

STRATEGIES AND TECHNOLOGIES FOR RAPID PRODUCT DEVELOPMENT

Time-Compression TECHNOLOGIES

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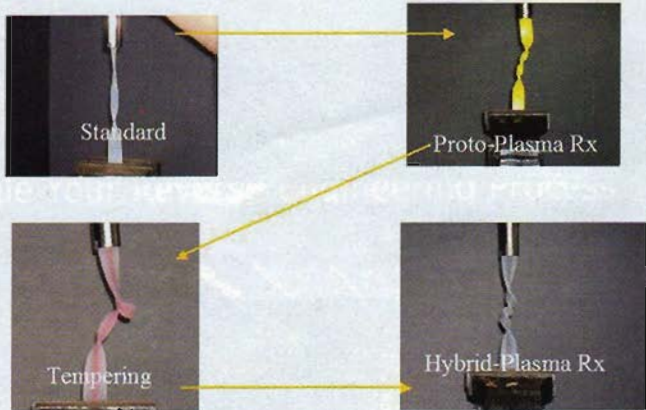
RP Tempering™ Technologies: Nanotechnology CNT's Enhance Fragile Rapid Prototyping Parts

Functional prototype parts from manufacturing systems like SLA, SLS and others still have too many limitations in mechanical, physical and typical properties. RP Tempering™ slows down these limitations significantly.

FUNCTIONAL PROTOTYPE PARTS ARE THE HOLY Grail for the SFF (solid freeform fabrication) industry. Parts made from manufacturing systems like SLA (selective laser apparatus), SLS (selective laser sintering) and others still have too many limitations in mechanical, physical and typical properties to include chemical resistance and thermo-properties. Limitations include accelerating life aging problems because of UV and high heat breaking down cross linking and deterioration of the base material parts, high temperature resistance, high heat deflection, thermo expansion and contractions, brittleness, impact strength, torsion strength, three point and four point flex, lowering vibration signatures, EMI shielding or FRI shielding capabilities and chemical hazards. Oftentimes, heat/temperature and moisture will decrease the strength of a prototype part. RP Tempering™ slows down this process significantly.

The recent onslaught of additive and subtractive technologies has increased the durability of prototype parts made from SL, LS, digital printing, Z Corp.'s starch parts and RTV casting. Resin companies are progressing with chemical research and apparatus OEMs are engineering more capable machines but the end user is always screaming out for more durable or even production representative parts. To meet actual production use of these materials, enhancements usually have to be done to the base materials. For example, impregnating SLS and applying epoxies, acrylics and fiberglass to SLA parts. Both of these additive processes use hazardous materials, long curing cycles, hard to control process capabilities and only enhance mechanical properties.

What are companies looking for in the next generation? Process capability will be number one with anyone using SFF/RP processes and materials for production application, testing and future prototyping. The tempering application process will hold



This picture is a comparison for torsional strength between a standard SL part untreated/plain and three of the initial tempering technologies. Each of them will progressively get stronger starting with just one coating on the part to the engineering technique of tunnels, and the last picture adding both of them together to achieve the strongest part possible call Hybrid Temp.

Image courtesy of Porter Engineering Test Lab.

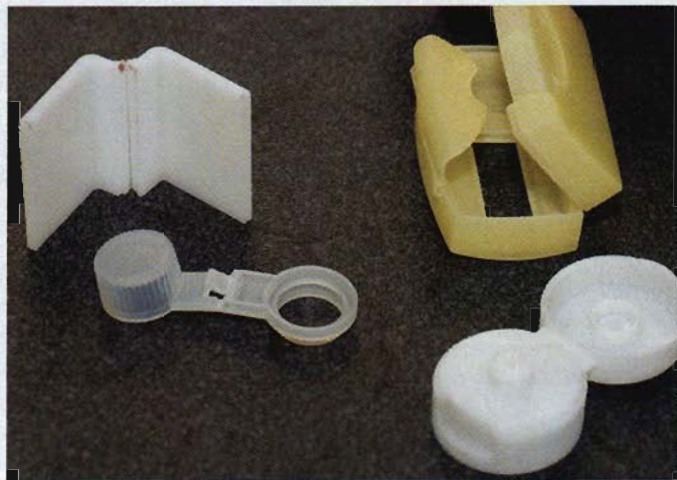


Figure 1: SLS and SLA and digitally printed and urethane silicone cast living hinge using RP Tempering™.

