SLS POWDER LIFE STUDY

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ABSTRACT

Producing acceptable models on the Selective Laser Sintering (SLS) machine involves adjusting machine parameters relative to powder age. Typically, a fraction of the powder is used and the remainder of the unused powder is recycled. After 5-7 recycles, this method leads to a powder inventory with inconsistent characteristics. The goal of this study was to apply a new recycling program to extend powder life, reduce powder inventory, and improve part quality. This study looks at various material properties of processed powder over its lifetime, including: surface quality, toughness, impact strength, elastic modulus, tensile strength, and shrinkage. A new approach to powder recycling and machine parameter adjustment will be recommended.

INTRODUCTION

Since build parameters vary for different machines and powders, this study focused on the Sinterstation 2000 using DuraForm™ Polyamide powder. Previously, during model building, a fraction of the powder is used and the remainder of the unused powder is re-processed (recycled). Recycling DuraForm™ powder involves mixing 33% unused (or new) powder and 67% used (or old) powder through a sifter with a 50/70 Mesh Screen. After 5-7 recycles, this method leads to a powder inventory with inconsistent characteristics that will produce unacceptable models using default machine parameters – *as defined by the manufacturer*. It became expensive building models over 4 inches high on a consistent basis, considering the amount of powder required for recycling. This method also failed to accurately indicate the number of recycles possible before the powder was unusable.

OBJECTIVE

The main objective of this study was to determine when powder is no longer usable. Primarily, start with enough powder so that it will provide 300 hours of build time without running short. Explore the effect on mechanical and physical properties if laser power, glaze, and crack point are determined and adjusted before each build. Determine optimal laser power and glaze point as a function of powder age and desired property.

APPROACH

Part Geometry

The part was designed to capture several characteristics of parts produced using SLS nylon. As shown in figure 1, the overall part is composed of three smaller parts joined together. The tensile sample captures mechanical properties such as, tensile strength, modulus of elasticity, percent elongation, and toughness. The smaller, rectangular part captures un-notched impact strength. The tensile and impact samples capture process shrinkage and warpage. The

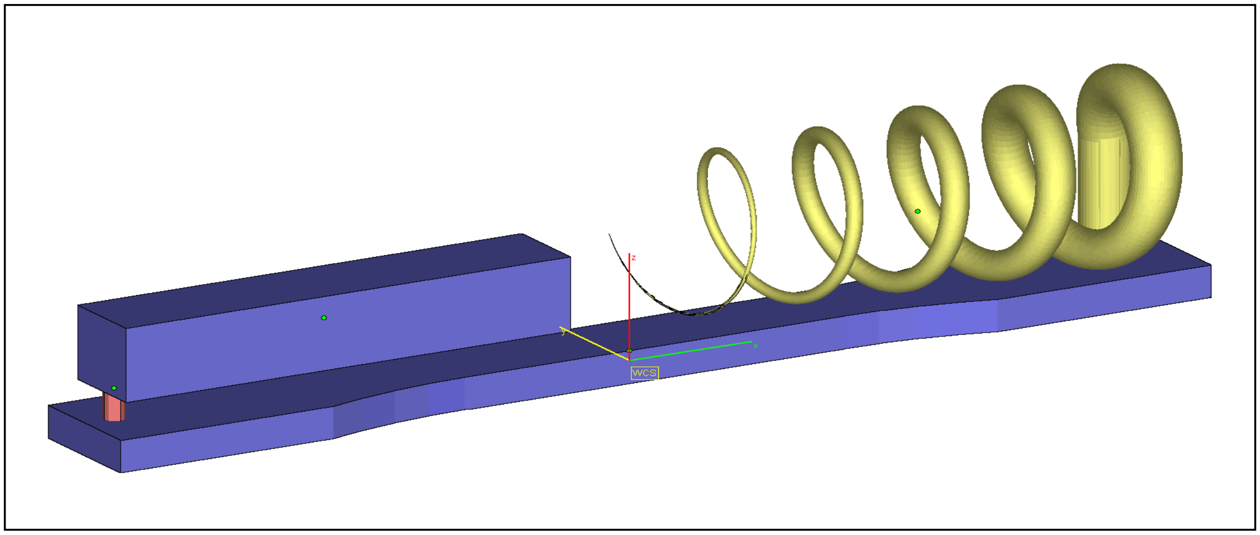

Figure 1. Test Sample Geometry

tapered helix provides information on minimum cross-sections and non-vertical surface finish. The combination of all parts provide information on sharpness of edges and surface quality.

