling set up, the levelling process may take hours to perform depending on the tool used. This is part of ongoing research to design a new leveling system for FDM 3D printer performed by Agile and

Sustainable Manufacturing Research Unit (ASMARU-IIUM). Previous research by ASMARU team has managed to develop a manual rapid levelling tool system (Figure.2) [10]. This research was conducted to offer some suggestion further design consideration for this new system.

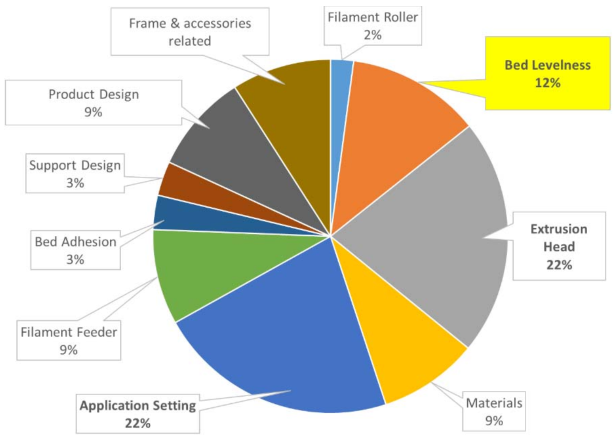


Fig. 1. Cause of Failure in 3D Printing.

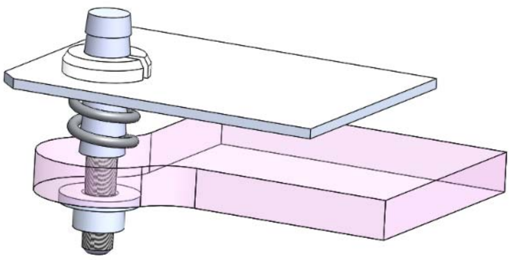
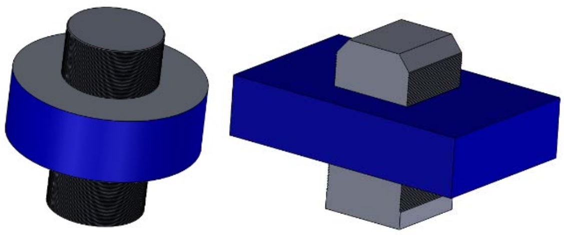


Fig. 2. Manual Mechanism Concept.

II. MATERIALS AND METHOD

This research analyze the possibility of the selected design to be implemented in real condition in term of the strength of materials and shapes. The analyzing is based on the comparison of Von Misses Stress (VMS) obtained using Solidworks Simulation as Finite Element Analysis software. Finite Element Method (FEM) is an application used to solve complex mathematical expression for analysis of complicated structure or simple structure with many parameter's configuration [11]. The calculation in this FEA technique runs by an analytic software as it is an effective and efficient approach [12]. Many FEM software available such as; Nastran, Ansys, CATIA, Solidworks, etc. Solidworks simulation is one of widely use FEA analysis software for its user friendly interface. SolidWorks is used in the research of finite element static and dynamic analysis studies for its abilities to analyze the process for a gradually increasing load with uniform distribution, various factors like VMS, maximum deflection or displacement occurred, strain are developed on the system [13]. The VMS is an appropriate analysis method of failure criterion based on an equivalent stress response [14].

Simulations applied to Stainless Steel (SS316), Aluminum 1060, Polyethylene (PE) and Acrylonitrile Butadiene Styrene (ABS) materials, with two different designs; round pin (Fig. 3a) and rectangular pin (Fig. 3b). All materials are considered with ease of manufacture. The SS316 and Alu1060 are selected for its strength, good maintainability and availability, materials can be manufactured by subtractive manufacturing process while PE and ABS are common polymer material that used for mass production process that could be manufactured by additive manufacturing process such as injection molding and rapid prototyping.



(a) (b)

Fig. 3. a) Round Pin Design, b) Square Pin Design

In the world of rapid prototyping process Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA) are the most frequent used materials. PLA have higher material density for 1,21-1,25 g/cm^3 compared to ABS that make it heavier, so PLA is used to calculate the maximum product's weight. The heated bed must be able to hold the heaviest weight of printed part with 200mm x 200mm x 200mm of solid product size will be used here (1).

$$W = (\text{length} \times \text{width} \times \text{height} \times \rho) / 1.000.000 \quad (1)$$

ρ = Density (g/cm^3)
W= Weight of Part (Kg)
F= Force (N)

W= (200 x 200 x 200 x 1.23) /1.000.000
W= 9,84 Kg

Force acted in pin will be 0,25% of product weight because it was distributed uniformly to 4 pins (2).

$$F = (W \times 10)/4 \quad (2)$$

F= (9,84 x 10) / 4
F= 24,6 N
The force applied then rounded to 25N

Staggered shape was design (Fig.4) with pitch height (h) of 0.1, 0.15 and 0.2mm and pitch angle (α) of 85°, 60° and 45° (Table.1).

