Development and Analysis of Rapid Prototype Parts for Classroom Applications

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SUMMER RESEARCH EXPERIENCE FOR UNDERGRADUATES

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Background

- Rapid prototyping has become an important part of the engineering curriculum
- The Rapid Product Realization Lab is an important asset for students and faculty
- It is important to understand the strengths and weaknesses of rapid prototyped (RP) parts for use in functional prototypes and final products

Scope

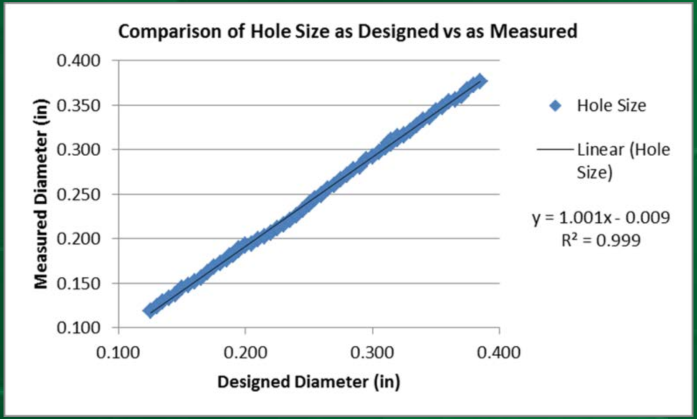
- Analysis of circular fits (press, sliding, etc.)
  - As designed versus model
  - Strength of fit

- Use of rapid prototyping to produce power transfer devices (gears, pulleys, etc.)
  - Limits of gear pitch
  - Orientation of build
  - Strength of part

- Utilization of Roland MDX-20 desktop Router
  - Chip and dust removal
  - Noise concerns

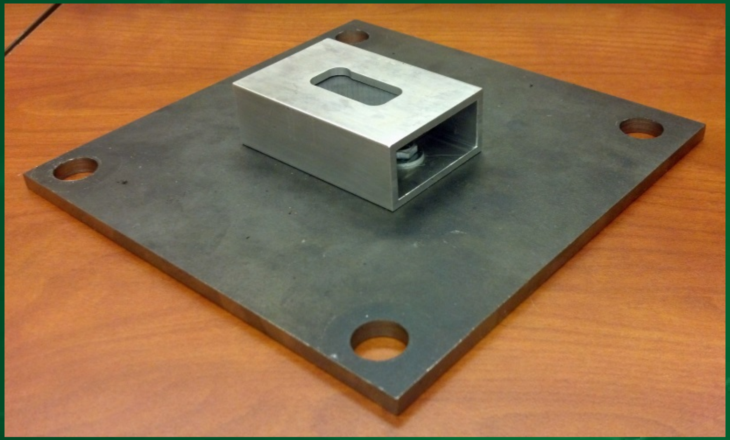
Hole Size Comparison

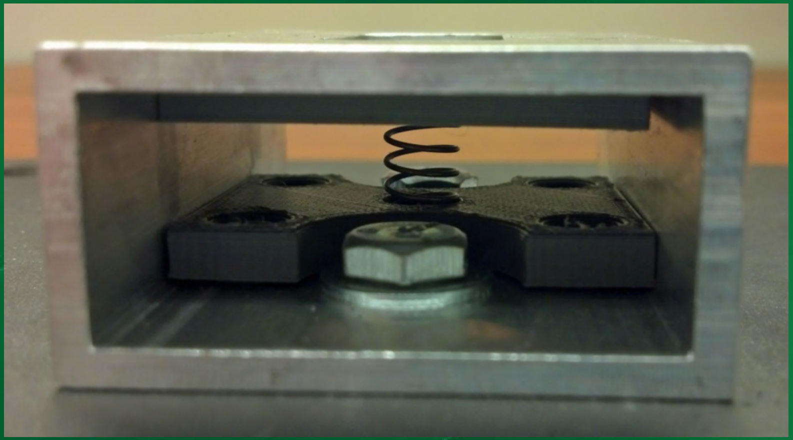
- Compare the diameter of a hole as designed on CAD software against the rapid prototyped part
- Created plates of known variable diameter
- Measured plates using calipers
- Analysis of data using a least squares fit resulted in a relation between design diameter and final diameter of y=1.001x-.009, where x is the design diameter and y is the RP part diameter