Part Processing

Five drums of powder were used for the experiment, all verified to be from the same lot of powder. As shown in figure 2, powder samples were taken at the start of each run. The same powder was reused during the entire series of runs. The glaze and crack point were determined and used for optimal settings before building each set of test parts. The glaze point is the temperature at which powder on the part bed begins to melt. The crack point is the temperature at which powder on the feed heaters begins to melt. Before each run, small disks were built to determine the laser power range of the aging powder. The disks were not removed from the machine, but were visually inspected to determine upper and lower limits. After the range was determined, three sets of two samples were produced with low, medium, and high power. For the

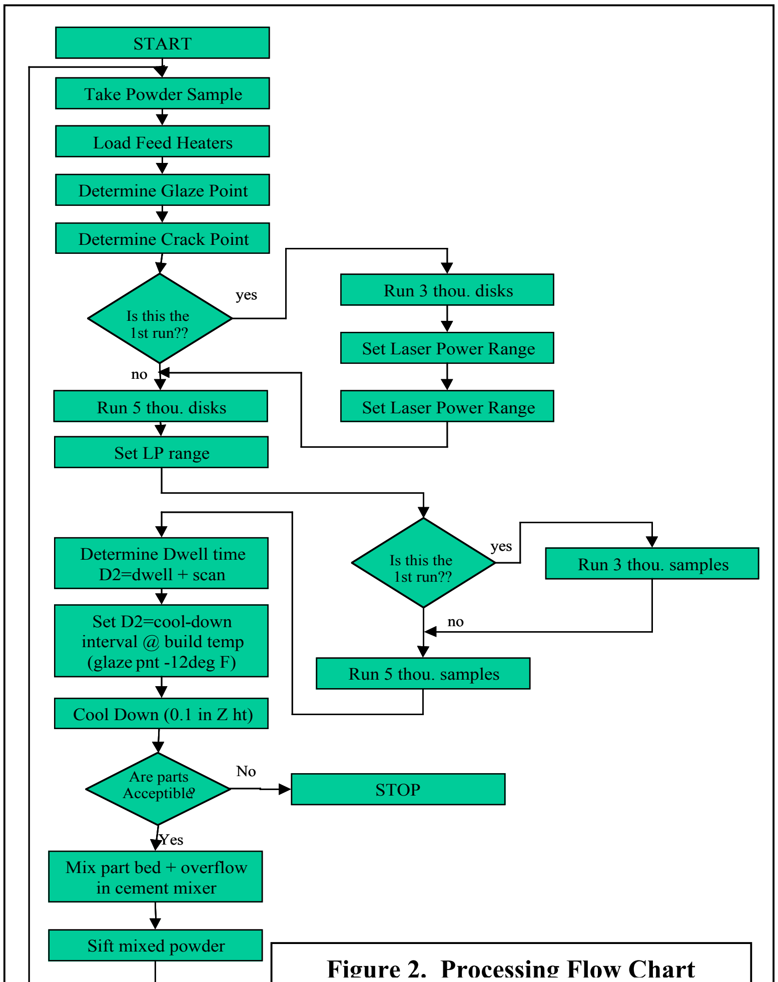

Figure 2. Processing Flow Chart

first run, one set of 0.003 inch layer thickness parts was included followed by 0.005 layer thickness parts. After the first run all test parts were produced in 0.005 inch layer thickness. The z-height of the test parts produced was not large enough to use up all the powder in the feed heaters. All powder in the feed heaters needed to be used in order to age the powder at the same temperature by passing it through the part bed, which is at about 65^{o}C degrees above the temperature of the feed heaters. To better simulate a taller build and age all the powder in the feed heaters, each 5-6 hour run was stretched to 24 hours. This was necessary to realistically age the powder until it degraded to the point where it is no longer useful. A method was created to age the powder at the same temperature by utilizing the cool down process on the Sinterstation to simulate the build process. Typically, the cool down process starts when the laser has scanned the last part in the part bed. This process cools the part bed and lowers the temperatures of the feed heaters in a controlled manner while spreading the powder from the feed heaters onto