SL 5410: High Humidity, Water, and Heat Resistant Resin for Stereolithography

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Abstract

A new Stereolithography (SL) resin, CibaTool® SL 5410, which imparts good humidity and heat resistance, was released in July, 1997. This epoxy based resin for SLA-500 was developed mainly to eliminate the relatively weak resistance to high humidity and high heat that the first generation of resins suffered from. Namely, with this new resin, strength of QuickCast part and solid parts can now be maintained under high relative humidity. Even when immersed into water, part strength of SL 5410 is essentially preserved. Thermomechanical properties have also improved significantly relative to those of SL 5180. Heat deflection temperature and Tg values increased by +15°C to +40°C, to as high as 88 °C and 105°C, respectively, for SL 5410, when parts were additionally thermally postcured. Improvements in mechanical properties are also included in this paper. These property enhancements were achieved while further improving part accuracy, vertical surface finish, and productivity. Productivity may increase by as much as 2.5-fold over SL 5180. Also, SL 5410 requires no predip delay, hence cutting the overhead time. These newly achieved resin characteristics for SL 5410 are expected to improve the ease-of-use in today's applications, and open new fields of applications in the near future.

Introduction

Since the first commercialization in 1987, Stereolithography (SL) has established as one of the most accurate, efficient, reliable, versatile, and most widely used Solid Freeform Fabrication (SFF), or Rapid Prototyping and Manufacturing (RP&M) technologies available today, and continues to find worldwide acceptance. Among various elements that make SLA successful, resin technology is undoubtedly one of the key elements. Specifically, the upgrading of acrylate based to epoxy based SL resins in 1993 has shifted the paradigm of what can be achieved through SLA technology.

The first generation of epoxy based resins for 3D Systems Stereolithography Apparatus (SLA) were commercialized in 1993. The major advantages of these epoxy resins were their high accuracy, dimensional stability, mechanical properties, and numerous other positive characteristics that were not attained with the earlier acrylate based resins. However, one of the disadvantages of these first generation epoxy resins were their relatively poor humidity and water resistance. Also, their thermomechanical properties were often insufficient for thermally challenging applications[1] since they were not designed for that purpose.

SL 5410 was developed to combat these shortcomings, while maintaining almost all, or even improving some, of the positive traits generally associated with epoxy based SL resins. In the following sections, performance characteristics of SL 5410 will be presented, along with experimental data to support the claims. Improvements in high humidity and water resistance, heat resistance and other mechanical properties, as well as in part accuracy, surface finish, and productivity will be presented below. Other relevant material properties will also be included for purposes of reference.

Humidity Resistance

In order to measure humidity resistance, a small test part called "flexbar" having dimensions of 2.5 mm X 10 mm X 70 mm were built in the desired build style on an SLA. These parts were exposed to a designated relative humidity. Flexural modulus is then determined using a method similar to ASTM D790, as the samples were exposed over time to each environment. Both ACES solid and QuickCast quasi-hollow parts built in SL 5410 were tested in comparison with that of SL 5180.