Press Fit Using an RP Hub

- Design an experimental setup for testing pull out strength of a steel shaft pressed into an RP hub.
- Produced a custom jig for use on the Instron 5582
- Designed for a hub to be inserted then twisted to restrict vertical motion
- Spring loaded plate was used to keep test piece level and against the upper surface of the test jig.





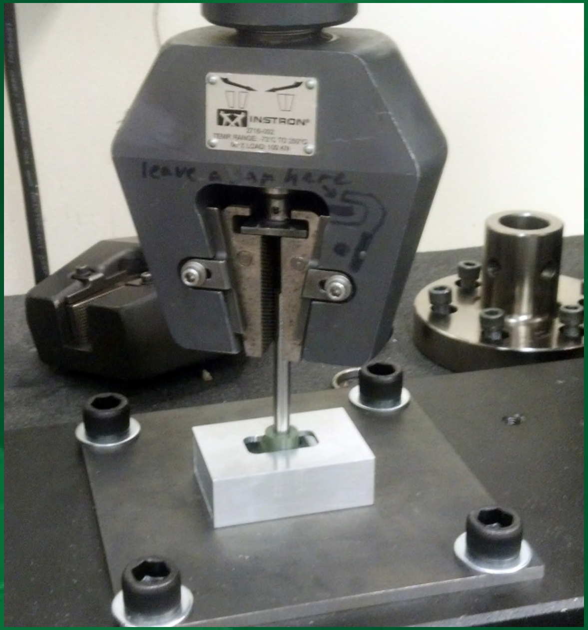
Press Fit Using an RP Hub

- Test hubs were designed with an outer diameter twice the size of the inner diameter
- The design diameter and hub depth were printed onto each hub base
- Hole size equation was used to determine output hole diameter and amount of interference
- Shafts were prepared by chamfering the ends to be press fit
- Shafts were press fit into hubs using an arbor press
- Formula for press fit into plastic hub was used to estimate forces between 87lbf and 438 lbf
- 3 of each of the combinations from the table below were modeled

0.25″ Hub Depth	0.5″ Hub Depth	0.25″ Hub Depth	0.5″ Hub Depth
0.125″	0.125″	0.1282″	0.1282″
0.1875″	0.1875″	0.189″	0.189″
0.25″	0.25″	0.255″	0.255″
0.3125″	0.3125″	0.315″	0.315″

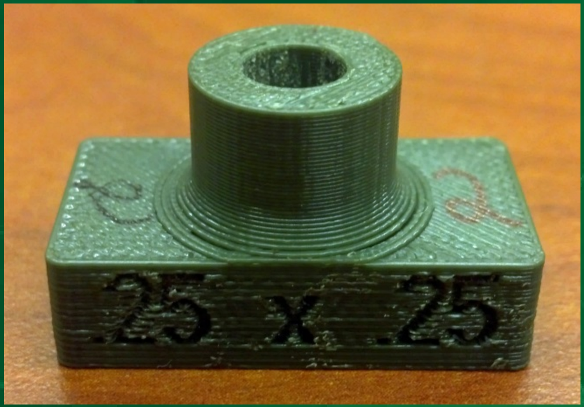
RP Press Fit Testing

- The press fits were tested using an Instron 5582 tensile test machine using Blue Hill software
- Test Pieces were inserted into the testing jig and the shaft was clamped
  - Mass of the clamp caused problems with smaller diameters
- The test procedure was run using Blue Hill and the data was saved