the part bed. We revised this process to maintain the same temperatures experienced during part building in order to age the powder uniformly. The average scan time of each layer was used as the time interval between layers during the revised cool down process, until most of the powder in the feed heaters was used and enough remained to allow for the normal cool down process. After each run, the parts were visually inspected for physical defects, characteristic of fully degraded powder, to determine when to end the experiment. Powder degradation has a direct impact on the surface finish of the parts. It is important to note that mechanical properties did not determine the number of runs, appearance was the deciding factor in when to stop. All remaining powder from the part bed, feed heaters and overflows was thoroughly blended and sifted before the start of each run.

Testing

Testing can be divided into three categories, including tensile testing, impact testing, and physical testing. After samples were processed on the SLS they were stored under the same conditions until all samples were complete and ready for testing. All samples were tested within a two-day period under the same test conditions.

RESULTS & DISCUSSION

Glaze & Crack Point

Glaze point, shown in figure 3, was fairly constant to around 150 hours at which point it declined up to 192 hours. It should be noted that before the final run the IR sensor failed and was replaced. Actual temperature was higher (by a constant factor) than set temperature in the runs before 216 ^{o}C. Crack Point was steady at 96 ^{o}C.

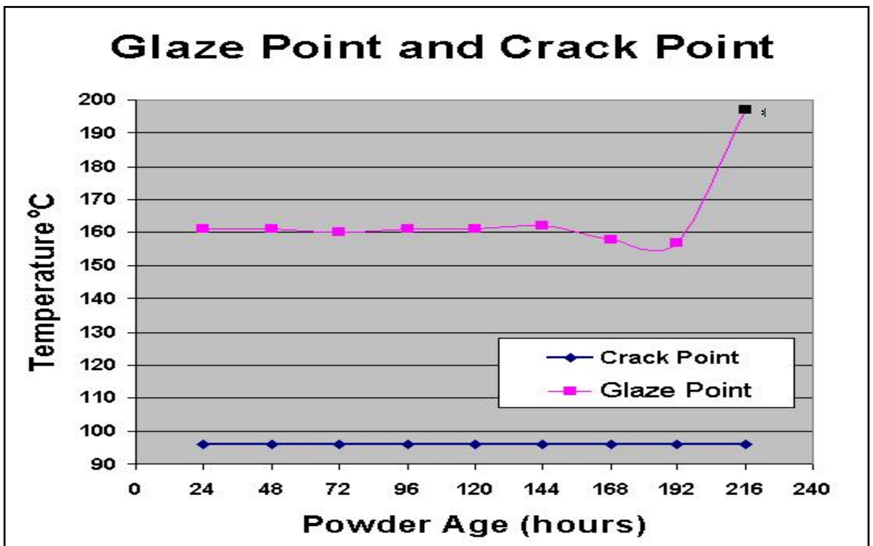

Figure 3 *glaze point increase on last run is due to IR sensor change

Laser Power

Low, medium and high laser power were increased as needed before each build. Figure 4 illustrates an increase in laser power settings from a range between 3 and 5 watts in the first run to a range between 6.5 and 8.5 watts in the final run. This study shows the importance of increasing laser power relative to powder age to maintain part quality.

