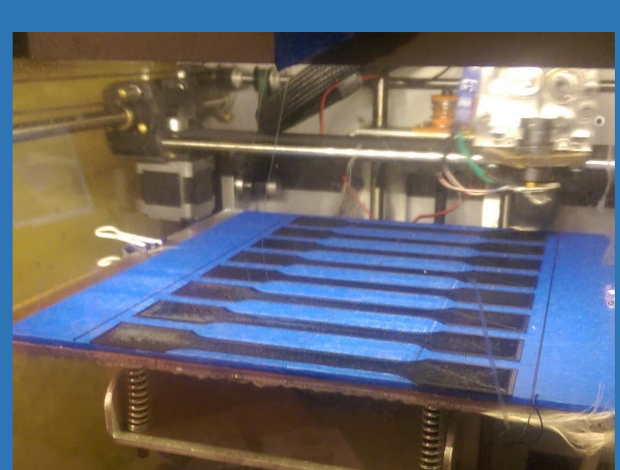
Annealing 3D Printed Parts

Michael Rosplock –College of Science and Engineering

Introduction

After finding past research into the topic of annealing 3D printed parts, it seemed reasonable to study this topic even further with this UROP project. The basic idea behind annealing an object is to favorably change the mechanical properties of the material to better suit the needs of a design. In this case either stiffening or softening the part would have been desirable traits. Stiffer samples would lead to stronger but more brittle parts, which have application in some instances. Softening the part would have increased ductility while decreasing the overall tensile strength. This should lead to a tougher part that is less susceptible to fracture when dropped, repeatedly loaded, etc. This was the result that was originally predicted for the two materials tested.

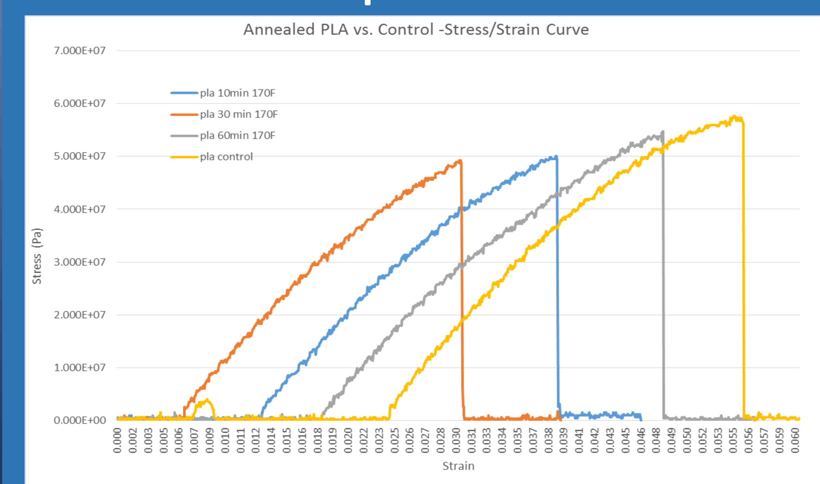


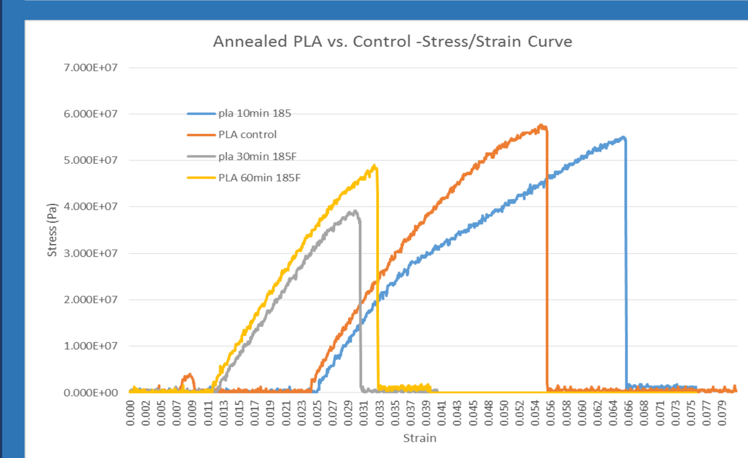
Methodology

Two different materials (ABS and PLA) and multiple annealing processes were used to determine the effect on the mechanical properties of 3D printed samples. With temperatures ranging from 170 to 200 F and times ranging from 10 to 60 minutes, over 100 samples were tested to create a large sample set. These samples were then tested in an Instron tensile testing machine to determine their tensile behavior.