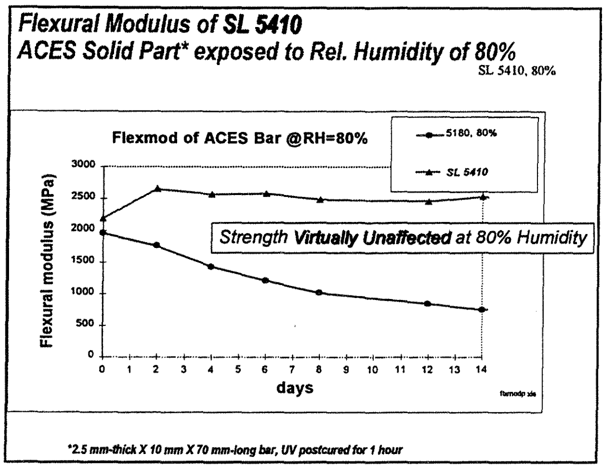

Figure 1

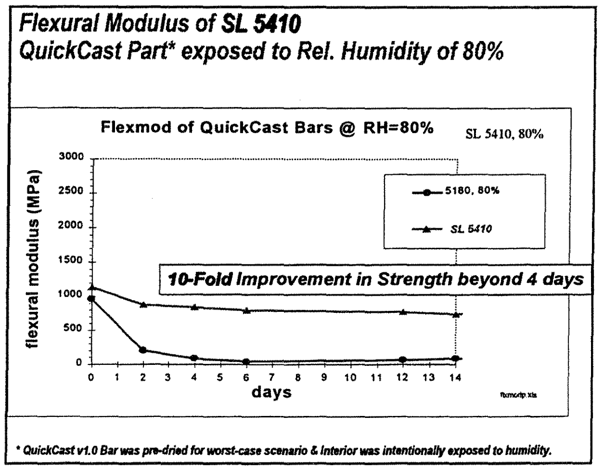

Figure 2

Flexural modulus of a solid test part built in SL 5410 is shown in **figure 1**. Notice that the flexural modulus of SL 5410 is almost invariable even when it is exposed to a relative humidity of 80%, while that of SL 5180 tends to decrease over time. In fact, the ultimate flexural modulus of SL 5410 is greater than at time = 0 since the resin undergoes continued epoxy crosslinking reaction. Hence, *flexural modulus of solid parts built in SL 5410 are virtually unaffected by humidity.* This property ensures that SL parts made in SL 5410 do not require special handling even under high humidities conditions. This should significantly prolong the useful life and increase the range of environments in which SLA parts can be used.

SL 5410 is also QuickCast capable. Based on one Beta test source, SL 5410 has not failed in the several months of testing, involving many different geometries. QuickCast parts for investment casting were built in the QuickCast 1.1 style. However, for purposes of comparing flexural modulus with data in the past, test parts were built using QuickCast version 1.0. Holes were drilled at the downfacing skins at the corners of the QuickCast flexbar test parts, and were left open to intentionally expose the internal sections to the surrounding humid air. This accelerates the water absorption and simulates the worstcase scenario of unsealed QuickCast parts.

The flexural modulus data of such a QuickCast test part built in SL 5410 is shown in **figure 2**. Here, there is an observable drop in modulus from about 1100 MPa to 800 MPa in about 2 days. Henceforth, the strength stays relatively constant. Notice that beyond about the 4-day mark, the *difference between the strengths of QuickCast parts built in SL 5410 and SL 5180 is more than ten-fold!*. This humidity resistance of SL 5410 is the key for potentially achieving much greater accuracy than SL 5180 for QuickCast casting process, since deformation is not expected to occur, and swelling due to humidity would be much reduced. Exposing SL 5410 QuickCast parts to atmosphere on or after a rainy day, or a humid day would not impair part strength.

Water Resistance

Water resistance has been measured with respect to part strength, shown in **figure 3**, and also with respect to photospeed variation, shown in **figure 4**. For the water resistance test, the flexbar part built in SL 5410 and SL 5180 were both completely immersed in water following the 1-1.5 hour of UV postcure. Notice that flexural modulus decreases for both resins during the first 7 days. However, the difference between SL 5180 to SL 5410 becomes very clear immediately.

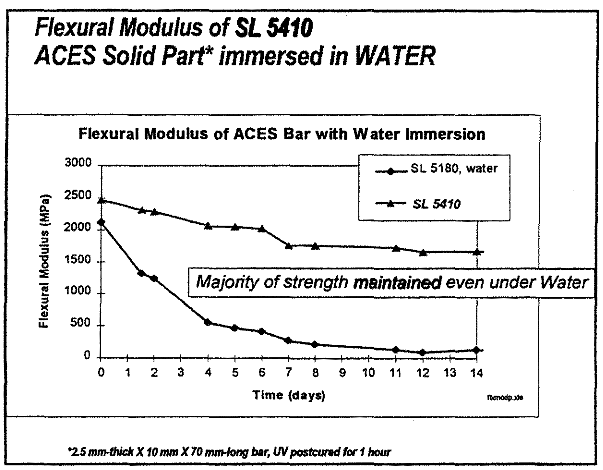

Figure 3

For example, let us define a 0.80-life to be the time that takes the modulus to drop by 20% of the initial value (e.g. down to 0.80 of initial), analogous to the concept of "half-life". Then, "0.80-life" of SL 5180 is one day. On the other hand, 0.80-life of SL 5410 is at least 5 days. By this measure, SL 5410 softens 5 times slower than SL 5180. An important point to make, however, is that after 7 days, SL 5410 stops becoming any softer. In comparison, modulus of SL 5180 continues to drop, and at 7 days it is only about 1/6 that of SL 5410. From this data, SL 5410 is expected to maintain flexural modulus of about 1700 MPa (~250 ksi) almost indefinitely in water, which should be sufficient for many applications.

This property shows that SL 5410 can be used in applications where the part may be constantly exposed to water. This is a new application area which could not have been easily carried out with, for example, SL 5180, unless surfaces were thoroughly coated with water repellent sealants beforehand. This was especially true to SL 5180 parts with very thin walls. However, now with SL 5410, even parts having thin walls have the potential to be used in under water applications.