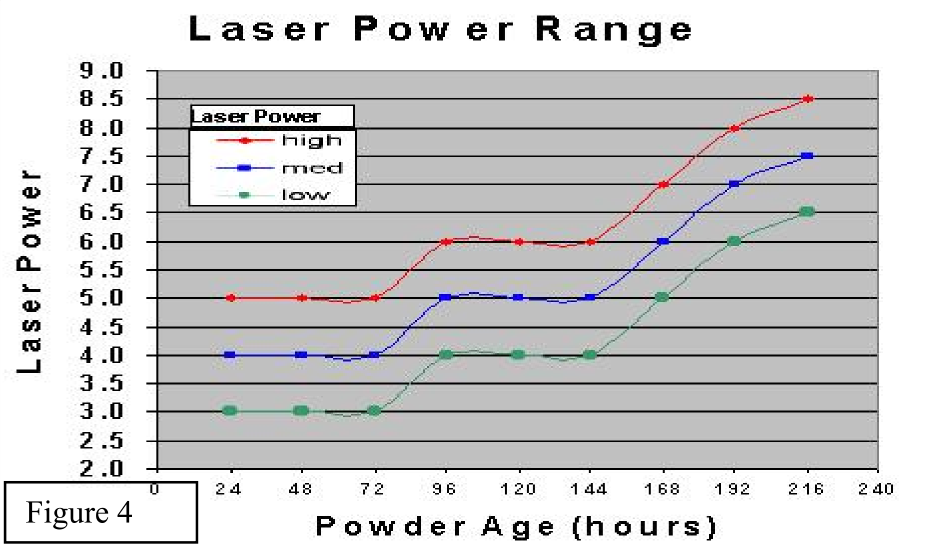

Figure 4

Tensile Strength

As shown in figure 5, the ultimate tensile strength is higher for the high power setting and steadily declines below the low and medium powder settings, at around 150 hours of powder age. A combination of higher than needed power and older powder may tend to chemically degrade the powder. Typical UTS fell between 5000 to 7000psi, which corresponds with vender's claim of 6400psi.

Young's Modulus of Elasticity

Modulus of elasticity was fairly stable averaging around 250 Ksi, as shown in figure 6.

