Industry Viable Strategic Tooling Enablers for MRB (Material Review Board) Elimination 67th Technical Conference and Expo

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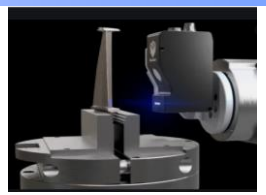
Casting: An Ancient Material Process Technology

- **First known castings, 3200 BC**
- **Cast iron, 700 BC**
- **Cast aerospace components, 1903**

. . . Continually evolving and seeking to leverage digital technology capabilities

Cast Product Goals

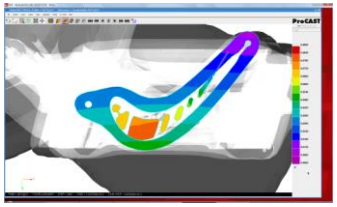


- ➢ 50% Improvement in product capability (tolerance)
- ➢ 50% Improvement in time between tooling replacement and die repair

- ➢ 50% Reduction in structural rework

- ➢ 50% Reduction in scrap
- ➢ 25% Reduction in tooling procurement time

- ➢ 30% Reduction in production cycle time
- ➢ 50% Reduction in new part design and process development time
- ➢ 6 weeks to first casting after receipt of digital data



- ➢ Incorporate O/H Repair Technology to Reduce Scrap

But what NEEDS to CHANGE to ACHIEVE these IMPROVEMENTS?

Tooling Wear has a Significant Impact on an Investment Casting Company's Bottom Line

- Results in wax and core die refurbishment causing, casting product line stoppage or increases plant operation costs due to requiring spare tooling
- Results in recurring costs due to replacement cutting tool inventory requirements
- Worn tooling also results in increased Manufacturing Review Board (MRB) activity which can involve personnel, high demand equipment, quality, and potentially plant operations
- ***What if traditional high pressure ceramic core injections became the thing of the past?***
- ***What if a new ceramic core system was developed that required a significantly lower firing temperature and time (energy savings)?***

What would it be worth to your company if Tool Dimensional Variation was no longer of PRIMARY concern?

The ***END*** of Significant Wear Related Tool and Die Issues in Industry

Surface Treatment System (STS)

- **STEP 1** – ***Environmentally Friendly*** process Removes Surface Contamination from manufacturing and post manufacturing ***CLEANING PROCESSES*** to increase coating durability

Tests conducted by the U.S. Navy have concluded that the "laser process is effective in removing chloride contamination from grit-blasted surfaces and that this results in substantial improvements in the corrosion resistance of the coatings that were applied to laser-prepared surfaces"

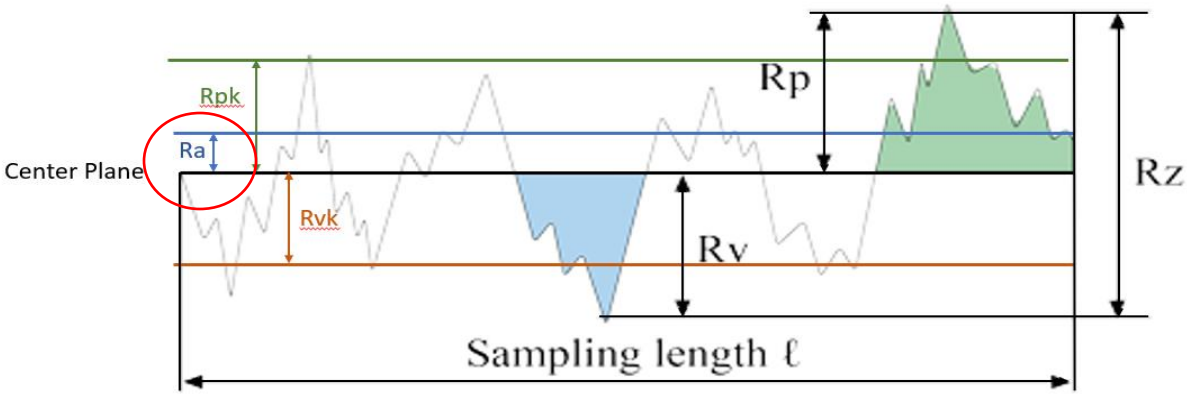
- **STEP 2** – Reduce Surface Roughness using an ***Environmentally Friendly*** process that doesn't re-contaminate the surface as many others do

- **STEP 3** – Apply a very thin adhesive and Diamond Like Carbon (DLC) coating leaving an ***Extremely Durable***, ***Military Proven*** surface that is nearly impervious as well as ***omniphobic*** *with 10 times lower surface friction than TEFLON*, which oils, machining chips, ceramic mixtures, etc. ***Will Not Stick Too!***

Preliminary Evaluation on an Industrial Ceramic Core Die showed a Dramatic Reduction in Wear!