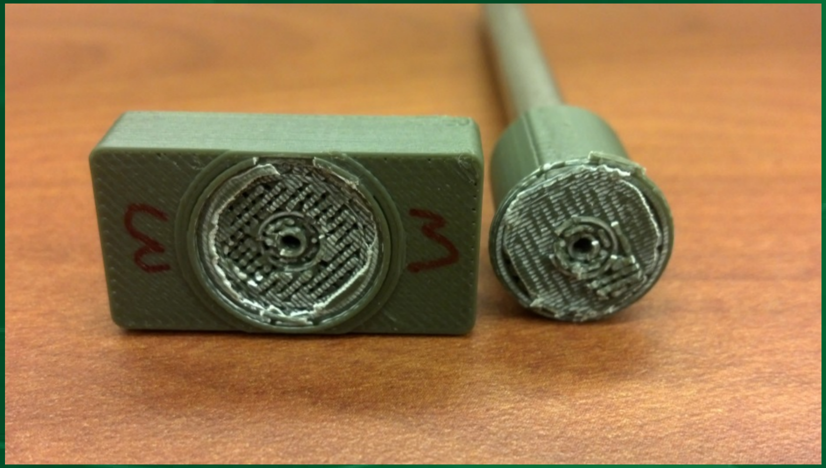
RP Hub Press Fit Results

- 0.125" hubs
  - A large portion of these test pieces broke before testing
    - Press fit
    - Instron clamp
  - Not enough data
- 0.1875" hubs
  - An increase in interference and hub depth significantly increased holding capacity
  - Failed at joint for these tests



RP Hub Press Fit Results

- 0.25 ″ hubs
  - An increase in interference and hub depth significantly increased holding capacity
  - Some failed at joint, some failed through material failure at the base
- 0.3125 ″ hubs
  - An increase in interference and hub depth significantly increased holding capacity
  - Some failed at joint, some failed through material failure at the base



RP Hub Press Fit Results

- Hubs designed to conform to metal hub parameters
- 0.189” and 0.255 ” not following expected trend
- Possible outliers
- Larger sample size would improve results

Diam	0.1282		0.189		0.255		0.315	
Depth	0.25		0.25		0.25		0.25	
Thdia	0.1193282		0.180189		0.246255		0.306315	
Interf	0.0056718		0.007811		0.003745		0.005685	
	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)
	1		1	27.503	1	22.527	1	42.288
	2		2	32.389	2	8.446	2	35.964
	3		3	31.278	3	28.497	3	29.69
	Mean		Mean	30.39	Mean	19.823333	Mean	35.980667
	Standard Deveation		Standard Deveation	2.5611827	Standard Deveation	10.295291	Standard Deveation	6.2990165
	Spread		Spread	4.886	Spread	20.051	Spread	12.598
	Conf T 95%		Conf T 95%	6.3623306	Conf T 95%	25.57492	Conf T 95%	15.647625
		0.125		0.188		0.25		0.312

Diam	0.1282		0.189		0.255		0.315	
Depth	0.5		0.5		0.5		0.5	
Thdia	0.1193282		0.180189		0.246255		0.306315	
Interf	0.0056718		0.007811		0.003745		0.005685	
	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)
	1	31.292	1	60.525	1	63.851	1	114.604
	2	16.568	2	59.659	2	45.334	2	78.353
	3 (B)	43.596	3	50.738	3	57.905	3	89.304
	Mean	30.485333	Mean	56.974	Mean	55.696667	Mean	94.087
	Standard Deveation	13.532045	Standard Deveation	5.417865	Standard Deveation	9.4539608	Standard Deveation	18.592783
	Spread	27.028	Spread	9.787	Spread	18.517	Spread	36.251
	Conf T 95%	33.615462	Conf T 95%	13.458723	Conf T 95%	23.48494	Conf T 95%	46.187033

