FLATNESS EVALUATION FOR A V-FLASH RAPID PROTOTYPE (RP) MACHINE

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Abstract

In today's society manufacturing is very critical for innovation and progress. Rapid prototyping (RP) is one of the processes that can produce net-shape parts quickly. RP is computerized method to build a physical object from a 3-Dimensional model of the object.

There are two main types of RP:

- Subtractive Manufacturing
- Additive Manufacturing

This research focuses on additive manufacturing (AM). V-Flash is a machine (see figure 1) that uses Stereolithography (SLA) for AM. A photo curable resin is used in layers to build a part. A UV light passes through a mask and hardens the exposed resin layer.

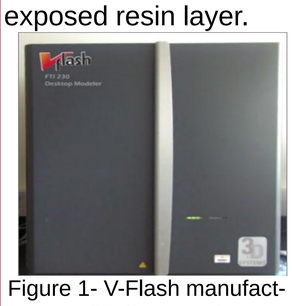

Figure 1- V-Flash manufactured by 3D Systems Inc.

The V-Flash 3D printer:

- Divides the 3D object into layers, each layer being 0.004 Inch thick.
- Lays down each layer of the model on top of the previous layer, continuously until the object is printed.

With AM comes the problem of "stair stepping" where each layer being built depending on the thickness of the layer will cause greater surface deformations such as form variations and surface roughness.

In this research we will be studying how positioning different surfaces at different locations and angles affect flatness. Flatness will be measured using a NextEngine 3D scanner (see figure 2) and an algorithm to compute flatness from point clouds.

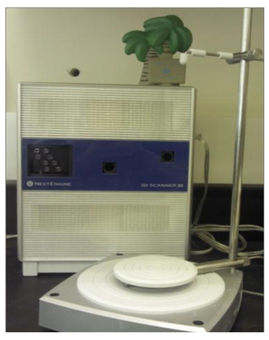

Figure 2- NextEngine 3D Scanner Manufactured by NextEngine Inc.

My results show that:

- Positioning the same model at an upright angle has a great change on the surface.
- The layers are causing stair stepping. We propose to position the model as horizontally to prevent roughness and flatness errors on the object being built.

With RP and AM manufacturing is more conventional than:

- Grinding
- Drilling
- Subtracting from a large block
- Less waste
- Easier to use
- Take up less space
- Cheaper overall
- Less time (4-6 Hrs depending on model)

Motivation

- AM is very fast and convenient but can not produce surfaces to meet or exceed the geometric quality obtained from machining.
- As a first step, the understanding of the sources of form errors because of the inherent nature of the AM process is critical.
- One type of form error called flatness error is investigating in this research.

Approach

- Build a 3D model in SolidWorks (seen in figure 3), which included 21 different parts places at different angles with thickness of 0.1" as well a second model with parts with 0.05" thickness separately.

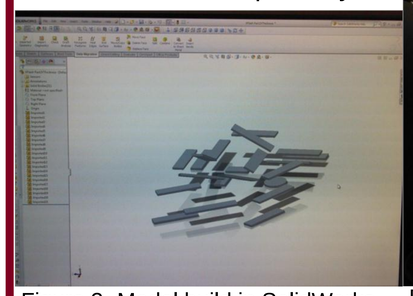

Figure 3- Model build in SolidWorks

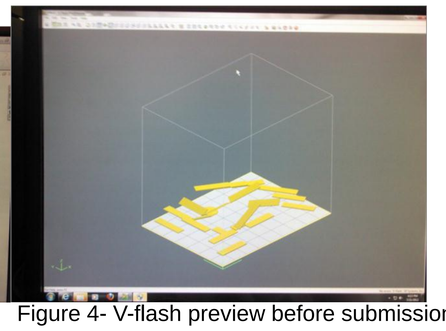

Figure 4- V-flash preview before submission

- Saved the file as an STL format to send it to the 3D printer to print the 3D model.
- Rotated the model and translate it to the center to fit on the pad it was going to be printed (see figure 4).
- The model was printed using FTI-GN Material(see figure 5).
- V-flash Part Washer (see figure 6) uses long lasting Clean-A-Part solution to clean and rinse the model for 5 minutes, the model was also washed in water for 5 minutes to remove build material and to prepare it for final curing.

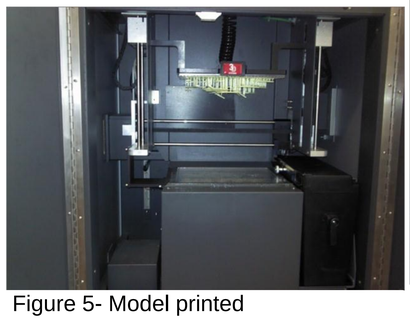

Figure 5- Model printed

Figure 6-V-Flash Washing unit Manufactured by 3D Systems Inc.

- After washing the model we dried it with soft paper towel to cured it in the V-Flash curing unit (see figure 7) to harden the material to produce final models (see figure 8).
- The results we gather were from scanning the model (see figure 9) with 21 surfaces, each surface was trim separately and saved as an OBJ file so after all surfaces were done, ran it with C++ Software to calculates the surface flatness.

