Optimizing a 3D Printed Lego Solar Car Using a Design of Experiment Factorial Design Approach

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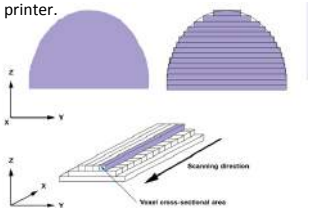
Introduction

- **3D Printing:**

A process used to make a 3D prototype of an object. The material that is used in the experiment is ABS (Acrylonitrile Butadiene Styrene). Soluble support material is laid down first then the ABS, both materials are laid down layer by layer. The printer gets the part from an STL file that is transferred over from Solid Works to the printer.



- **Design of Experiments:**

DOE is the use of statistics to explain and define the significant factors in an experiment. In DOE the program that is used is Minitab. Minitab is used to organize and setup the data. When the data is setup it is set at randomization. This setup is to make sure the data that is given is accurate and true for each of the factors due to the replications. Replications are used to make sure the information that is being given is true.

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•**Factorial Design:** Use of factorial experiments instead of the one-factor-at-a-time method. These are efficient at evaluating the effects and possible interactions of several factors.

•**Solar Car:**

Objective

The objective is to create a more efficient in terms of time to build and strength Solar Car. To do this, the Lego parts used will be printed using the 3D printing technology. The objective is to find the best combination of factors so that the Solar Car will be strengthen and less material will be used to take less time.

Methodology

The following steps were followed in order to perform the research:

1. Using Solid Works the Lego piece is made using Solid Works.

2. Find Factors and create a design matrix using Minitab. 2^3 factorial design is used for the experiment. This shows there is 3 factors and 2 levels for each factor, a high and low. The factors used:
   - **Model Interior**-How the material is laid down
   - **Support Fill**-Support material used to base the model
   - **Layer Resolution**- How thick the layers are

StdOrder	RunOrder	CenterPt	Blocks	Support Fill	Model Interior	Layer Resolution
8	7	1	1	Surround	Solid	0.330
1	8	1	1	Basic	Sparse Low Density	0.254
7	9	1	1	Basic	Solid	0.330
16	10	1	1	Surround	Solid	0.330
11	11	1	1	Basic	Solid	0.254
3	12	1	1	Basic	Solid	0.254
4	13	1	1	Surround	Solid	0.254
15	14	1	1	Basic	Solid	0.330
2	15	1	1	Surround	Sparse Low Density	0.254
9	16	1	1	Basic	Sparse Low Density	0.254

3. Print the Lego Pieces according to the factors using the Uprint 3D printer from Stratysys.

4. Test parts for the outcome:
- Strength: a machine compressed the part until it broke

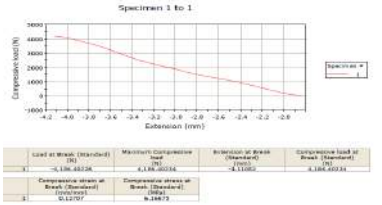
- Time and Material Used: a chart is made to see the time and material

uPrint SE Plus Build Queue

Job Name	Owner Name	Submit Time	Estimated Build Time	Estimated Finish Time	Model Material (in³)	Support Material (in³)	Model Cartridge (in³)	Support Cartridge (in³)	Pack List
RIM	Administrator	2014-07-09 10:42	1:13	2014-07-09 12:07	0.340	0.335	10.170	4.303	RIM
RIM	Administrator	2014-07-09 10:43	0:53	2014-07-09 12:08	0.359	0.210	10.011	4.055	RIM
RIM	Administrator	2014-07-09 10:46	1:07	2014-07-09 14:08	0.439	0.181	10.072	3.972	RIM
RIM	Administrator	2014-07-09 10:47	0:57	2014-07-09 15:06	0.437	0.216	10.136	3.998	RIM
RIM	Administrator	2014-07-09 10:49	0:52	2014-07-09 15:59	0.436	0.182	10.136	3.913	RIM
RIM	Administrator	2014-07-09 10:50	1:07	2014-07-09 17:06	0.340	0.181	17.698	5.913	RIM
RIM	Administrator	2014-07-09 10:51	0:58	2014-07-09 18:04	0.359	0.216	17.550	5.252	RIM
RIM	Administrator	2014-07-09 10:52	1:13	2014-07-09 19:17	0.439	0.335	17.656	5.166	RIM

Results

- **Strength:** The factors that made the strongest piece are: Model Int.- Solid(highest level), Support Fill- Surround(highest level), Layer Resolution- 0.330 (highest level)



- **Time :** The factors that effected the time to less are: Model Int.- Solid(highest level), Support Fill- Surround(highest level), Layer Resolution- 0.330 (highest level)

Job Name	Owner Name	Submit Time	Estimated Build Time
RIM	Administrator	2014-07-09 10:42	1:13
RIM	Administrator	2014-07-09 10:43	0:53
RIM	Administrator	2014-07-09 10:46	1:07
RIM	Administrator	2014-07-09 10:47	0:57
RIM	Administrator	2014-07-09 10:49	0:52
RIM	Administrator	2014-07-09 10:50	1:07
RIM	Administrator	2014-07-09 10:51	0:58
RIM	Administrator	2014-07-09 10:52	1:13

- **Material Used :** the less material used is .62 this was due to the factors of Model Int.- Solid (highest level), Support Fill- Basic(lowest level), and Layer Resolution- .254 (lowest level)

Job Name	Owner Name	Submit Time	Estimated Build Time	Estimated Finish Time	Model Material (in³)	Support Material (in³)
RIM	Administrator	2014-07-09 10:42	1:13	2014-07-09 12:07	0.340	0.335
RIM	Administrator	2014-07-09 10:43	0:53	2014-07-09 13:00	0.359	0.210
RIM	Administrator	2014-07-09 10:46	1:07	2014-07-09 14:08	0.439	0.181
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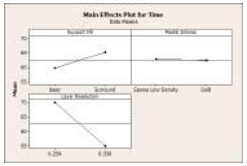
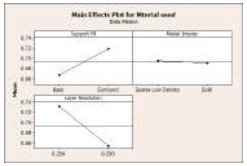
Conclusion

Our goal was to produce a stronger part that used less material and took less time to make. We used the following factors as a guide for us to reach our final goal: support fill, model interior and layer resolution. Using 8 variations and testing each variation twice we concluded that variation 4 took less time to produce and was the strongest part, however, it used more material during the production.
Keeping the above mentioned factors in mind, the following are the final levels used in the production of variation part 4.

- **Model interior: Solid (high level)**
- **Support Fill: Basic (low level)**
- **Layer resolution: 0.330 (high level)**





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