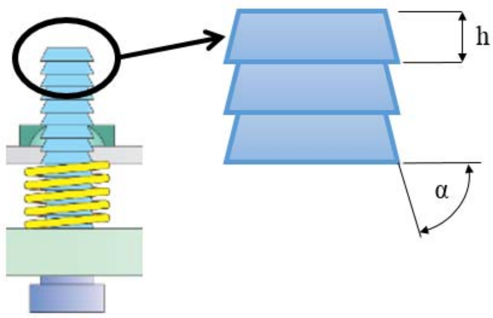


Fig. 4. Staggered Pin Design

TABLE 1. DESIGN CONFIGURATIONS

No	Configurations	Dimension / Materials
1	h1	0,1
2	h2	0,15
3	h3	0,2
4	α1	45°
5	α2	60°
6	α3	85°
7	Material 1	Acrylonitrile Butadiene Styrene (ABS)
8	Material 2	Polyethylene (PE)
9	Material 3	Aluminum 1060
10	Material 4	Stainless Steel (SS316)

Working concept of this system is that the staggered pin bolted fix to the Y-axis base, and the pin will be pushed upward by a spring force (Fig.5). Force of 25 N applied to the pin as maximum weight of solid printed product using PLA. Fix node was applied in the bottom pin (green arrow) and the 25N force applied upward (magenta arrow) from the bottom of the ring. The force pushes the pin's tooth upward by the ring's tooth.

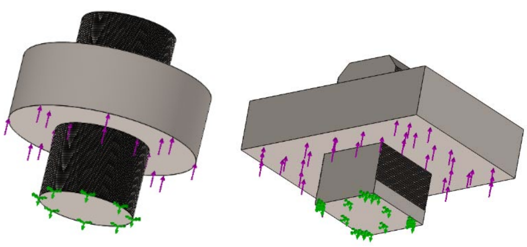


Fig. 5. Simulation Load and Fixation Positions.

III. RESULT AND DISCUSSIONS

The FEA simulations produce 72 results, the maximum stress obtained indicated by the value of VMS. The VMS value obtained must be lower than material's Yield or Tensile Strength (Table. 2). FEA simulation for round shaped pin design (Fig. 6) shown in Table.2, while table.3 shows results for rectangular shape pin design (Fig.7).

TABLE 2. MATERIAL STRENGTH VALUE

ABS	Alu 1060	PE	SS316
Tensile Strength N/m²	**Yield Strength N/m²**	**Tensile Strength N/m²**	**Yield Strength N/m²**
30.000.000	27.574.200	22.100.000	172.368.932

TABLE 3. SIMULATION RESULT FOR ROUND PIN

No	Round Pin		Max VMS of Materials			
	Pitch Height	Pitch Angle	ABS	Alu 1060	PE	SS316
1	0,1	45°	904.438	958.982	894.672	985.987
2		60°	1.000.944	1.149.240	955.398	1.206.030
3		85°	840.299	893.512	832.652	900.529
4	0,15	45°	897.140	990.549	870.658	1.030.175
5		60°	954.621	1.045.654	927.855	1.082.795
6		85°	775.135	793.516	769.715	801.554
7	**0,2**	**45°**	**681.107**	**701.859**	**676.072**	**711.706**
8		60°	816.908	835.979	812.645	845.350
9		85°	716.739	741.775	708.606	751.650

Data performed in tabel.3 shows that configuration no.8 obtained lowest VMS value in all materials specimens with PE materials obtained the lowest value. Pin with 0,2mm height and 45° angle of pitch will be the best choice since it has smallest VMS value among others for round type of rapid pin.