Image courtesy of Laser Reproductions, Matt Lucas and Mark Jones.

[RP TEMPERING]



Image courtesy of American Precision Prototypes' Jason Dickman and Mark Mey.

Figure 2: Water tight flexible tempered SL bottles.



Figure 3: DSM 11120 SL resin tempered only showed 5 percent deflection at 400 degrees. Image courtesy of Total CS Team's Marty McGough and Andrew Graves.



Figure 4: Computer tempered SLA fan and under hood automotive applications for fuel, oil and water. Image courtesy of Davcos' Mike Centilver.

tighter tolerances than injection molding capable of +/-0.001"; tolerance and mechanical property enhancements within 4 percent of the specific die Electrical Properties (EMI & RFI shielding),

RP Tempering—The Next Generation

RP Tempering technologies involve a patented 3D CAD engineering technique, subtractive engineering process and additive technologies. A key aspect of tempering is the additive process using compounds with multi-wall carbon nanotubes and micron sized carbon fibers. RP Tempering will dramatically increase a prototype part's mechanical, thermo, chemical, physical and typical properties within minutes cost-effectively to include:

- Increase impact strength 300 percent compared to standard SLA or SLS parts
- Increase torsion strength 300 percent compared to standard SLA or SLS parts
- Increase three point flex by 800 percent compared to standard SLA or SLS parts
- Tensile strength, flexural modulus and stiffness stay the same
- Heat resistance from 750 to 1000 degrees compared to standard SLA and SLS parts
- Heat deflection of 400 degrees in SLA parts and higher on SLS parts compared to standard SLA and SLS parts
- Chemical resistant (fuel, oil, sludge and water/moisture)

Mechanical properties can be increased using new patented 3D CAS subtractive engineering techniques and additive technology using compounds and coatings. The engineering technique is defined in our world as a subtractive technology. The engineering CAD process creates tunnels or other geometric geometries within the internal walls of a part design before the build. Then we can backfill this tunnel after the part is grown with the RP Tempering™ Multi-wall Carbon Nanotubes (MWCNT). This will improve mechanical properties like impact strength, torsion strength, three point and four point flex strength, inner laminar strength, flex strength and lower vibration signatures. The additive technology compounds and coatings will increase the same mechanical properties about 80 percent of what the tunnels and CAD engineering technique will do. By using both the 3D CAD technique and the coatings/compounds, these mechanical properties will be enhanced even more. The coatings and compounds will also achieve properties that today's SFF/RP processes and materials can't do such as electrical (RFI/EMI shielding), fire retardant parts, 300 percent higher heat deflections and 500 percent higher heat resistance on average.

RP Tempering could change the rapid prototyping industry.¹ Tables 1 to 5, pages 42 and 44 shows comparisons to standard SLA and SLS parts. Some of the mechanical property differences are staggering.² This technology will work on most any composite to

Heat Deflection ASTM D648		
	Temperature Deflection (Degrees F)	Temperature Resistance
WS11120 Plain	128.6*	130* F
Somos 9120 Plain	132.3*	30* F
Watershed 11120 with Hi-Temp Protoplass©	403.3*	750* F
Somos 9120 with Hi-Temp Protoplass©	430.5*	750* F
* Average of 30 samples		

Fire Resistance Hi-Temp Protoplass™ Data Sheet			
	Powder	Resin	
	SLS	11120	
	Duraform	9120	
	GF & PA, 12110	14120	
	Nylon11	Prototherm	Bluestone™
Degrees F Heat Resistance	1000	750	1250
Degrees F Heat Deflection	600	400	700
MVSS302 Automotivce FR	Pass	Pass	Pass

Charts courtesy of Par3 Technology.