There are Various Methods and Techniques for Determining the Roughness of a Surface

BUT WHO REALLY CARES?

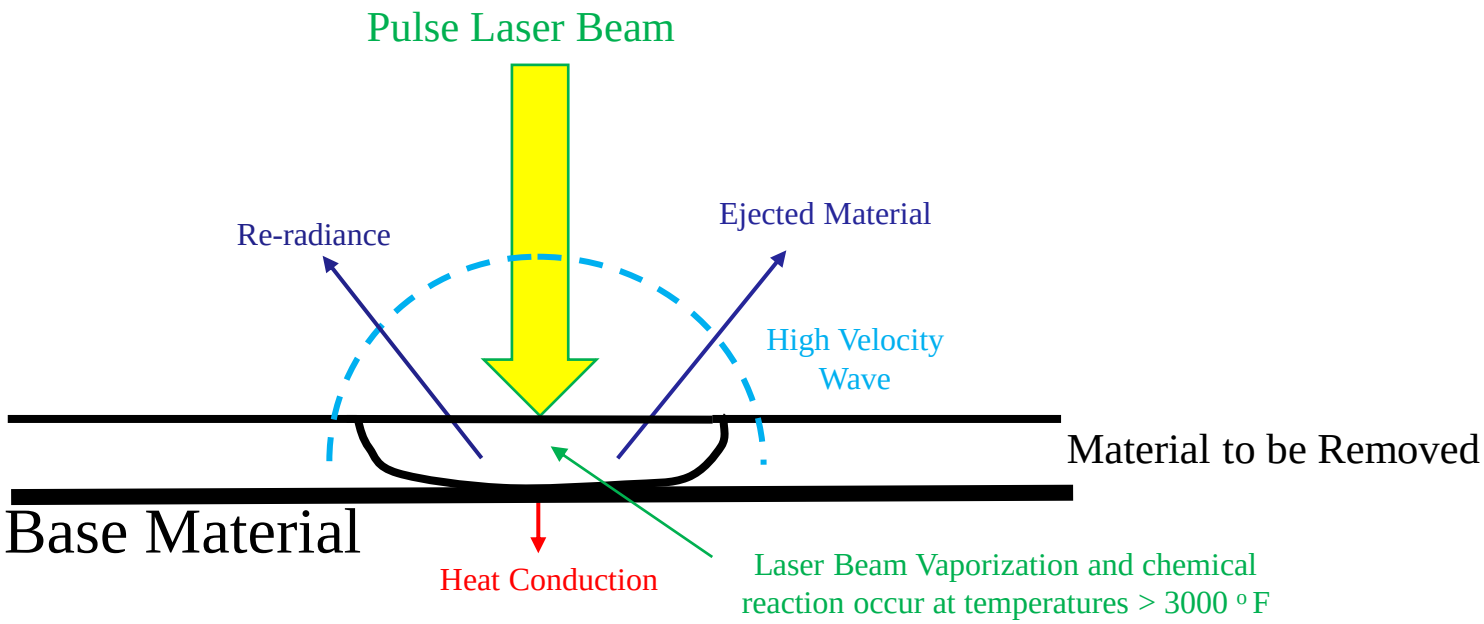


- Sometimes manufacturers want to increase a products surface roughness while others sometime want to reduce it?
- Sometimes the increased roughness makes the product easier to handle while other times the intent is to make it as *smooth as possible!*
- But no matter what a manufacturer does to reduce the surface roughness!

THE VALLEYS WILL STILL REMAIN!

- The OXIDES, CHORIDES and other surface contamination accumulated during the manufacturing and CHEMICAL CLEANING processes will start their ATTACK

How Does Laser Ablation Actually Work?