RP Hub Press Fit Results

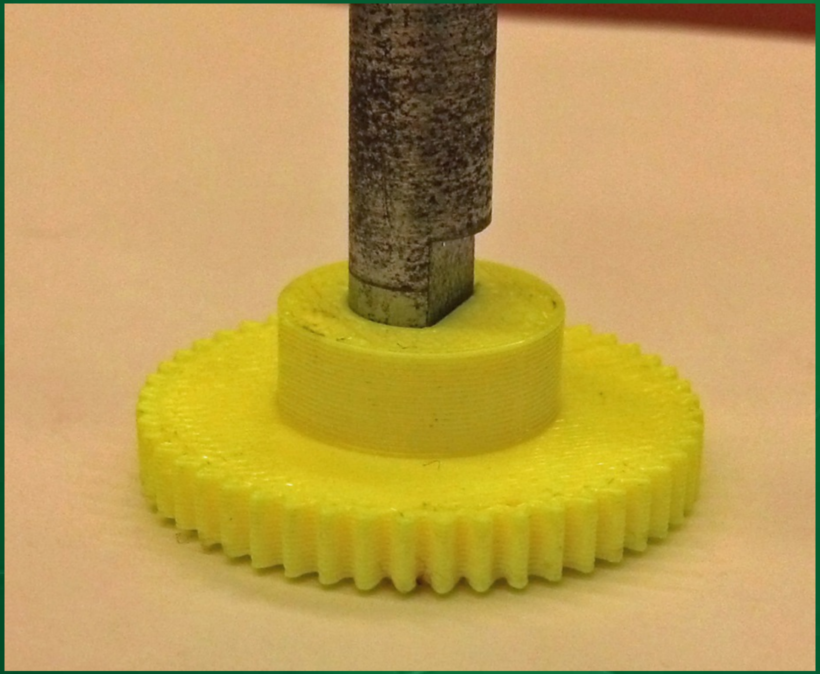
- Hub designed with larger amount of interference
- Increases in holding strength did not follow expected trend
- Many of the test pieces failed during testing
- Significantly higher force required than previous tests
- Possible cause of unexpected results probably due to the part fill style

Diam	0.125		0.1875		0.25		0.3125	
Depth	0.25		0.25		0.25		0.25	
Thdia	0.116125		0.1786875		0.24125		0.3038125	
Interf	0.008875		0.0083125		0.00875		0.0081875	
	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)
	1 (B)	40.871	1	56.962	1	80.206	1	42.66
	2	43.832	2	32.089	2	65.632	2	95.787
	3		3	53.912	3	54.279	3	63.667
	Mean	42.3515	Mean	47.654333	Mean	66.705667	Mean	67.371333
	Standard Deveation	2.0937432	Standard Deveation	13.565962	Standard Deveation	12.996804	Standard Deveation	26.756515
	Spread	2.961	Spread	24.873	Spread	25.927	Spread	53.127
	Conf T 95%	18.811536	Conf T 95%	33.699718	Conf T 95%	32.28585	Conf T 95%	66.466868
		0.125		0.187		0.25		0.312

Diam	0.125		0.1875		0.25		0.3125	
Depth	0.5		0.5		0.5		0.5	
Thdia	0.116125		0.1786875		0.24125		0.3038125	
Interf	0.008875		0.0083125		0.00875		0.0081875	
	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)	Sample	Maximum Force (lbf)
	1 (B)	45.533	1	114.42	1 (B)	172.533	1 (B)	198.51
	2 (B)	47.91	2	122.144	2 (B)	201.362	2	155.474
	3 (B)	29.082	3	150.896	3 (B)	194.742	3	
	Mean	40.841667	Mean	129.15333	Mean	189.54567	Mean	176.992
	Standard Deveation	10.253285	Standard Deveation	19.221673	Standard Deveation	15.100636	Standard Deveation	30.431047
	Spread	18.828	Spread	36.476	Spread	28.829	Spread	43.036
	Conf T 95%	25.470572	Conf T 95%	47.749283	Conf T 95%	37.51206	Conf T 95%	273.41211

Hub Press Fit Recommendations

- Find a way to control test parameters (lighter clamp)
- Print the pieces using a solid fill as opposed to the sparse-high density
- Perform torsional testing of different hub setups (spline, D-shaft, press fit)