Results

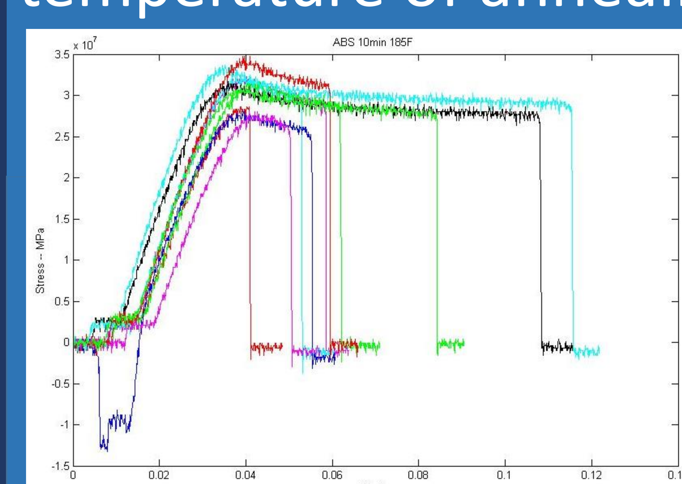
Experiment 1: An initial experiment to determine if there is any change in mechanical performance due to annealing.

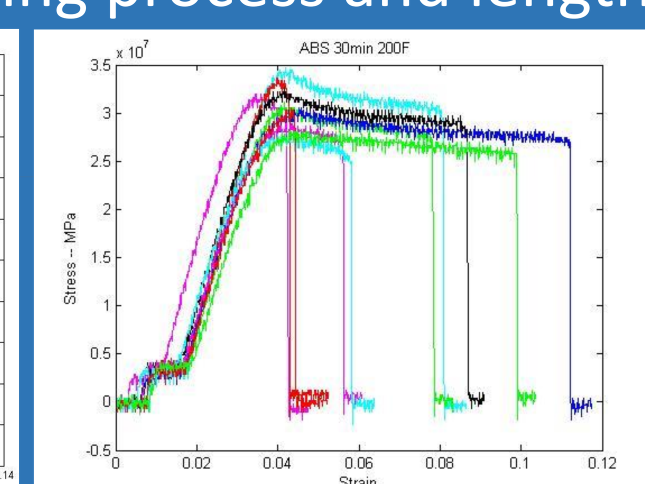


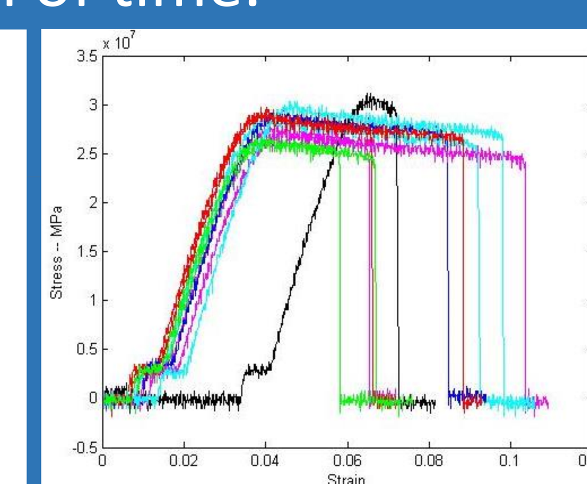


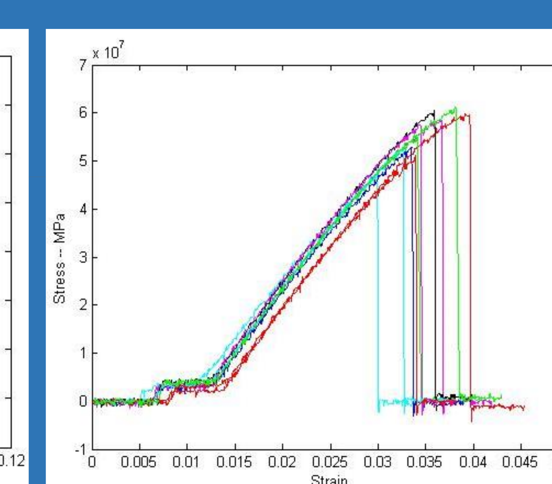
These graphs demonstrates my original findings on annealing. The first graph deals with PLA and the second with ABS samples. The sample sets were small, but the results were interesting enough to pursue in full scale.

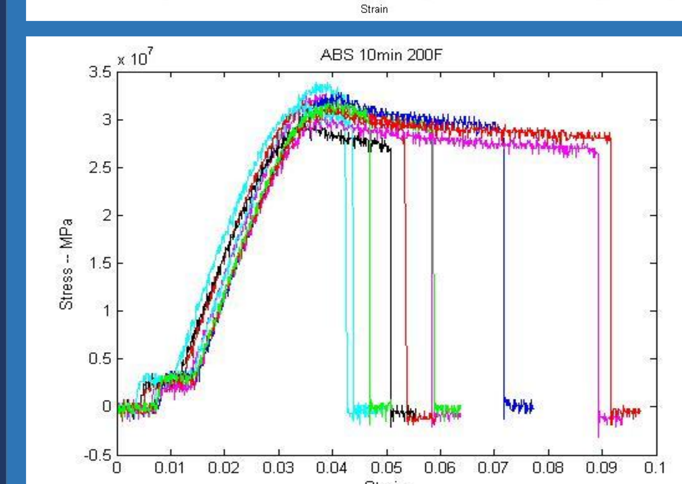
Experiment 2: This experiment used a much larger sample set and more rigorous quality control to try and isolate tensile strength according to two variables, temperature of annealing process and length of time.