Figure 7- Curing Unit

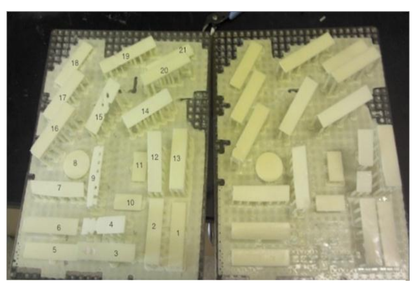

Figure 8- Left: 0.05 Inch thickness
Right: 0.1 Inch thickness

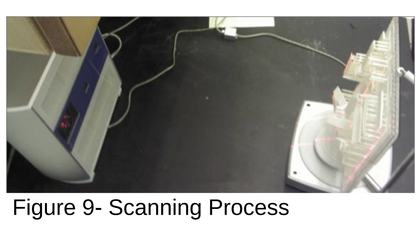

Figure 9- Scanning Process

Results

We ran four different scans:

1) When printed
2) 24Hrs
3) 72Hrs
4) Week

The scans were averaged and compared (see figure 10, 11).

Surface property	Surface Number	0.05 thick Average	0.05 thick Min	0.1 thick Average	0.1 thick Min
flat	1	0.012626	0.01082	0.011741	0.011741
flat at height	2	0.012326	0.008133	0.040175	0.036535
flat 90Z at height	3	0.008651	0.008487	-	-
90Z - tilted x	4	-	-	-	-
flat 90Z	5	0.013903	0.013027	0.020108	0.015803
flat 90Z height	6	0.013683	0.012529	0.037247	0.037247
90Z - tilted y	7	0.025404	0.025404	0.017142	0.017142
circular	8	0.008596	0.008596	0.008332	0.008332
tilted x	9	0.020998	0.014881	-	-
small rect - 90Z	10	0.008408	0.007965	0.017093	0.017093
small rect	11	0.011789	0.006668	0.007475	0.007475
tilted y	12	0.029619	0.029619	-	-
flat at height	13	0.013452	0.010497	0.032323	0.032323
tilt x - 60Z	14	0.017016	0.017016	0.020473	0.020473
tilt y - 30Z	15	0.006348	0.005744	-	-
30Z at 2* height	16	0.016119	0.016119	0.028231	0.028231
30Z at height	17	0.012	0.012	0.012106	0.012106
30Z	18	0.012355	0.00971	0.023427	0.021099
60Z at height	19	0.010278	0.010099	0.009805	0.009805
60Z at 2*height	20	0.008099	0.007924	0.008786	0.008786
60Z	21	0.011991	0.009787	0.015457	0.011845

Figure 10: Average and Minimum flatness values

	surfaces	Average comparison 0.05-thick	Average comparison 0.1-thick	Min comparison 0.05-thick	Min comparison 0.1-thick
flat	1	0.012626	0.011741	0.01082	0.011741
flat at height	2	0.012325667	0.0401745	0.008133	0.036535
flat 90Z at2* height	3	0.0086505	#DIV/0!	0.008487	0
flat 90Z	5	0.0139025	0.020108	0.013027	0.015803
flat 90Z height	6	0.013683333	0.037247	0.012529	0.037247
circular	8	0.008596	0.008332	0.008596	0.008332
small rect - 90Z	10	0.008407667	0.017093	0.007965	0.017093
small rect	11	0.011789	0.007475	0.006668	0.007475
flat at height	13	0.013452	0.032323	0.010497	0.032323
30Z at 2* height	16	0.016119	0.028231	0.016119	0.028231
30Z at height	17	0.012	0.012106	0.012	0.012106
30Z	18	0.012355333	0.0234265	0.00971	0.021099
60Z at height	19	0.010277667	0.009805	0.010099	0.009805
60Z at 2*height	20	0.0080985	0.008786	0.007924	0.008786
60Z	21	0.011991	0.0154565	0.009787	0.011845
	Average	0.011830262	0.0194503	0.010277	0.018459

Figure 11: Comparison of horizontal surfaces

The Data was than put on chart to visually compare the two models (see figure 12).

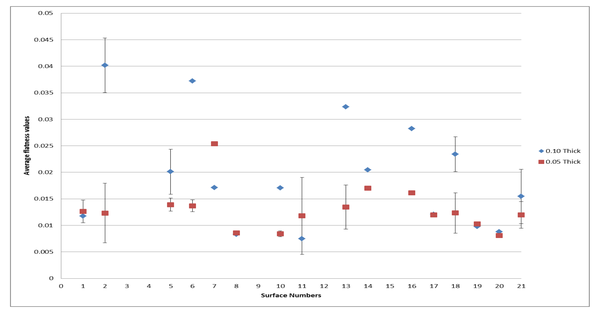

Figure 12: Comparison of different thicknesses

Conclusion

For the horizontal surfaces:

- Overall flatness has become worse as thickness increases
- Circular surfaces has better flatness
- Smaller surfaces has better flatness than larger ones
- Flatness is better for 60Z surface than 30Z
- 90Z has slightly worse flatness at both the thicknesses
- Can't conclude from the data that height has an effect on flatness

For tilted surfaces:

- Overall tilted surfaces have problems. Flatness is better for 0.1 inch thick surface than for 0.05 inch thickness surface

Future Research

Manufacturing technology is evolving, future research on this project is necessary to achieve better quality of flatness.

Some areas of work would be:

- Position build pad at different heights
- Thinner layers
- How time affect surface flatness

Acknowledgements

Thank you to the School of Mechanical and Material Engineering.

This research was supported by the National Science Foundation's (NSF) Research Experience for Undergraduate (REU) program under grant number EEC-1157094.