Power Transfer

- The production of power transfer parts such as gears and belt pulleys can be a useful tool
- Several different gears of differing diametral pitch were printed using the Stratasys Dimension sst 1200es and the Stratasys Prodigy Plus machines
- The pieces maintain their involute profile for 16, 24, and 32 pitch teeth
- 48 pitch gears appear to be too fine to be produced on these machines
- Results are only qualitative at this time

Power transfer

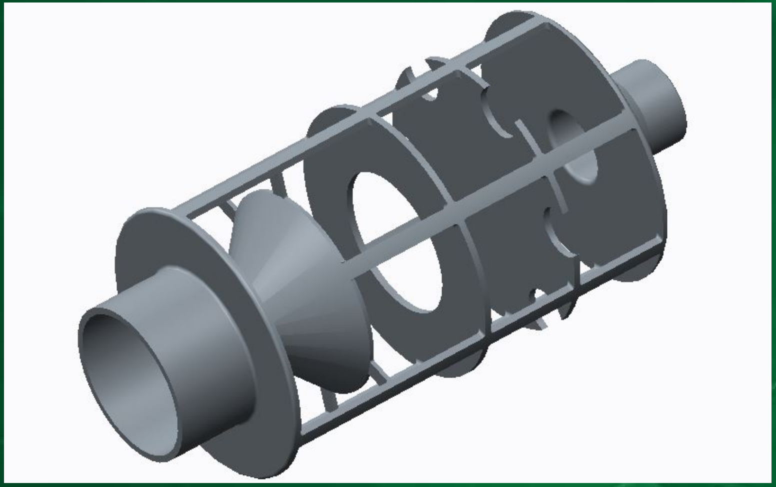
- No strength or functional tests have been performed on the printed gear sets at this time
- Printed gears have been used successfully in do it yourself applications
- Would be important to test if they mesh with conventionally manufactured parts
- Strength and durability compared to conventional parts should be examined

MDX-20 Vacuum System

- The Roland MDX-20 already had a custom enclosure to house a vacuum and reduce noise
- Vacuum did not have an exhaust outlet, cabinet would overheat
- No effective nozzle for the removal of chips and dust while machine was operating

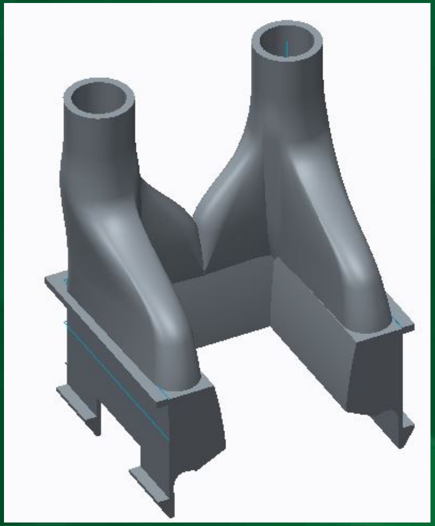
MDX-20 Vacuum System

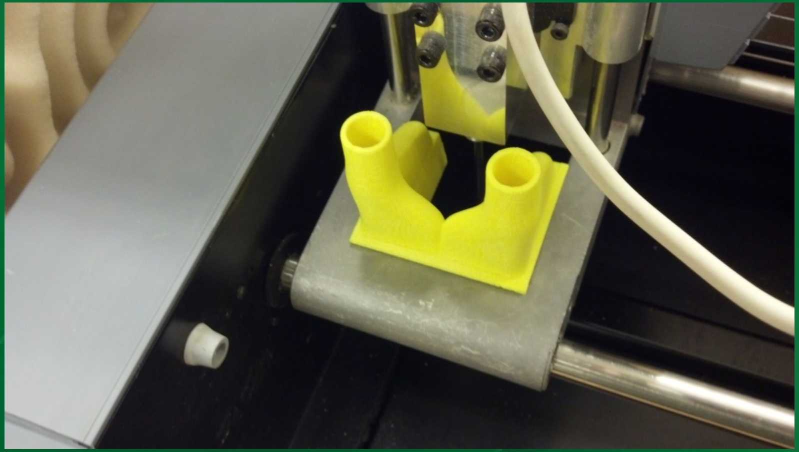
- It was necessary to design a muffler system so the vacuum exhaust could be vented outside of the cabinet
- A basic baffle design was created using Creo and modeled using the Stratasys Dimension machine
- The muffler was designed to use a 4 inch pvc pipe as the outer shell
- A small amount of open cell foam was inserted inside a portion of the assembly