To ensure that the photospeed of SL 5410 does not significantly change under high humidity environments, water was intentionally added to liquid resin, simulating water pick up by SL 5410. Standard WINDOWPANE working curves were constructed to measure the photospeed of the water-contaminated SL 5410. Water was added to the SL 5410 resin, up to a point (~ 2%) where the SLA laboratory environment corresponds to a relative humidity of 85%. Of course, if the SLA room is air-conditioned, such a high humidity is unattainable under normal circumstances. Therefore, this test simulates the worstcase that may more closely simulate an SLA that is placed in a non-air-conditioned room, and where the SLA may be exposed to the outdoor environment.

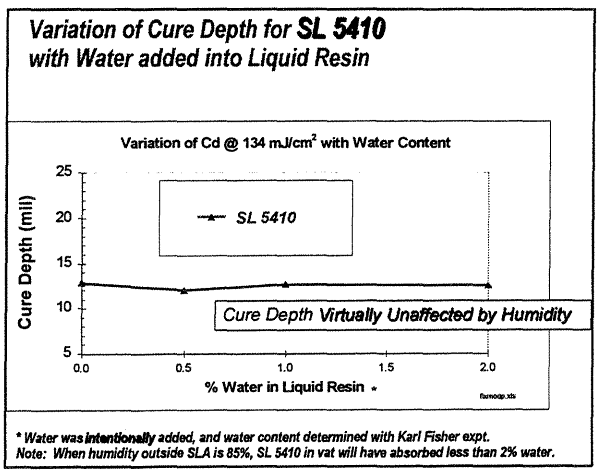

Figure 4.

In **figure 4**, cure depths at a constant laser exposure of 134 mJ/cm^2 are plotted as a function of the water concentration, as a measure of photospeed. Water concentration in the liquid resin was later confirmed by Karl Fisher titration. The data in this figure shows that the change in photospeed of SL 5410 is negligible within the external relative humidity range of 0-85%. The cure depth variation for this test of ±0.3 - 0.4 mils, is actually well within the range of WINDOWPANE repeatability for the same resin. This test provides users the assurance that, not only do the cured parts perform, but liquid SL 5410 will build well on the SLA under high humidity conditions.

As an addendum, SL 5410 has also been confirmed to build well, while maintaining its photospeed, under extremely dry conditions. While no tests were run exclusively, SL 5410 continued to build good parts for several months in California, where the environmental humidity level at the time (inside the SLA lab), has been as low as 15-25% for a considerable period during the testing phase.

Mechanical Properties

Mechanical properties of SL 5410 are summarized in **Table 1**. Notice that both tensile and flexural strengths have increased by about 45-70% over SL 5180. Hence, SL 5410 would be able to take on higher loads than SL 5180 before part would give. Part rigidity, as measured by both tensile and flexural modulus, has also increased, making SL 5410 the most rigid SL resin for the SLA-500. This enhances the dimensional stability of parts made in SL 5410, especially under high humidity conditions, as discussed earlier. Elongation to break, however, decreased by about a factor of 2. Nevertheless, impact strength remains to be about the same as SL 5180, at a respectable 0.73 ft-LBS/inch, due to the increase in the ultimate strength compensating for the loss in elongation. These data show that SL 5410 has improved in many of the mechanical properties over SL 5180, in addition to the previously discussed improvements in humidity and water resistance. However, the most notable advances have been made in the thermomechanical properties, discussed in detail in the next section.

	SL 5410	**SL 5180**	Method
Tensile Strength	*10,450 psi*	6,150 psi	ASTM D638
Tensile Modulus	*449,000 psi*	391,000 psi	ASTM D638
Flexural Strength	*18,400 psi*	12,700 psi	ASTM D790
Flexural Modulus	*413,000 psi*	366,000 psi	ASTM D790
Elongation at Break	*4 - 7%*	6 - 16%	ASTM D638
Impact Strength, notched	*0.73 ft-lb/in*	0.6 - 0.8 ft-lb/in	ASTM D256
Hardness, ShoreD	*86*	84	ShoreD
Glass Transition Temp.	*105° C**	85°C	DMA tan delta @1Hz
	*88° C**	69°C	DMA E" peak @1Hz
Heat Deflection Temp.	*88° C**	49°C	ASTM D648 (@66psi)

** UV + thermally postcured @ 80°C for 2 hours.*
note: 145 psi = 1 MPa = 1 N/mm²

Table 1.

Thermomechanical Properties

Thermomechanical properties are not always as straight forward as one would like it to be. A simple statement of "a part having a Tg of 80°C cannot be used above 80°C" is not always true. This is because each testing method is performed in such a way as to address only one of many modes of application for the test material. For example, some SL parts are bent, while others are stretched. Others are exposed to hot air, and others are exposed to steam. The term "heat resistance" must be defined by special test methods.