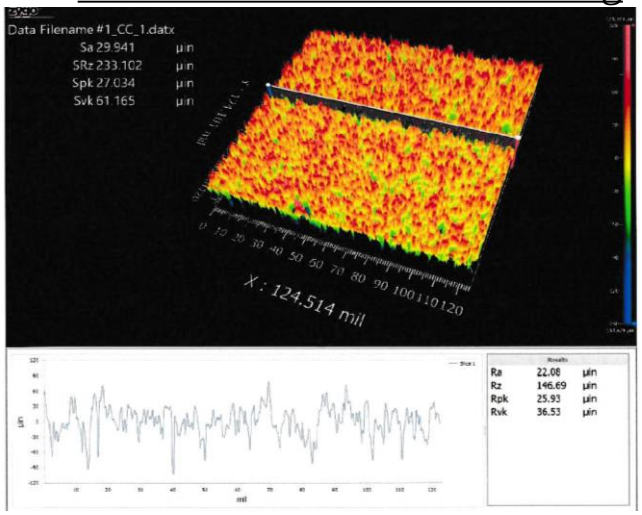


- Laser Ablation uses a "Pulse Type Laser" which can typically turn on and off between 10,000 – 25,000 times every second!
- The very fast pulse rate allows the laser to vaporize the "top layer" that is the target of removal, while not over heating the parent material
- For the STS application process, the two most important things for the laser is to be ***Environmentally Friendly*** and ***remove any surface contamination*** to maximize coating system durability

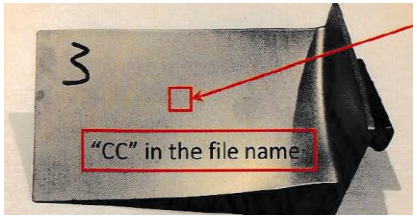
Paint & Primer Example

Surface Finish Data

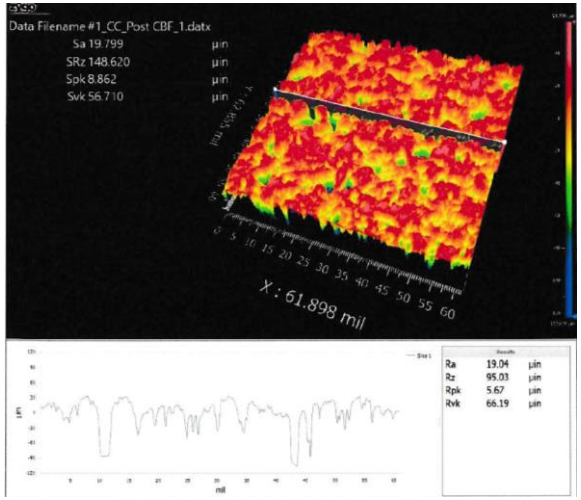
Before Micro Surface Finishing



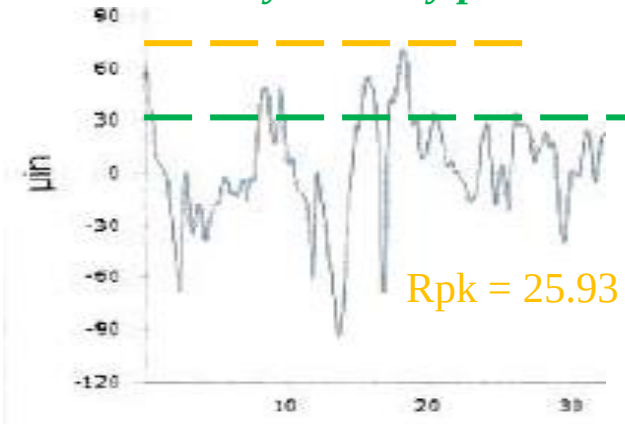
Location of 3D Scan



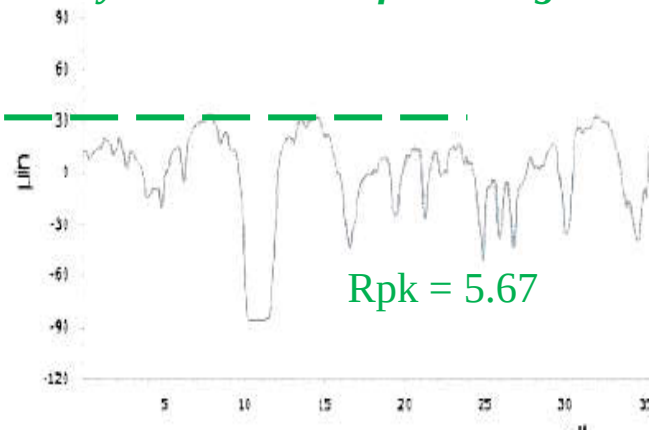
After Micro Surface Finishing



Environmentally Friendly process has the Capability to Reduce Surface Roughness Further!