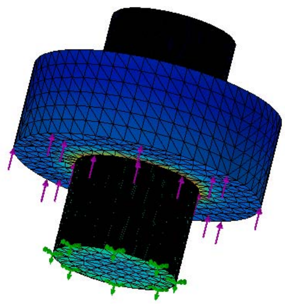


Fig. 6. Stress Deformation in Round Pin

For the rectangular shaped pin, the configuration no.4 obtained lowest VMS value of all metallic materials while configuration no.6 more suitable for polymeric materials (Table.4). Specification of 0,15mm height and 85° angle of pitch looks more suitable for polymeric materials choice, while 0,15mm of height and 45° angle of pitch looks more suitable for metallic material. Specimens with PE materials with 0,15mm height and 85° angle of pitch will be the best option since it obtained the smallest VMS value among others for this shape.

TABLE 4. SIMULATION RESULT FOR RECTANGULAR PIN

No	Rectangular Pin		Max VMS of Materials			
	Pitch Height	Pitch Angle	ABS	Alu 1060	PE	SS316
1	0,1	45°	1.391.149	1.472.486	1.364.199	1.537.667
2		60°	1.580.438	1.694.824	1.544.678	1.777.649
3		85°	1.328.591	1.388.310	1.312.723	1.438.037
4	0,15	45°	1.118.127	**1.195.662**	1.095.478	**1.259.140**
5		60°	1.270.928	1.372.159	1.238.945	1.444.302
6		85°	**1.113.985**	1.196.485	**1.088.568**	1.259.433
7	0,2	45°	1.235.732	1.266.692	1.226.375	1.292.356
8		60°	1.278.532	1.365.920	1.253.832	1.439.644
9		85°	1.130.599	1.209.699	1.106.365	1.271.150

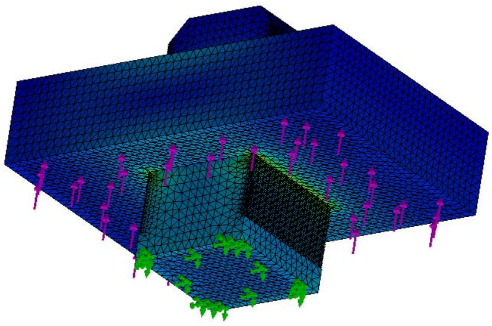


Fig. 7. Stress Deformation in Rectangular Pin

The simulation result for both shapes of rapid pins shows that all of the configurations are in strong condition where Maximum Von Misses Stress (VMS) are far below material's Tensile or Yield Strength (Table. 2). Whichever option selected will be strong enough to hold the force since value of the critical area still far below the yield strength. Further research is to configure the best detail design because material friction rate and manufacturing process must also be put into consideration.

IV. CONCLUSION

By using Solidworks simulation, 18 configurations of design have been simulated and analyzed. Data obtained shows that all configuration are strong and safe to apply and can be carried on for further research. From all of those configurations PE material with 85° of pitch angle obtained the lowest VMS value and could be the best material to be chosen. PE material also the best option for mass production because it could be manufactured by plastic injection molding process and can be sold in relatively low price.

ACKNOWLEDGEMENT

This research was conducted in collaboration between Innovation Lab of International Islamic University Malaysia, 3D Printing Lab of Higher Colleges of Technology, Fujairah, UAE and 3D Modeling Lab of Muhammadiyah University, Sumatera Barat, Indonesia.

REFERENCES

[1] S. P. Deshmukh *et al.*, "Design and development of XYZ scanner for 3D printing," *2017 Int. Conf. Nascent Technol. Eng. ICNTE 2017 - Proc.*, 2017.

[2] E. Fang and S. Kumar, "The Trends and Challenges of 3D Printing," in *Encyclopedia of Information Science and Technology, Fourth Edition*, 4th ed., no. August, M. Khosrow, Ed. PA: IGI Global, 2018, pp. 4382–4388.

[3] B. M. Schmitt, C. F. Zirbes, C. Bonin, D. Lohmann, D. C. Lencina, and A. da C. Sabino Netto, "A Comparative Study of Cartesian and Delta 3D Printers on Producing PLA Parts," *Mater. Res.*, vol. 20, pp. 883–886, 2017.

[4] R. Jerez-Mesa, J. A. Travieso-Rodriguez, X. Corbella, R. Busqué, and G. Gomez-Gras, "Finite element analysis of the thermal behavior of a RepRap 3D printer liquefier," *Mechatronics*, vol. 36, pp. 119–126, 2016.

[5] M. Teliskova, J. Torek, T. Cmorej, M. Kocisko, and J. Petrus, "Adjustments of RepRap type printer workbench," *2017 4th Int. Conf. Ind. Eng. Appl. ICIEA 2017*, pp. 15–19, 2017.