Description of all of the test methods is beyond the scope of this paper, however, end-use application testing beyond the perceived thermomechanical values are highly recommended. Much of the recent, new applications of SL parts have emerged due to innovative pioneers pushing the envelope beyond the perceived limitations of the SL materials at the time.[2] These include such applications as direct tooling wherein engineering thermoplastics have been successfully injection molded into tools made of epoxy resins such as SL 5170, 5180, or 5190.[3,4] It was, indeed, quite non-intuitive that SL 5180, having Tg_{DMA} of only 69°C, survived injection of thermoplastics at temperatures in excess of 200°C!

Three thermomechanical properties are presented here for both SL 5180 and SL 5410 resins, shown in **figures 5** and **6**. The first one is the heat deflection temperature (HDT), the second is the transition of coefficient of thermal expansion (CTE transition), and the third is the glass transition by dynamic mechanical analyzer (Tg_{DMA}).

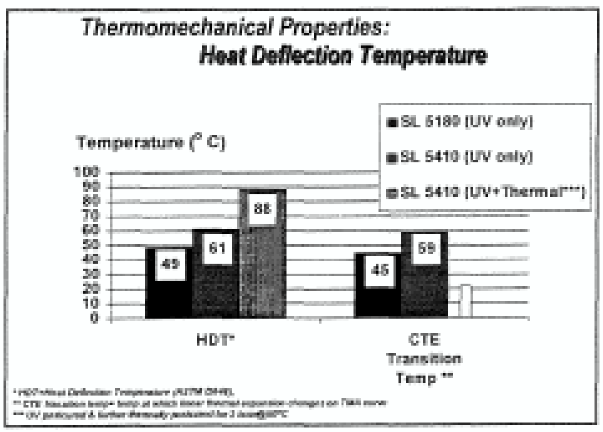

Figure 5

Heat Deflection Temperature

In short, HDT* shown in **figure 5**, is the temperature at which a beam (0.5 X 0.5 X 5 inch length) deflects by 10 mils at the midpoint when the midpoint is pressed at a fiber stress of 66 psi, when the surrounding temperature is constantly increased by 2°C/minute. *(Other variants are also allowed under ASTM D648.) In other words, this test measures how well a material can resist deformation under a load as the surrounding temperature is increased. The property may be translated to be a measure of how well a material is able to maintain a given dimension when the part is placed under load. This is probably one of the most relevant properties for SL parts.

With UV postcuring alone, HDT of SL 5180 is 49°C and that of SL 5410 is 68°C. Interestingly, the HDT of SL 5180 does not significantly change upon further thermal postcuring. However, SL 5410 has shown a marked increase in HDT value when thermally postcured. Thermal postcure of 2 hours at 80°C was selected since higher postcuring temperatures increase the chance of significantly distorting SL parts. This defeats the whole purpose of maintaining high dimensional accuracy. With thermal postcuring, *HDT of SL 5410 increased to 88°C, which is nearly +40°C above that of SL 5180.* Coupled with the improved humidity resistance, dimensional stability under higher temperature conditions is expected to be much greater compared to SL 5180.

Transition of Coefficient of Thermal Expansion (CTE)

Another thermal property, the CTE (coefficient of thermal expansion) transition temperatures, are sometimes also referred to as the glass transition temperature. This property is measured with a thermomechanical analyzer, or TMA. In this test, a small sample is heated and its linear dimensional change (expansion) is measured as a function of the corresponding increase in temperature. The slope of the curve generated from measuring expansion versus temperature while the sample is a solid, represents the CTE of the solid. As the material becomes softer upon heating, it expands at a faster rate, and another CTE with a greater slope is eventually reached. This value is the liquidous CTE. The extrapolated intersection of these two nearly straight lines is the CTE transition temperature. Below the CTE transition temperature, the material expands like a solid, and above it, like a pseudo liquid. Of course, since SL resins are crosslinked, they do not flow like a liquid, as discussed elsewhere.[5] The CTE values for SL 5410 are tabulated in the last section, **Table 3**.

CTE transition temperature of SL 5410 is about 60°C, which is 15°C greater than that of SL 5180, which in turn is 45 °C. This means that the expansion upon heating up to 60°C is much smaller for SL 5410 than for SL 5180. SL 5410 may have significant advantage in having much smaller thermal expansion between the temperature range of 45-60°C. This expansion characteristic may be taken advantage of for secondary applications, especially where part must be heated.

For example, these applications may involve curing silicone rubber molds around an SL master pattern at a higher temperature, or directly pouring & heating castable urethane materials, or even injecting wax into SL toolings for eventual investment casting. All of these processes rely on the high dimensional tolerances of the SL master pattern.

Glass Transition Temperature, Tg

The last thermomechanical property is the glass transition temperature, Tg, as measured on a dynamic mechanical analyzer (DMA), shown in **figure 6**. DMA is a sophisticated thermomechanical analyzer that measures the change of dynamic mechanical properties as a function of temperature by deforming the sample dynamically at a given frequency, and is a very common mechanical means of measuring the Tg.