Before Micro Surface Finishing



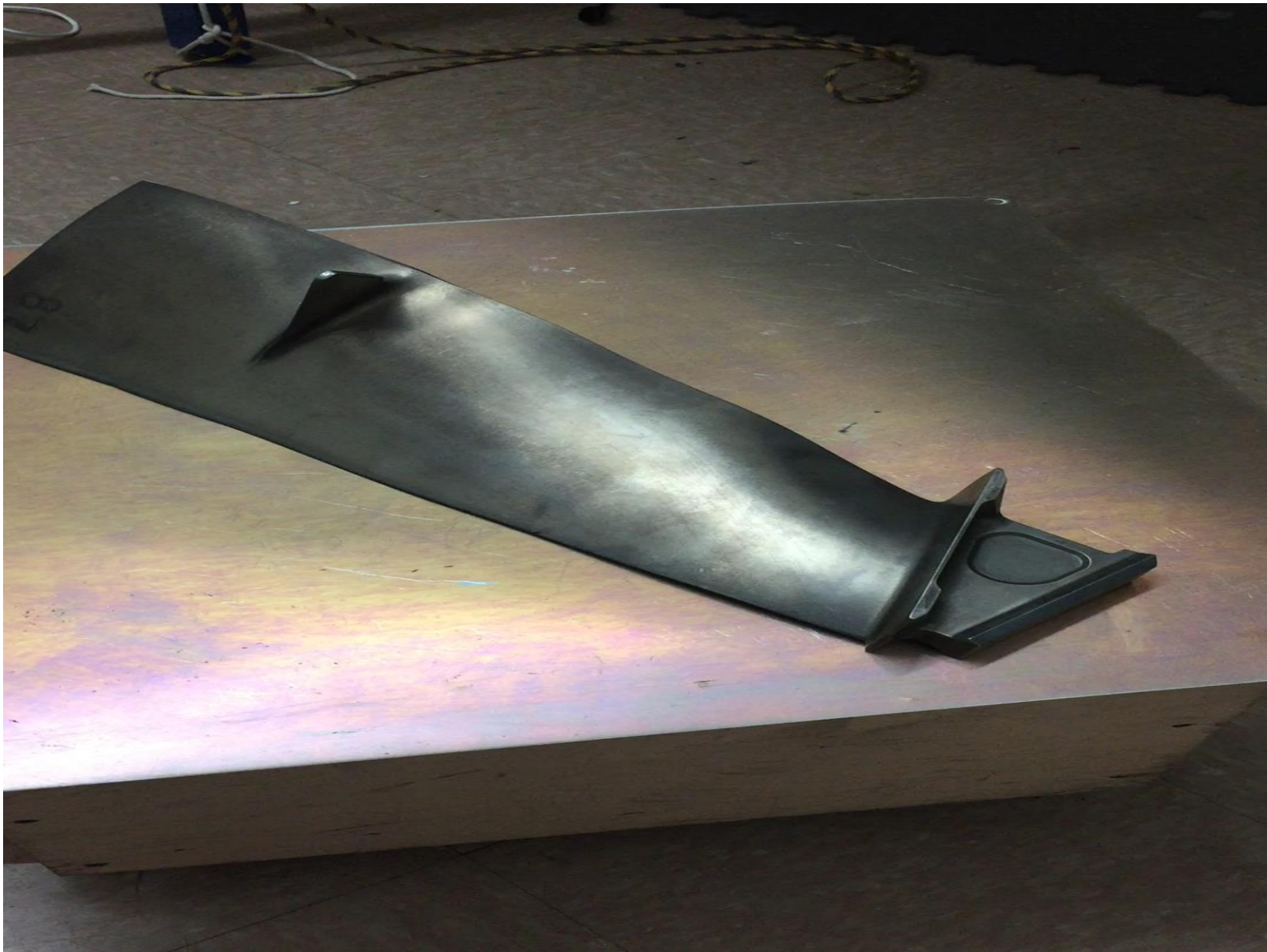
After Micro Surface Finishing

STEP 1 – Laser Ablation Cleaning

CFM-56 Airfoils

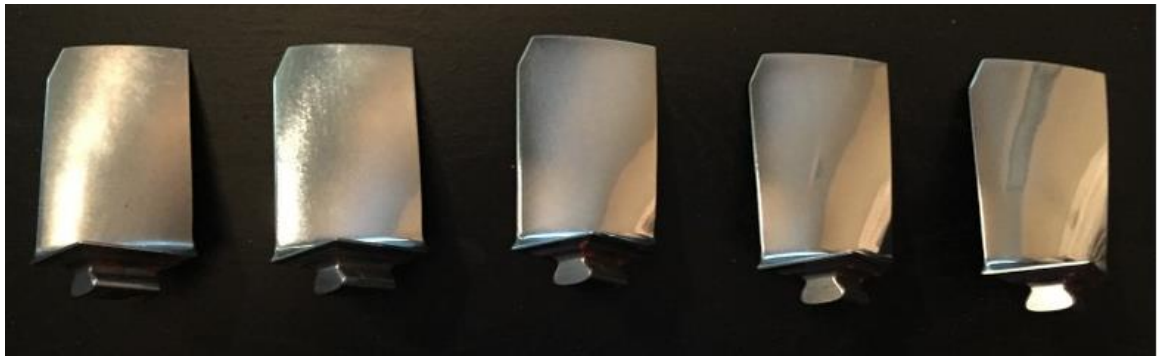
- Over 20 used 1st stage Compressor and Fan Blades were used as STS test pieces
- After tens of thousands of hours in operation, the level of surface contamination as well as increased surface roughness, these airfoils were considered challenging candidates for the three step STS process
- The largest of these test airfoils is ~ 20” long by 5” wide, and the laser ablation cleaning process took ~ 2 minutes for both sides
- Several materials have been examined by a Scanning Electron Microscope (SEM) and found no evidence of any negative impact to the parent material. This included stainless steels, aluminum, Ti-6-4 and composite materials.
- Laser ablation systems have been approved by the FAA for the removal of paint from aluminum and composite aircraft structures while the U.S. Navy has approved them for use on Naval steel and aluminum used for surface ship construction