Heat Deflection Data

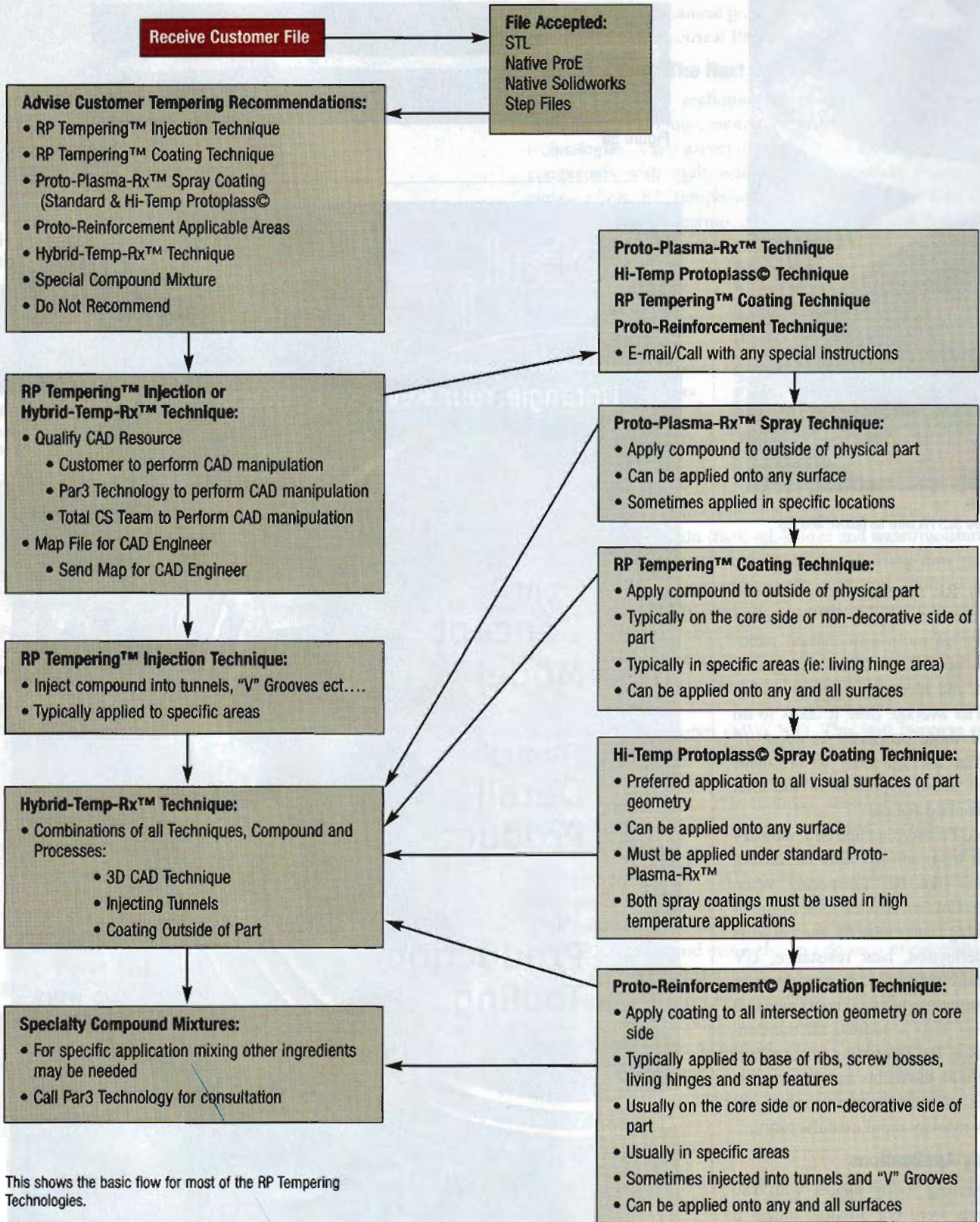
Table 1:

The Watershed 11120 and Somos 9120 with Hi-Temp Protoplass© passed the ASTM Heat Deflection test in all of the samples tested, where all of the samples without the coating failed.

Table 2:

Hi-Temp Protoplass© can provide adequate heat resistance and heat deflection for various powder based materials and resins.