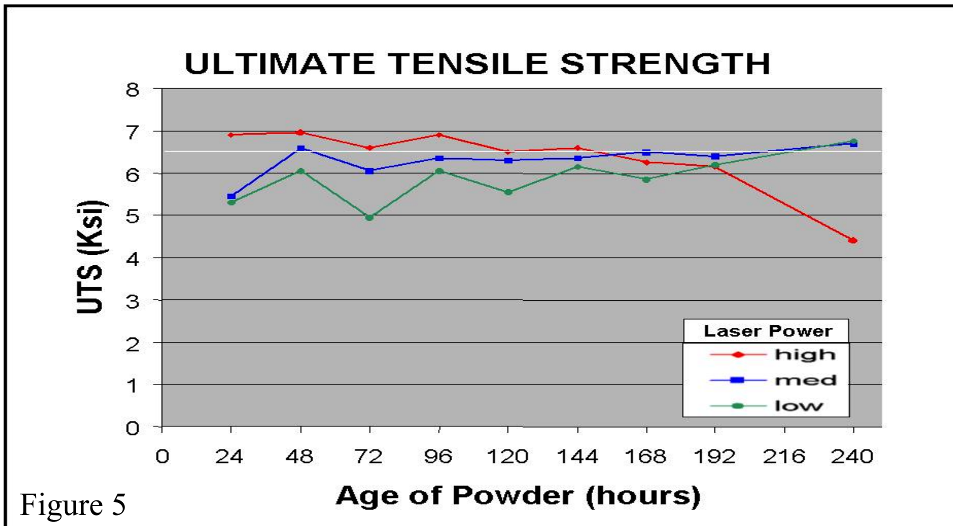

Figure 5

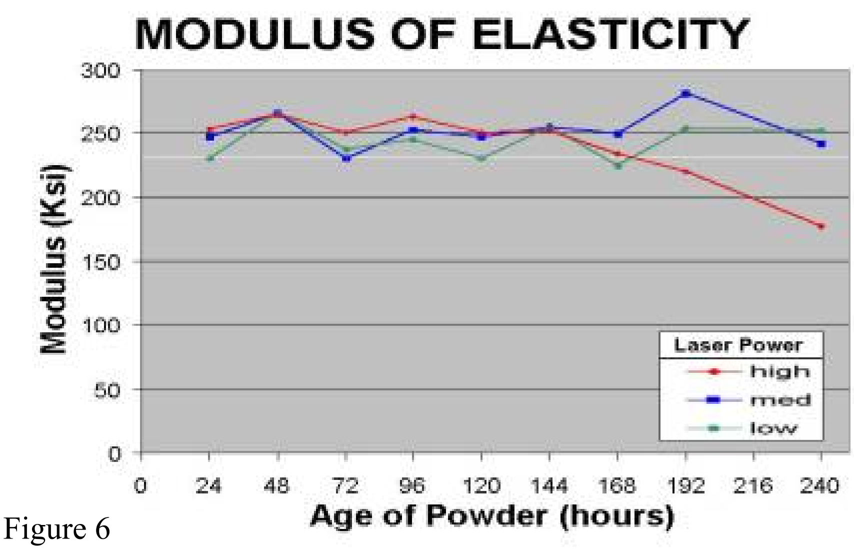

Figure 6

For the samples with high laser power modulus declined after 150 hours. The modulus corresponds with the vender's claim of 232 Ksi.

Toughness

Toughness is determined by calculating the area under the stress strain curve on each specimen. As shown in figure 7, the toughness increases to a point around 168 hours and then declines for med and high laser settings. The low laser setting increases to a high in toughness at 240 hours. Figure 7 suggests that toughness has much to do with the amount and intensity of heat the powder has been exposed to over its lifetime, reaching a threshold at around 160 hours for the medium and high laser power.

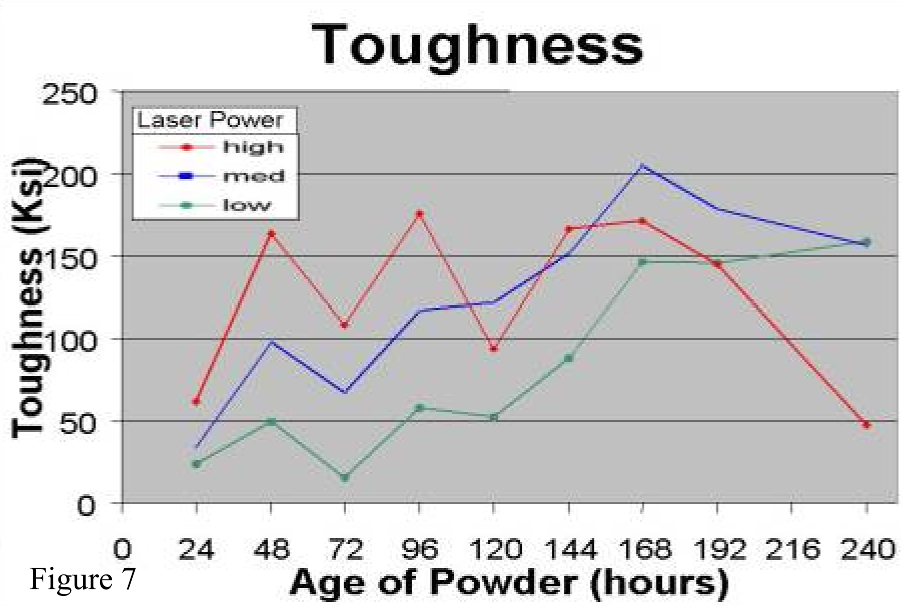

Figure 7

Impact Strength

Impact strength, shown in figure 8, follows a pattern comparable to the toughness results, in the previous graph, with impact strength declining after 150 hours. In this test all three samples decline at the same age, suggesting that impact strength declines due to powder age more than the combination of laser power and powder age.