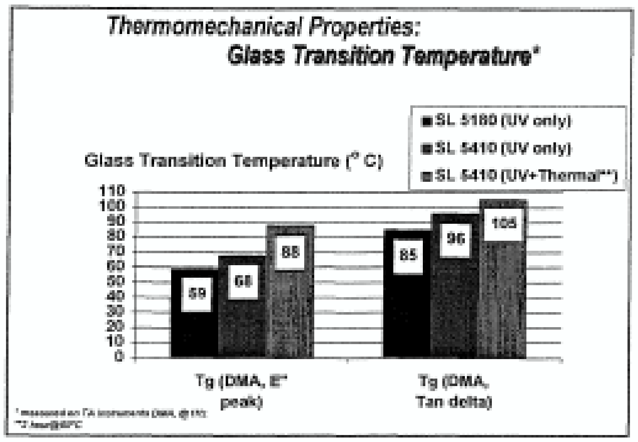

Figure 6

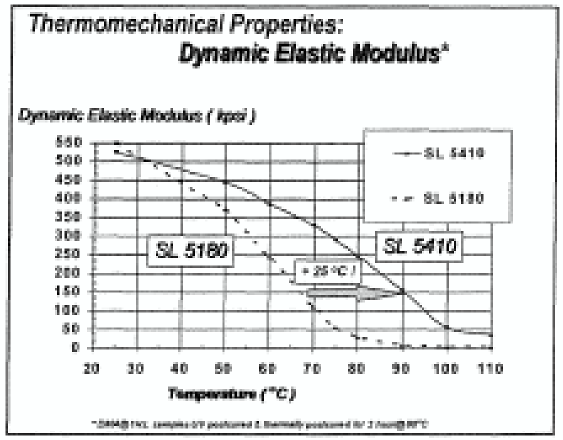

Figure 7

Instead of presenting one "Tg" value as is often the case, two "Tg" values will be given here. These two commonly quoted values arise from two different curves obtained from the same DMA test. These values are 1) Tg at dynamic *loss* modulus peak ($Tg_{E''peak}$), and 2) Tg at tangent delta ($Tg_{tan\ del}$). In many industries, Tg designations are not always clear, and often lead to skewed comparison of materials.

While not necessarily correct from theory, $Tg_{E''peak}$ for epoxy based SL resins tend to occur at approximately 1/3 of the dynamic elastic modulus, shown in **figure 7**, and $Tg_{tan\ del}$ occurs when the same becomes almost negligibly low. This may be a good rule of thumb to remember for similar epoxy based SL resins. In other words, at $Tg_{E''peak}$ SL parts have significant strength, but by the time temperature reaches $Tg_{tan\ del}$, most of the strength has been lost. Therefore, the $Tg_{E''peak}$ would be the relevant temperature for applications where SL parts are placed under some load, and $Tg_{tan\ del}$ would be relevant wherein SL parts are not stressed.

As shown in **figure 6**, ultimate $Tg_{E''peak}$ for SL 5410 is 88°C when thermally postcured. This *ultimate* $Tg_{E''peak}$ *of SL 5410 is almost +30°C greater than that of SL 5180.*

Similarly, $Tg_{tan\ del}$ of SL 5410 is 105°C, compared to that of SL 5180, which is 85°C. This is an increase of +20°C. The $Tg_{tan\ del}$ value suggests that SL 5410 may be used at temperatures as high as 105°C, when one only needs to maintain its original geometry.

It is important to remember that Tg is a term that indicates a change of property, and focuses on a contrast in the thermomechanical property as it traverses from the glassy to rubbery states. Therefore, it does not necessarily include the absolute strength of materials at a given temperature. Hence, knowing Tg does not necessarily give you the confidence that the material can be applied for your application where a finite resistance to stress is required. For this, one needs to know the residual strength of the material at each temperature.

The concept of dynamic elastic modulus provides this information, and may even be a little more intuitive parameter than Tg. Dynamic elastic modulus is a time-independent, residual modulus of a material, obtained from the same DMA test used to determine Tg. Theoretically, this is the part of the dynamic modulus that changes as a function of temperature, but essentially stays invariant even as the dynamic test frequency is reduced to zero. In SL applications, this modulus is simply a minimum measure of how strong the material is at each temperature. The Dynamic elastic modulus curves for SL 5180 and SL 5410 are shown in **figure 7**.

From **figure 7**, it is apparent that SL 5410 maintains dynamic elastic modulus at higher temperatures than SL 5180. In order to compare the heat resistance of each resin, let us consider the temperatures corresponding to modulus of 300 kpsi and 150 kpsi as an example. Assume here that application A requires 300 kpsi, and application B requires 150 kpsi, and one would like to know what temperature can each of the two applications in each of the two materials withstand.