[RP TEMPERING]



This shows the basic flow for most of the RP Tempering Technologies.

Image courtesy of Gail Giffey, Par3 Technology.



Image courtesy of Accelerated Technologies, Inc.'s Mike Durham.

Figure 6: RP tempered SLA fan blade design.

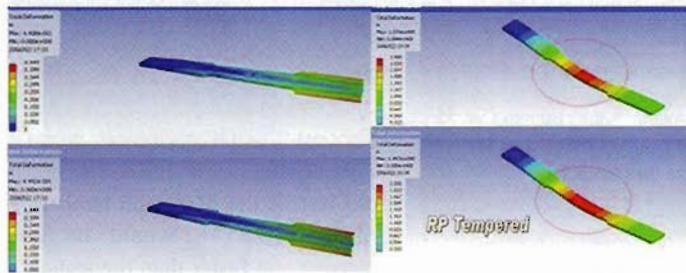


Figure 7: FEA torque analysis DSM 11120 SL resin plain verses RP tempered part. FEA impact flex analysis DSM 11120 SL resin plain verses RP tempered. Image courtesy of Par3 Technology's Kevin South.

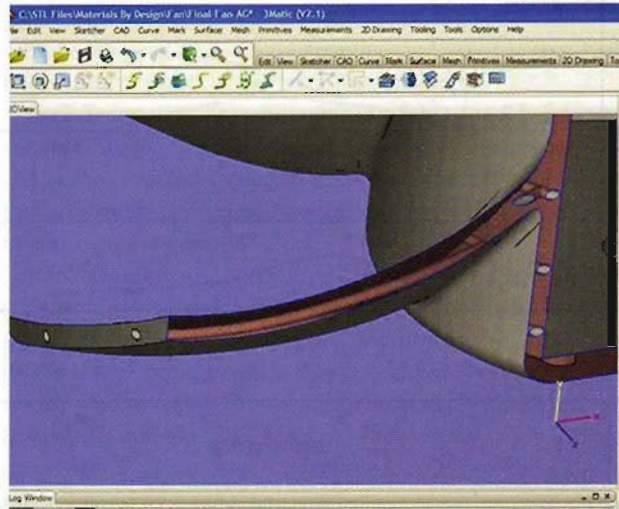


Figure 8: Materialise 3Matic software module for RP Tempering patented engineering technique. Image courtesy of Andrew Graves, CTO of Total CS Team licensed agent for Materialise and Marty McGough.

RP Tempering technique can do living hinges in SLA, SLS and digitally printed parts in less than one minute. The living hinge will last over 200 bend according to said life cycle and fatigue test. The RP Tempered living hinges were made at Laser Reproductions Company. Mark Jones refined the tempering technique and has success with SL resins and RTV Casting (see **Figure 1, page 41**).

American Precision Prototypes (APP) has made fully functional bottles of various sizes and shapes. The actual fully functional tempered bottles were presented to a major closure OEM. The bottles could not only be squeezed as seen in the picture but they could hold fluid for actual dispersing of fluid according to Jason Dickman, president of APP (see **Figure 2, page 42**).

The Total CS Team Company (TCST) test was the BETA site for the new Hi-Temp Protoplass[®]. Marty McGough, president, and Andrew Graves, CTO, wrote the initial report back to Par3 Technology. The RP Tempered DSM Watershed 11120, Somos 9120 and 14120 resulted in only 5 percent heat deflection at an average of 400 degrees shown in

Figure 3, page 42. These resins had results of heat resistance at an average of 750 degrees.

Other applications that involve heat resistance and chemical resistance include oil, water and fuel shown in **Figure 4, page 42**. The fan shown passed an air flow test at 100,000 RPMs for a major computer OEM. The RP Tempered part is a DSM Somos 9120 SL resin. The center part pictured is an SLS PA fuel and water separator for an automotive under hood application for DAVCO Company in Michigan. The check valve passed a two-week life cycle and fatigue test submerged in #2 fuel. The picture on the right is a centrifuge oil sludge separator. Inside is a tempered SLS GF Nylon centrifuge fan blade that separates the fine particles from the oil in a Cummins Manufacturing Company engine.