- The FAA and U.S. Navy have concluded that the laser ablation process has no negative impact on material strength while the Navy also concluded it increases corrosion resistance

Service Run Part Example



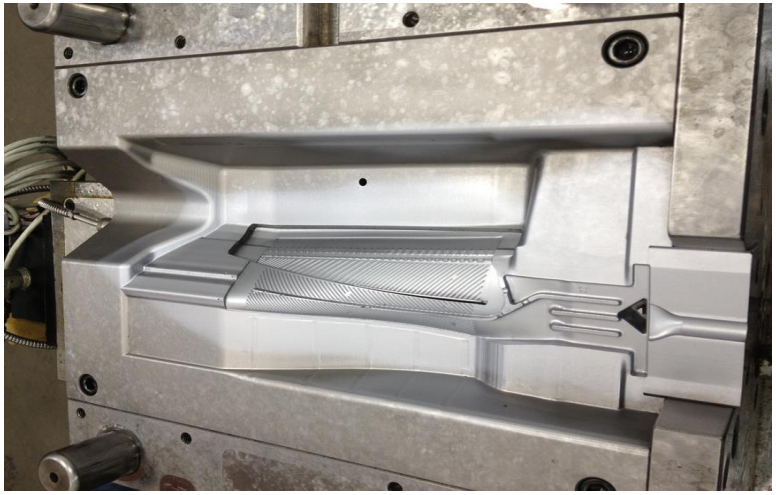
STEP 2 – Micro Surface Finishing

Environmentally Friendly Process



- Airfoil test samples for the initial evaluation of the Micro Surface Finishing process
- The service test sample airfoils in the figure above were only cleaned on the left while the one on the right had the highest level of Micro Finishing and those in between increasing levels of Micro Surface Finishing from left to right
- Our latest and larger group of test sample airfoils for the complete three step STS application process also varied the Micro Surface Finishing process to help optimize the process
- Early tests have shown that the Micro Surface Finishing process can bring the surface roughness so low that coatings will no longer stick to the surface!