SL 5180 maintains a modulus of 300 ksi at about 55°C, whereas SL 5410 does so at about 75 °C. This is a temperature resistance gain of about +20 °C. Similarly, SL 5180 preserves a modulus of 150 ksi at about 65 °C, compared to SL 5410, which does so at about 90 °C. This is a gain of +25 °C over SL 5180, designated by an arrow in **figure 7**. Hence, for application A, SL 5410 can be used at 75°C where SL 5180 may only be used up to 55°C. Similarly for application B where lesser strength is required, SL 5410 can be used at 90°C whereas SL 5180 can be used only up to 65°C. Depending on the needs of the application, a rough idea of the heat resistance can be obtained from the dynamic elastic modulus curve.

What would such increase in heat resistance offer to SL part users? In addition to numerous obvious uses of SL 5410, one useful application of this increase in temperature resistance may be the secondary process of curing silicone rubber mold at higher temperatures with SL 5410 as a master pattern. For example, if one has been successfully curing silicone rubber at 55 °C using SL 5180 as the master pattern, one should be able to do the same at 75 °C in SL 5410, based on the discussion above.

How would this increased curing temperature benefit the user for this application? Simple Arrhenius relationship tells us that the reaction rate would increase by a factor of four at 75 °C compared to 55 °C. Hence, a conventional (as an example) 24 hour silicone rubber mold curing time may be reduced by the same factor, down to 6 hours. This would be a substantial time savings for the users. As usual, actual cure times would vary based on the silicones used and part geometries.

Of course, other common applications of SL 5410 other than as master patterns may be for housings where higher heat resistance is required, or where water or high humidity environments exist such as in the design of air conditioners and refrigerators, or for any other general purpose applications. Here, the creative imagination of SLA users would be more appropriate.

Part Accuracy and Surface Finish

Part accuracy of SL 5410 was measured using the H-4 diagnostic test, which measures the SLA in-process build shrinkage. This shrinkage generates a distortion called either waist distortion, or bridge distortion.[6] This is a part that looks like a "letter-H", having the length of 4 inches. As the legs of the "H" builds and connects with the middle part of the "H" geometry, linear shrinkage of the downfacing and subsequent layer curing on top of each other pulls the two legs of the "H" shape closer with each other. The bridge distortion is the measure of the distance that these two legs are pulled in, as compared to a perfectly smooth-edged letter-H. Just as a reminder, this shrinkage is not necessarily related to the overall volume shrinkage, as discussed elsewhere.[7] Rather, this shrinkage is one that can not be removed by applying resin shrink factor, or even cured linewidth compensation on the SLA. Hence, H-4 bridge distortion is one of the most important distortion values that need to be minimized in order to build an accurate part in the SL process.

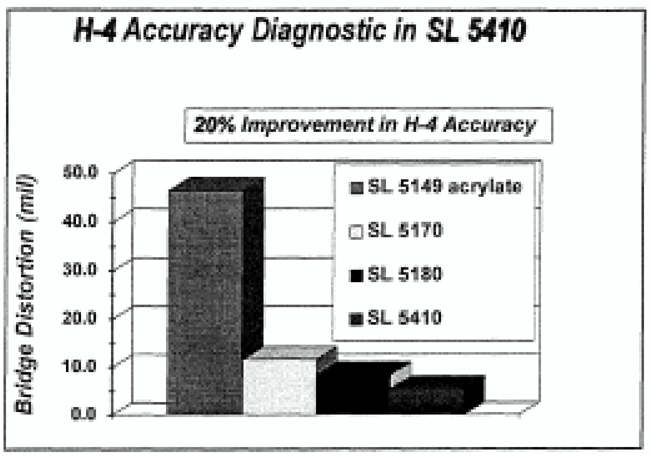

Figure 8

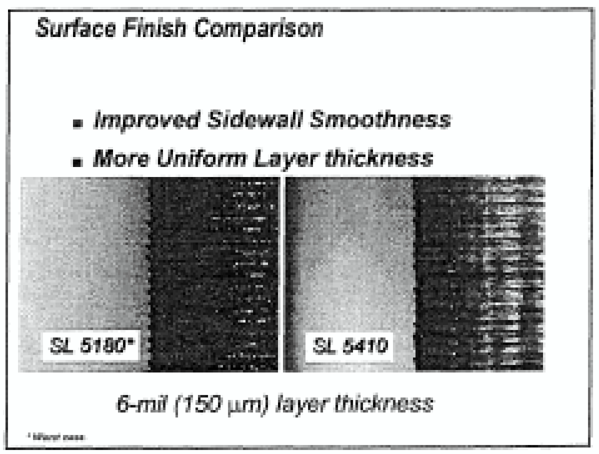

Figure 9

Bridge distortion values for SL 5149 urethane acrylate resin, and other epoxy based resins SL 5170 and SL 5180 are shown in **figure 8**, together with that of SL 5410. Based on the H-4 Bridge distortion values, SL 5410 is about 20% more accurate compared to other epoxy based resins that are considered very accurate already. SL 5410 should perform well where high accuracy is needed.