Protocall Company, a BETA test site for the RP Tempering processes, has probably done more practical applications than a licensed RP Tempering site. One of Protocall's OEM customer applications is a tempered SLS PA wire tie. These wire ties have been tempered and worked in SLA materials and digitally printed parts

RP Tempering Technologies Defined

Additive Application

- Involves: Engineered compounds, coating and aerosol spray
- Multi-wall Carbon Nanotubes (CNTs)
- Micron sized fibers
- Special application blends include: Barium, Ceramic, Tungsten and Copper

Subtractive Engineering Process

- Create specific geometric shapes within walls of part
- Reduce material mass in specified geometry

Patented 3D CAD Engineering Technique

- Create cylindrical tunnels, "V" grooves, "U" shape and other geometric shapes
- Create these shapes in the part file before the SFF build

Impact Data

ALAT Impact Data

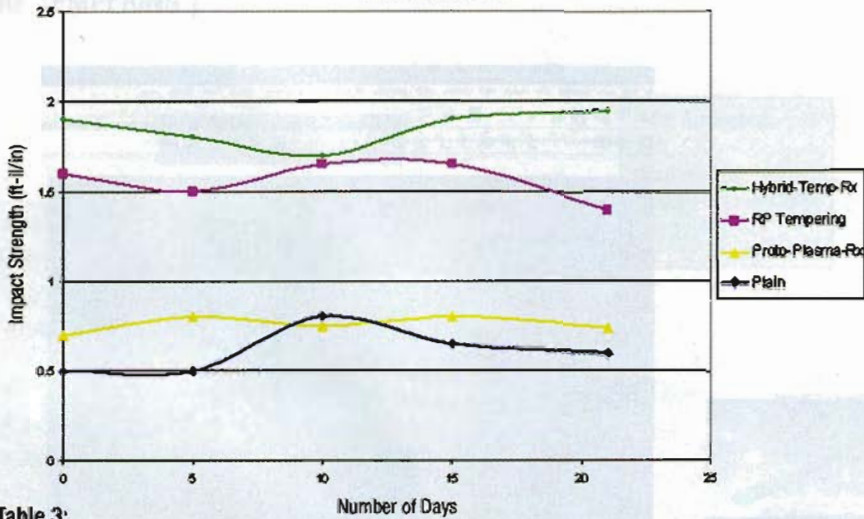


Table 3: Impact Strength remains relatively stable throughout the ALAT with Hybrid-Temp-Rx and RP Tempering™ providing the most resistance impact. The Hybrid-Temp-Rx and RP Tempered parts had more than twice the strength of the Plain parts.