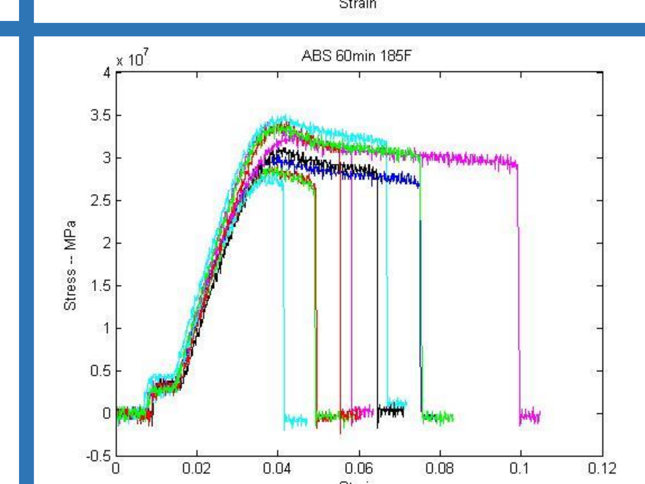


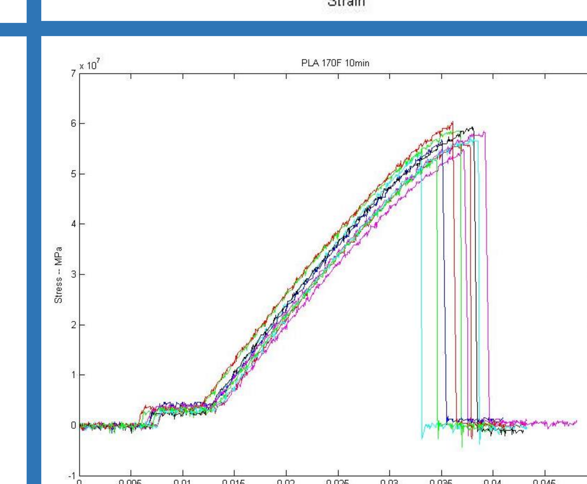


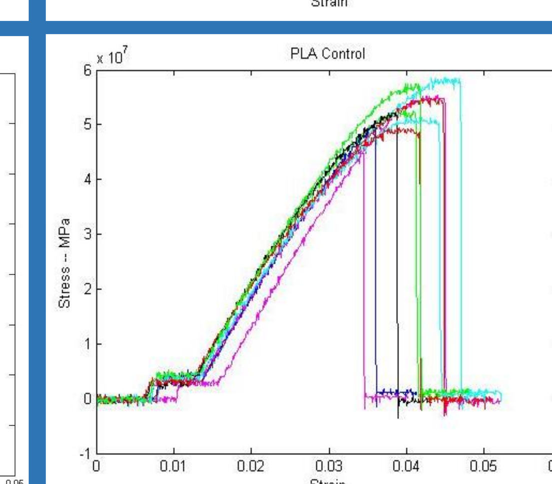


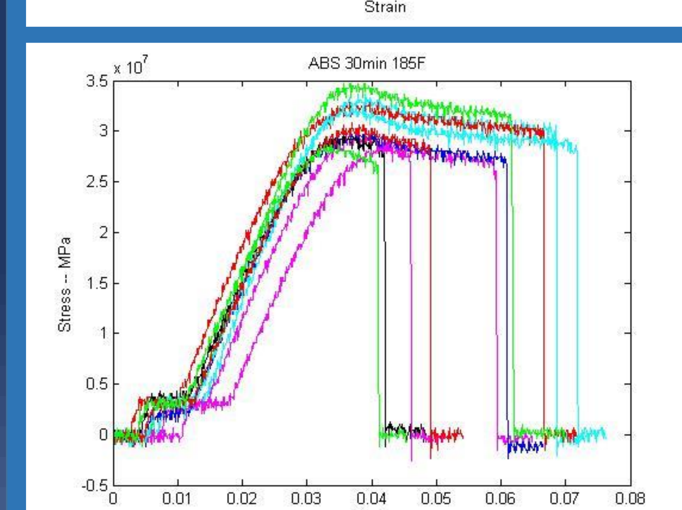


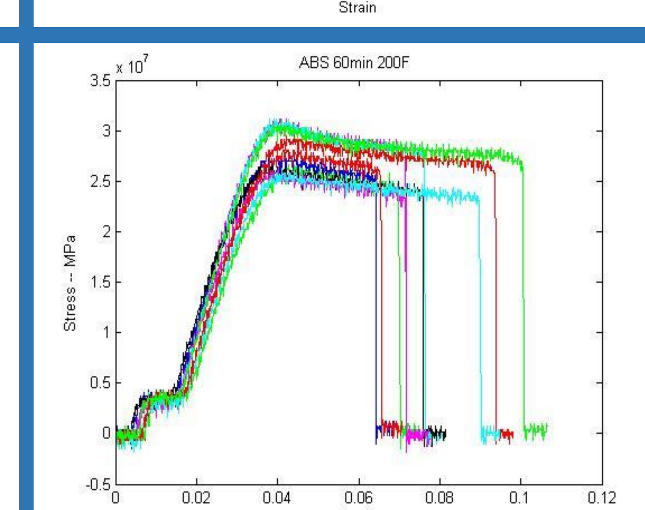


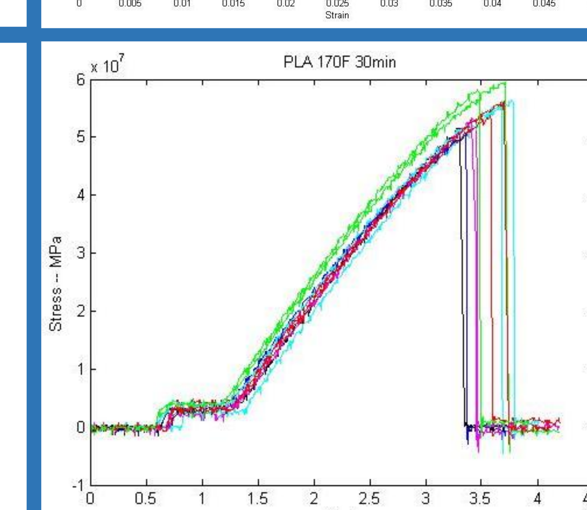












	UTS (Mpa)	Strain AB	difference	
ABS control	2.8180	0.0761	UTS (Mpa)	Strain AB
ABS 10min 185F	3.0880	0.0687	0.2700	-0.0074
ABS 10min 200F	3.1280	0.0619	0.3100	-0.0142
ABS 30min 185F	3.0680	0.0567	0.2500	-0.0194
ABS 30min 200F	3.0470	0.0701	0.2290	-0.0060
ABS 60min 185F	3.1300	0.0634	0.3120	-0.0127
ABS 60min 200F	2.7990	0.0808	-0.0190	0.0047

Standard Dev.				
Samples	UTS (Mpa)	Percent SD	Strain AB	Percent SD
ABS 10min 185F	0.2163	7.00	0.0239	34.83
ABS 10min 200F	0.1225	3.92	0.0163	26.34
ABS 30min 185F	0.1921	6.26	0.0107	18.94
ABS 30min 200F	0.2103	6.90	0.0236	33.69
ABS 60min 185F	0.2427	7.75	0.0160	25.25
ABS 60min 200F	0.2018	7.21	0.0119	14.69

	UTS (Mpa)	Strain AB	difference		percent change	
PLA control	5.205	0.0415	UTS (Mpa)	Strain AB	UTS (Mpa)	Strain AB
PLA 10min 170F	5.646	0.0367	0.4410	-0.0048	7.8108	-11.6358
PLA 30min 170F	5.447	0.0358	0.2420	-0.0058	4.4428	-13.8689
PLA 60min 170F	5.502	0.0349	0.2970	-0.0066	5.3980	-15.8516