STEP 3 – Diamond Like Carbon Coating



- The core die above is similar to the one that was used for the limited duration wear test with only step 3 DLC coating applied and yet still showed a ***dramatic reduction in die wear!***

- With the addition of STEPs 1 and 2 for the complete three step STS application process, wear reductions are expected to be significantly improved as compared to the original DLC coating

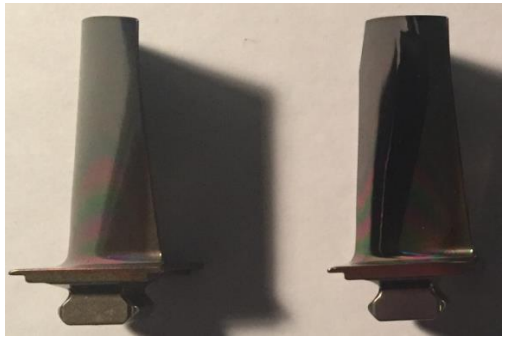
- With 10 times lower friction than *TEFLON,* the three step STS process results in an omniphobic surface that will significantly reduce the effort to separate dies thereby reducing core and wax pattern damage and the associated MRB repair costs

- With the elimination of tool die wear as a major issue, dies can be manufactured to nominal dimensions again reducing MRB repair costs

Surface Treatment System can be Applied to Numerous Products in Various Markets

Surface Finished Knee and Hip Parts

Surface Finished and DLC coated Knee and Hip Parts



Airfoils with Three Step STS Applied

- The above photo's are examples of early test samples for various products and phases of the STS application process

- The STS application process is the only coating ***SYSTEM*** that focuses on the:

  - Elimination of corrosion and coating attacking surface contaminates

  - Elimination of the highest surface defects that can protrude from the 0.000078 inch thick DLC coating system allowing external chemical attack on the exposed parent material

  - Elimination of the ability to attack the parent material with a nearly impervious *Military Proven* Diamond Like Carbon coating that will improve the durability and life of Investment Casting wax pattern and core dies, machine cutting tools to name only a few of the nearly endless list of application possibilities that only leaves it to the imagination for application

Solid Stable Core (SSC)

- A new low pressure ceramic core system called the "***Solid Stable Core***" is currently in co-development with an investment casting company

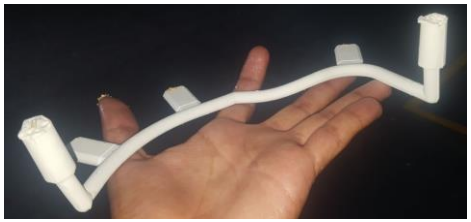
- The SSC system coupled with our STS allows the use of less expensive, rapid prototype, 3D printed core and wax pattern die tooling for a significant reduction in *New Product Development:*

✓ ***TIME***
✓ ***COST***

- The SSC system has nearly ***ZERO SHRINK!*** significantly reducing MRB repair activity and results in a in a fine grain structure for superior "***As Cast Part***" quality!

- The SSC system requires a significantly lower furnace firing temperature and duration as compared to traditional ceramic core systems resulting in lower thermal stress for increased core yields for ***reduced MRB activity***

- With a significantly higher "green" strength than traditional core systems, no setters are required during the firing process allowing castings that are not possible with tradition ceramic processes



Conclusions

- STS is the only multi-step, system based, coating process that focuses on; eliminating surface contamination, surface roughness reduction and a nearly impervious Diamond Like Carbon coating with a special proprietary adhesive layer for increased durability and longer life

- Testing conducted to date on U.S. Flight Military hardware as well as a commercial core die has shown that DLC coating resists and/or eliminates Foreign Object Damage to IR lenses and core die wear

Next Steps

- Review surface roughness test results to determine how each variable impact's surface roughness reduction

- Verify that the DLC coating conforms to the more rounded peaks and determine if further micro surface finishing is needed

- Conduct STS durability testing on existing STS processed gas turbine fan & compressor airfoils

- Conduct STS Beta testing on selected commercial wax pattern and/or core die tooling

- Conduct STS Beta testing on selected cutting tools for durability evaluation

Questions and Discussion?