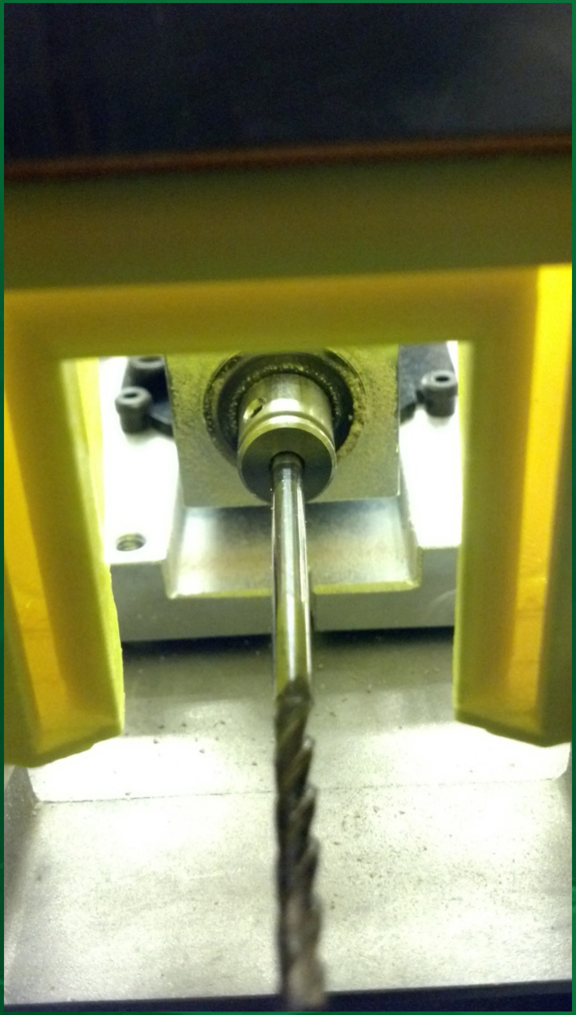
MDX-20 Vacuum System

- A nozzle to attach to the router head was designed using Creo and Modeled using the Stratasys Dimension
- Several iterations were generated to ensure head clearance and correct fit
- A separate piece was made to attach to the top and connect to the vacuum hose

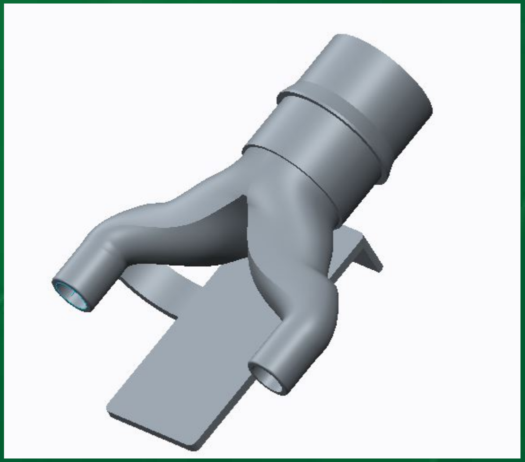




MDX-20 Vacuum System



- The muffler is currently installed on the vacuum and performing well
- The nozzle system is still near completion



Summary

- Press fits could be useful in rapid prototype design
  - More research to test the limits and create best practices for production and design
- Rapid prototyping can be a plausible solution to power transmission in prototype and small production systems
  - Research into strength and durability would be necessary
  - Research into strength of joints should be performed
- MDX-20 desktop router is better suited for an office environment
  - Process is more autonomous

References

- *General Design Principles for Dupont engineering polymers*. 2000.
- BASF, . *Design Solutions Guide*.