Standard Dev.				
Samples	UTS (Mpa)	Percent SD	Strain AB	Percent SD
PLA 10min 170F	0.2205	3.91	0.0019	5.11
PLA 30min 170F	0.2675	4.91	0.0016	4.38
PLA 60min 170F	0.4448	8.08	0.0027	7.62

Discussion

As one can see from both the graphs and tables for ABS, there was a huge amount of variation within the data, especially when looking at the strain at break. Standard deviation was translated to percent to make better sense of the incredibly small number. With standard deviation units as high as 35% of the entire value for strain, it's nearly impossible to pull any reliable or meaningful data from these results, though there was a trend that the ductility decreased from the annealing process

After processing the PLA data, an interesting change in consistency occurs. Instead of the huge variation seen in the ABS samples, the PLA sets actually have very consistent results. Unfortunately there were very small changes in tensile strength and strain when compared to the control set. Leading to an increase of about 5% in tensile strength with a 15% loss in strain at break. These results show that again, there is little value in annealing 3D printed samples, though it should be noted that PLA has more consistent mechanical properties compared to ABS.

One theory I came up with to explain the ineffectiveness of the annealing process is that since the part sits on a hot piece of glass in a relatively hot environment, the parts may already be 'annealed' due to the printing process. After being printed for a long time in a hot environment the parts may be annealed to some extent. Making further processing unnecessary.

Conclusion

After this extensive study into the effects of annealing on 3D printed parts' mechanical properties, it has been found that there is little value in the process for any purpose. The properties simply didn't change that much after averaging the values over data sets of ten with temperature or length of annealing time.

The most interesting part about the experiment was how varied the ABS samples were in general and how consistent the PLA samples were. With further testing this could lead to the conclusion that ABS is a less stable printing material, yielding less consistent results compared to PLA. This could have a large effect on choice of material when consistency between pieces is required.