An additional advantage of parts built in SL 5410 is that it generates smoother vertical walls than SL 5180, as can be seen in **figure 9**. Note that the sidewall of SL 5180 in the **figure** is the worst case scenario. Of course, the degree of sidewall roughness depends on other factors such as the laser beam diameter and irradiation distribution, layer thickness, border overcure values used, and somewhat on the recoater blade speeds and predip delay. Also, by virtue of the chemical modification newly applied onto SL 5410, predip delay is no longer needed. Predip delay increases productivity by reducing the overhead time. This is discussed in the next section.

Productivity

Productivity is a measure of the overall build time using a particular resin, taking into consideration all of the overhead requirements, including the loss or gain due to photospeed, recoating, and other process activities. In other words, it is what is truly relevant for SLA users. Other factors affecting productivity are photospeed and predip delay, both of which are shown in **Table 2** for SL 5410, with respect to SL 5180.

One of the key advantages of *SL 5410 is that it does not require any predip delay*, which significantly contributes to increased productivity. Another advantage is the increased scanning speed. Using recommended build styles for both SL 5180 and SL 5410, ACES hatch are 24% faster, while Borders are 30% faster for SL 5410.

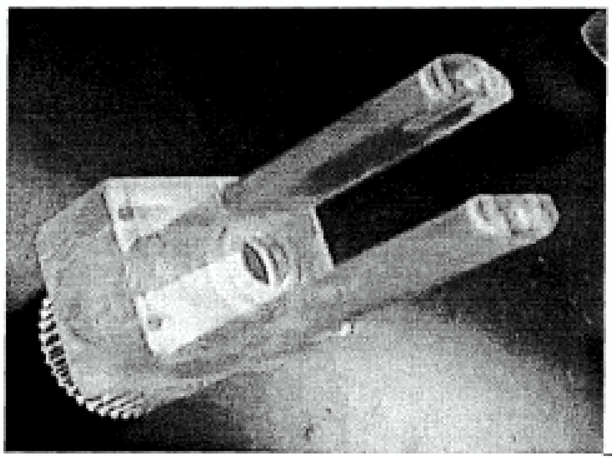

Figure 10: Hydraulic Wrench

Productivity of SL 5410

- *Faster Photospeed vs. SL 5180:*
  - ***Dp = 4.8 mil Ec = 10.1 mJ/cm^2***
  - ***24 % faster for ACES hatch scan****
  - ***30 % faster for Border scan****
- *Predip Delay :*
  - ***PR = 0 sec (NO Predip delay Required)***

** Based on Recommended Build Parameters for 6-mil layer thickness, e.g. considering appropriate border & hatch overcure values for both resins.*

Table 2.

Two geometries were selected to investigate the productivity of SL 5410. One was a part called the hydraulic wrench, shown in **figure 10**. This part is about 6 inches tall, and has a cylindrical bottom section, a rectangular and bulky middle section, and a pair of vertical sections on the top having pseudo crescent-shaped cross sections. This part was built in the upright configuration. Productivity for this part was calculated using the build estimator software, developed by 3D Systems. The second geometry, is a 12-inch long, 6-inch wide, and about 3-inch tall Racecar comprising of relatively thin walls. This part was built flat on the platform.

Productivity for this part was measured from actually building in SL 5180 & SL 5410 side by side on SLA-500 at 180 mW, using default build parameters for each resin.