Tensile and Elongation ALAT Tests

ALAT Ultimate Stress

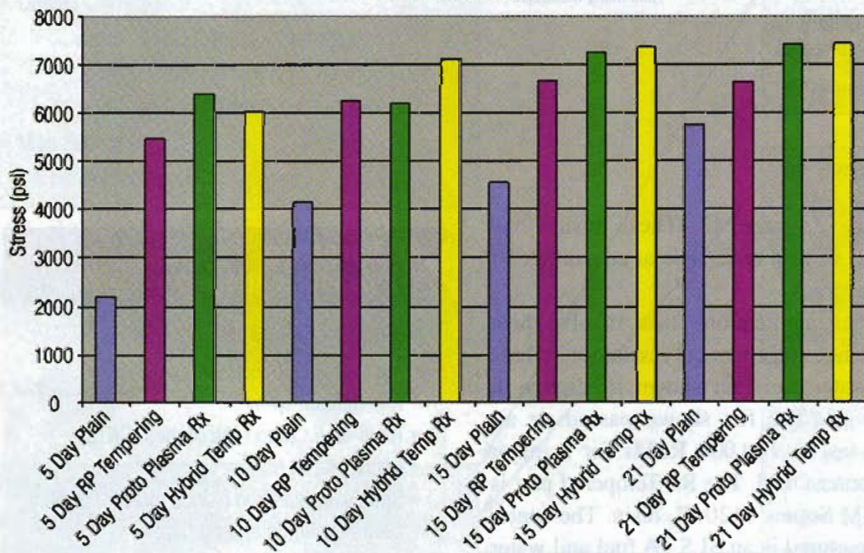


Table 4

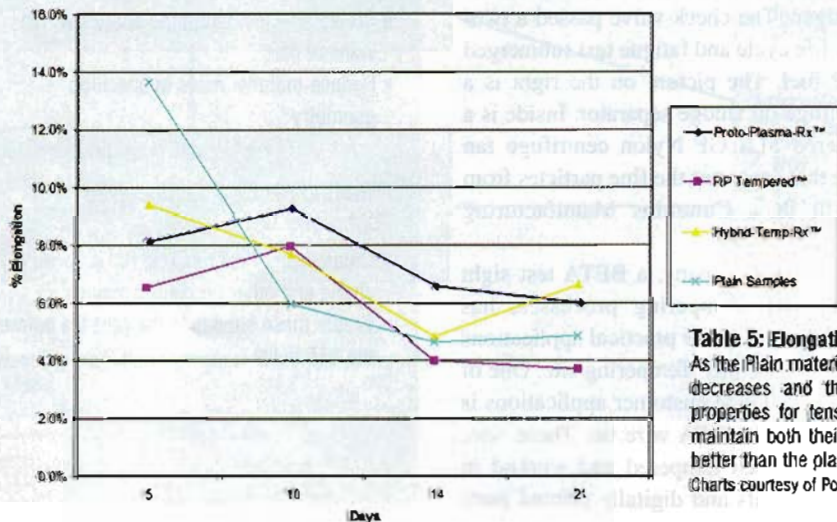


Table 5: Elongation Accelerated Life Tests

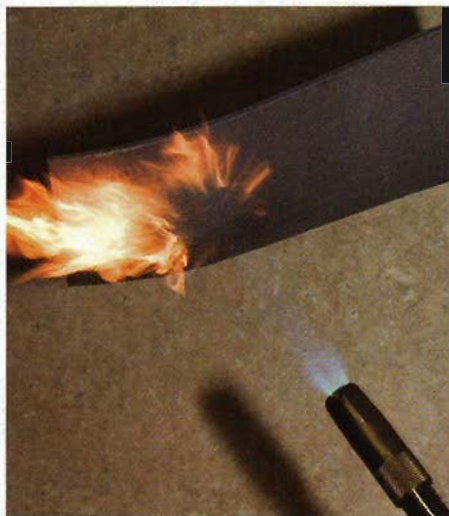
As the Plain material is aging it becomes more brittle because elongation dramatically decreases and the tensile is increasing. The material is sacrificing elongation properties for tensile. The Proto-Plasma-Rx, RP Tempered and Hybrid-Temp-Rx all maintain both their elongation and tensile strength during the life of the test much better than the plain samples.

(Charts courtesy of Porter Engineering and Gall Giffey of Par3 Technology.)

of an Eden apparatus. According to Doug Johnson, engineer and president of Protocall, this part was fully functional for the OEM. Johnson says other major applications involving the tempering process are pump housing, small engine parts and large medical closure parts (see Figures 5 and 5a page 43).

Accelerated Technologies (ATI) did an experiment to evaluate the RP Tempering process on SLA engineered fan applications. This experiment was to compare a tempered SLA fan versus a standard SLS GF Nylon fan without tempering in a life cycle and RPM speed test. If the SLA with tempering applied worked it would be less expensive and faster than the standard SLS GF Nylon, according to Mike Durham, general manager of ATI. Ronnie Dunlap, project manager for MBD, Inc., balanced the fan by filling the tunnels while balancing the fan on a round bearing. To balance the fan, Dunlap says he only filled the tunnel one-quarter of the way in each tunnel keeping the fan blade balanced. The tempering process only took 15 minutes to have a balanced fan. Durham said that an SLS GF Nylon fan would break at around 8,000 RPMs and the RP Tempered SLA fan passed the life cycle test at 10,000 RPMs shown in Figure 6, page 45.