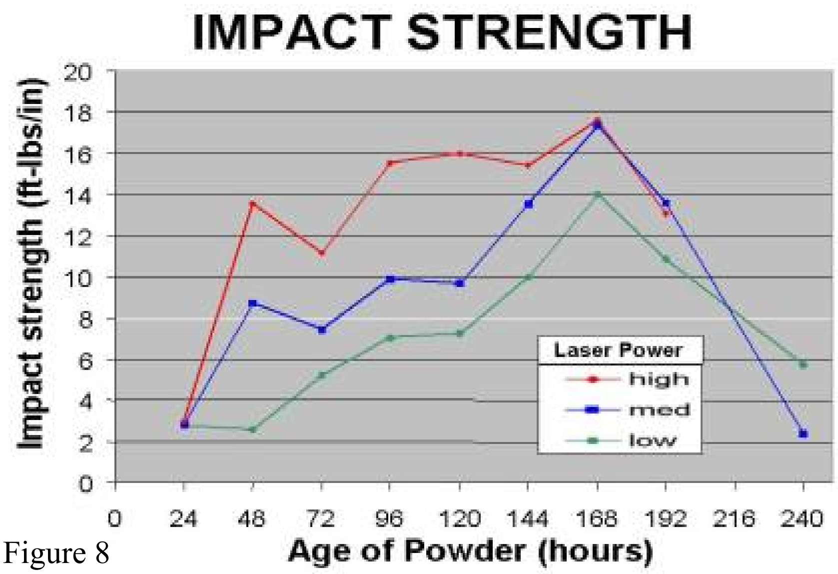

Figure 8

Shrinkage

Shrinkage as shown in figure 9, was not constant in this study. Shrinkage was least effected by laser power on the first run, holding steady at 3.8%. After 24 hours the powder shrinkage became more sensitive to laser power and held steady to 144 hours. At around 168 the shrinkage was very small at around 1%. After the powder aged past 168 the shrinkage again increased. From these results, average shrinkage as a function of laser power and powder age could be estimated. This change in shrinkage has not been verified with an additional study.

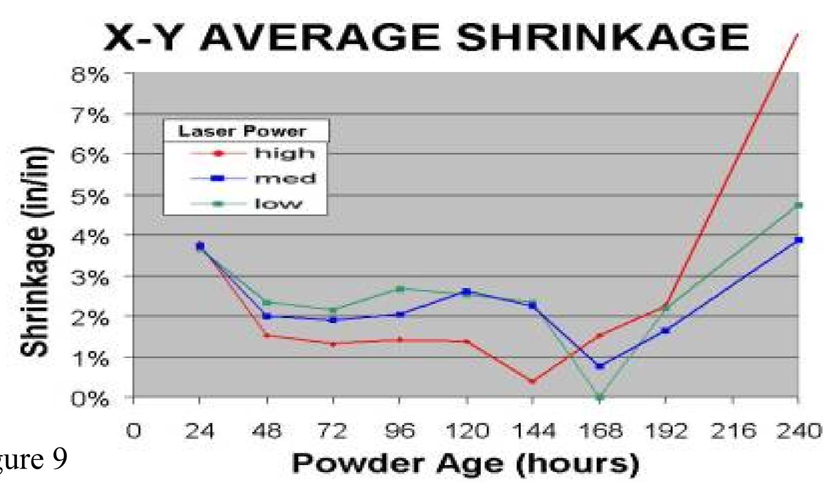

Figure 9

CONCLUSIONS

Glaze point and crack point are fairly stable as the powder ages while laser power must continually be bumped up.

Mechanical properties such as tensile strength and modulus of elasticity are fairly stable up to and past 192 hours of powder age. Toughness and impact strength generally improve up to around 168 after which they tend to decline.

Shrinkage decreases after the first powder usage and stabilizes around 2%. After the powder is older than 150 hours shrinkage decreases and then rises above 2%.

The SLS powder life study proved a tremendous success since we averaged 215 hours per 4 drums before the study and now averaging 315 hours. Using the experimental results, consider storing the used powder in separate bins based on the amount of hours spent on the machine instead of the number of builds. In the case of varying build times, which is inevitable, only mix and sift powders within a 5-hour age difference. This will ensure average powder characteristics.

Experimental results show a significant laser power change every 75 hours, therefore the NY Scale and laser discs should be built every 75 hours to determine the new shrinkage values and appropriate laser power. Although the glaze point show a minimum increase from the experimental results, it should be determined after150 hours to verify the experimental results.

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