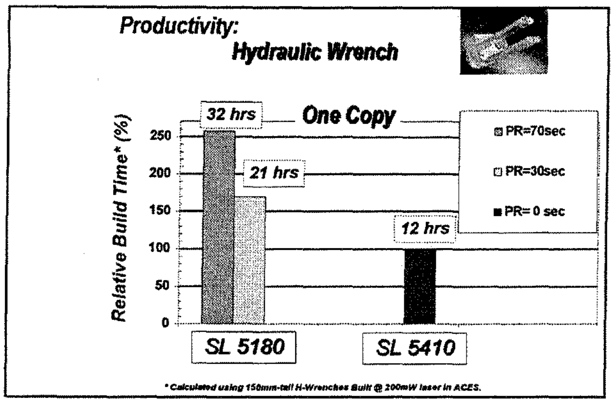

Figure 11

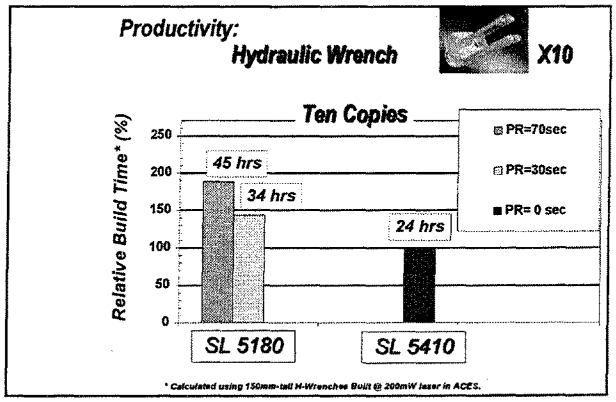

Figure 12

Since productivity is also a function of number of parts built on one platform, two scenarios were taken into account. The first case was that of building a *single* hydraulic wrench, shown in **figure 11**. The other case involved building *ten* of them, the result for which is shown in **figure 12**. Realistic situations for many SLA users may lie somewhere in between these two extreme cases. Also, comparisons have been made assuming a reduced, non-standard predip delay of 30 seconds for SL 5180, in addition to the standard 70 second predip delay.

Both **figures 11** and **12** show that SL 5410 has a significantly increased productivity compared to SL 5180. For example, as shown in **figure 11**, it takes about 32 hours to build one hydraulic wrench using SL 5180. SL 5410 would build the same part in only 12 hours, which corresponds to the productivity gain of about 2.5-fold. Even when predip delay for SL 5180 is reduced down to 30 second, SL 5410 is still faster by 1.7-fold.

Take the case of building ten copies of the wrench part, as shown in **figure 12**. The increase in number of parts places an emphasis on the difference in photospeed, and less on layer overhead parameters such as predip delay. Using SL 5180, about 45 hours is expended, whereas SL 5410 builds in 24 hours. This is an improvement of almost 1.9-fold. Similarly, even for the case of using the reduced 30 second predip delay for SL 5180, the advantage factor for SL 5410 of 1.4-fold is still achieved.

As a verification of these simulations above, a Racecar was built in SL 5180 and SL 5410. The Racecar took 27.5 hours in SL 5180, and 16.0 hours *in SL 5410, an advantage factor of 1.7-fold.* Depending on part geometry and the total, integrated suface scanning coverage, productivity gains in the range of 1.2 - 2.5-fold can be achieved with SL 5410.

An overall productivity comparison is the best way to compare one resin with another, instead of comparing each parameter piecemeal, since most often the effect on overall build speed is non-linear, and often non-intuitive. Using an overall productivity comparison, all of the relevant parameters have already been accounted for, and one can have high confidence at the results.

Other Properties of SL 5410

Other useful properties for SL 5410 are tabulated in Table 3 below for reference.

SL 5410 Resin Other Properties	
▪ Coeff. Thermal Expansion (Cured)	
▪ @ T < 50°C	82 ppm / °C
▪ @ T > 75°C	190 ppm / °C
▪ Refractive Index (liquid)	1.503
▪ Liquid Density	1.164 (25 °C)
▪ Cured Density	1.224 (25 °C)
▪ Brookfield Viscosity	560 cps (25 °C)
	370 cps (30 °C)

Table 3.

Summary

A new Stereolithography resin, CibaTool® SL 5410 was recently released for SLA-500. This epoxy based resin virtually eliminated the negative effects of high humidity and water experienced by the first generation epoxy resins. QuickCast and solid parts built in SL 5410 can withstand high relative humidity without impairing part strengths. Significant strength is maintained even upon immersing SL 5410 into water. Photospeed has also been confirmed to be invariable under both dry and humid environments, thus ensuring consistent performance under adverse environments. With SL 5410, even underwater application can be realized.

The new resin also significantly improves heat resistance of SL parts. Thermomechanical properties of SL 5410 have improved significantly, ranging in temperature increases by +15°C, to as much as by +40°C, relative to those of SL 5180. Heat deflection temperature increased to 88 °C and Tg value as high as 105°C, when parts were additionally thermally postcured. These thermomechanical properties should open up new high temperature applications with SL 5410.

Additionally, part accuracy increased, and vertical surface finish and productivity also improved significantly. Productivity increase by as much as 2.5-fold can be realized with SL

5410, compared to SL 5180. Also, SL 5410 requires no predip delay, hence reducing the overhead time significantly. These newly achieved resin properties characteristics of SL 5410 are expected to improve the ease-of-use in today's applications, and open new fields of applications in the near future, where the combination of high humidity and water resistance, high temperature capabilty, and increased accuracy and dimensional stability is needed.

References

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