[6] R. K. Arief, E. Y. T. Adesta, and I. Hilmy, "Hardware Improvement of FDM 3D Printer : Issue of Bed Leveling Failures," *Int. J. Technol. Explor. Eng.*, vol. 8, no. 4, pp. 603–614, 2019.

[7] N. I. Jaksic, "What to do when 3D printers go wrong: Laboratory Experiences," in *122nd ASEE Annual Conference & Exposition*, 2015, no. June 2015, pp. 26.1730.1-26.1730.11.

[8] S. K. Ueng, L. K. Chen, and S. Y. Jen, "A preview system for 3D printing," *Proc. 2017 IEEE Int. Conf. Appl. Syst. Innov. Appl. Syst. Innov. Mod. Technol. ICASI 2017*, pp. 1508–1511, 2017.

[9] R. Song and C. Telenko, "Material Waste of Commercial FDM Printers under Realstic Conditions," *Proc. 27th Annu. Int. Solid Free. Fabr. Symp.*, no. 2015, pp. 1217–1229, 2016.

[10] R. K. Arief, E. Y. T. Adesta, and I. Hilmy, "Design Selection of Manual Rapid Levelling Tool for Low-Cost FDM 3D Printer's Heated Bed Based on TRIZ Approach and Pugh's Selection," in *International Conference on Cumputer Science and Engineering*, 2019.

[11] M. N. Patil and S. Sarange, "Finite Element Analysis of Von Mises Stress & Deformation at Tip of Cutting Tool," *Interntional J. Innov. Res. Adv. Eng.*, vol. 1, no. 1, pp. 211–217, 2014.

[12] M. Azizi, M. Nor, H. Rashid, W. Mohd, and F. Wan, "Stress Analysis of a Low Loader Chassis," *Eng. Procedia*, vol. 41, no. Iris, pp. 995–1001, 2012.

[13] A. Toca, I. Stingaci, I. Rusica, C. Robinson, C. H. Cheng, and S. C. Chen, "Three dimensional design , simulation and optimization of a novel , universal diabetic foot offloading orthosis Three dimensional design , simulation and optimization of a novel , universal diabetic foot offloading orthosis," in *IOP Conference Series: Materials Science and Engineering*, 2016.

[14] M. Chen and R. Harichandran, "Statistics of the von Mises stress response for structures subjected to random excitations," *Shock Vib.*, vol. 5, pp. 13–21, 1998.

20% Overall Similarity

Top sources found in the following databases:

- 19% Internet database
- 16% Publications database
- Crossref database
- Crossref Posted Content database
- 0% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	coursehero.com Internet	3%
2	sersc.org Internet	3%
3	jtmiti.org Internet	1%
4	honors.libraries.psu.edu Internet	1%
5	Chand Sukumar, K I Ramachandran. "Three dimensional design, simula... Crossref	1%
6	amrita.edu Internet	1%
7	sphinxsai.com Internet	<1%
8	Helmi Ben Rejeb, Benoît Roussel. "Design and Innovation Learning: Ca... Crossref	<1%

9	Dan Segalman, Garth Reese, Richard Field,, Clay Fulcher. "Estimating th... Crossref	<1%
10	hindawi.com Internet	<1%
11	link.springer.com Internet	<1%
12	diva-portal.se Internet	<1%
13	coek.info Internet	<1%
14	Swapnil Sinha, Nicholas Alexander Meisel. "Influence of process interr... Crossref	<1%
15	irjet.net Internet	<1%
16	A.I. Salimon, F.S. Senatov, V.A. Kalyaev, A.M. Korsunsky. "Shape mem... Crossref	<1%
17	dergipark.org.tr Internet	<1%
18	Li, Wen Jie, Guang Peng Liu, Dao Hui Li, and Tao Yu. "Finite Element An... Crossref	<1%
19	etj.uotechnology.edu.iq Internet	<1%
20	muhammetbaykara.com Internet	<1%

21	theses.gla.ac.uk Internet	<1%
22	egr.msu.edu Internet	<1%

Excluded from Similarity Report

- Manually excluded sources

EXCLUDED SOURCES

Rudi Kurniawan Arief, Errv Yulian T. Adesta, Riyadh Ali Abdullah Hannaf, Irfan ... Crossref	86%
irep.iium.edu.my Internet	17%
ijitee.org Internet	12%
researchgate.net Internet	9%
ijraset.com Internet	7%
igi-global.com Internet	1%