Par3 Technology has performed extensive FEA analysis on multiple RP materials similar to the one on DSM 11120. Figure 7 (page 45) demonstrates torsional value on a plain SL part compared to a RP Tempered SL part. The top left picture is the plain SL part and the light and dark blue in the center shows breakage at about one-half turn. The dark blue has a space of



Fire retardant SL and LS parts: This picture shows an LS part with an engineered technique using layered coating application for fire retardant SL or LS part. This engineering technique and spray coating application will pass four automotive burn tests including the MVSS302 Vertical burn test. Engineers at Par3 Technology are now testing fire retardant for aerospace and marine applications. This is a three-step process and will resist open flames for extended periods of time and up to 2,000° F/22 seconds.

light blue in it from the center down toward the end of the part moving right. The tempered SL part at the bottom left shows the dark blue being solid at the same torsional value and also less red showing at the end to the part. This demonstrates no fractures. The tempered part will go a minimum of three complete 360 degree

revolutions without breaking.



EMI and RFI shielded LS, LS, digitally printed and actual plastic parts: This picture shows a simple EMI shielding application on SL and Plastic Parts. The process is fast and easy costing 90 percent less than sending the parts out to an EMI or FRI Shielding House. This application takes only minutes to apply and can be shipped within 30 minutes. Images courtesy of Andy Pardue.

The impact flex analysis picture on the right demonstrates stress distribution. The top right is a plain SL part. In the center of the part the red is concentrated, demonstrating collect mass that is getting ready to break. The picture on the bottom right is a tempered SL part. The red in the center of the part is more spread out versus the plain SL part. This demonstrates the stresses being distributed in a larger area meaning the mass is not consolidating as fast leaving room for more flex and being able to handle high impact force. The three point flex strength is 13

times stronger versus a plain SL part. The impact strength is three times stronger versus plain SL part.

Marty McGough, TCST, orchestrated a software deal with Materialise Company after recognizing the need to convert files in an STL format after receiving permission from Par3 Technology. Materialise created a special CAD module of their 3Matic software to support the RP Tempering patented 3D CAD process in STL files. The RP industry standard file is an STL file. To speed up the cycle the 3Matic software will place the tunnels and other

geometries needed for some of the tempering process in STL files without the need of the native parametric CAD file (see Figure 8, page 45).

Par3 Technology is continuing the R&D for RP Tempering to enhance SFF/RP parts. Some of the current developmental testing and analysis include: composite tooling inserts, thermo, vibration and structural properties. Nanotechnology will play a substantial role moving forward. **TCT**

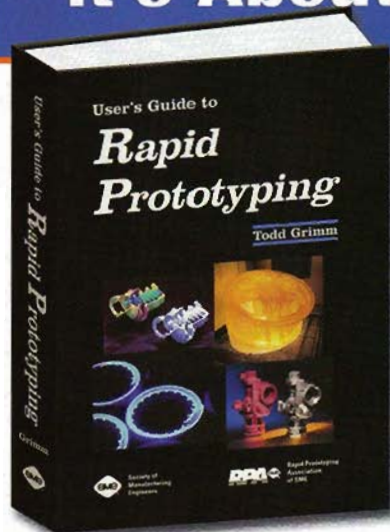
Earl Dunlap, P.E., is vice president of Par3 Technology (Cookeville, TN) and inventor of RP Tempering Technologies for the SFF & Rapid Prototyping Industrial. He has developed processes for rapid product development including rapid ideation system and analysis driven design process. His tooling systems inventions include STAT (Sample Time Acceleration Technology) and SPRinT (Short-run Production INsert Tooling). Involved in several hundred intellectual properties, patents and trade secrets, Earl can be reached at (317) 557-5018 or (931) 528-8578. For more information visit www.RPTempering.com and www.Par3Technology.com.

Sources

¹ Marty McGough, president, Total CS Team (Stevenson Ranch, CA) www.totalcsteam.com

² Doug Johnson, engineering manager, Protocol Prototypes Company (Waukesha, WI) www.protocolonline.com

Rapid Prototyping... It's About Time



Application
Process
Evaluation
Selection
Implementation
Management
Strategy
Benefits

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