Geomagic® Control X™

3D SYSTEMS

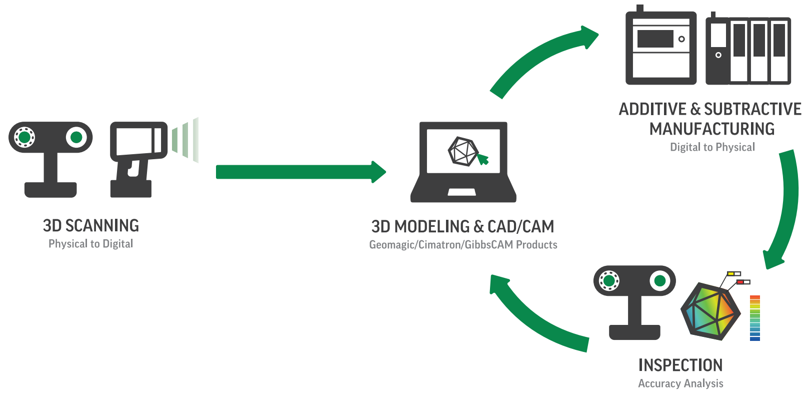
CUSTOMER STORY | ARTEC 3D

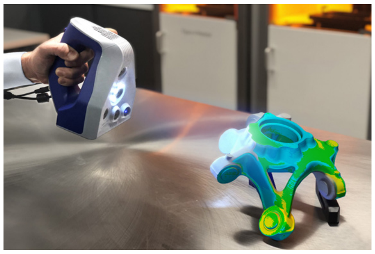
Improved Manufacturing Process with Artec 3D and Geomagic Control X

Scanning and inspecting additively-manufactured parts results in reduced costs, minimized iterations, and improved accuracy and quality.

As new production technologies evolve new technical challenges arise in manufacturing the best possible part. Oftentimes significant tuning of the new process is required the first time a contract manufacturer attempts production in order to understand elements such as shrinkage, surface finish and repeatability. Additive manufacturing is no exception and yet tools to track these elements for this production methodology have lagged behind. That is now changing.

Most manufactured goods follow a common process through their lifecycle to production. Design, Manufacture, Inspect is a generalized way to consider process, stages and responsibilities. Each one being key to producing high quality parts. Depending on the complexity and nature of the part being manufactured, the real workflow can have many tuning loops and feedback.





In our workflow example below, we demonstrate how Artec Space Spider & Geomagic software together provided total shape capture and analysis on 3D printed wax casting patterns and cast parts, at all stages in the design, prove out, and manufacturing process.

CHALLENGE

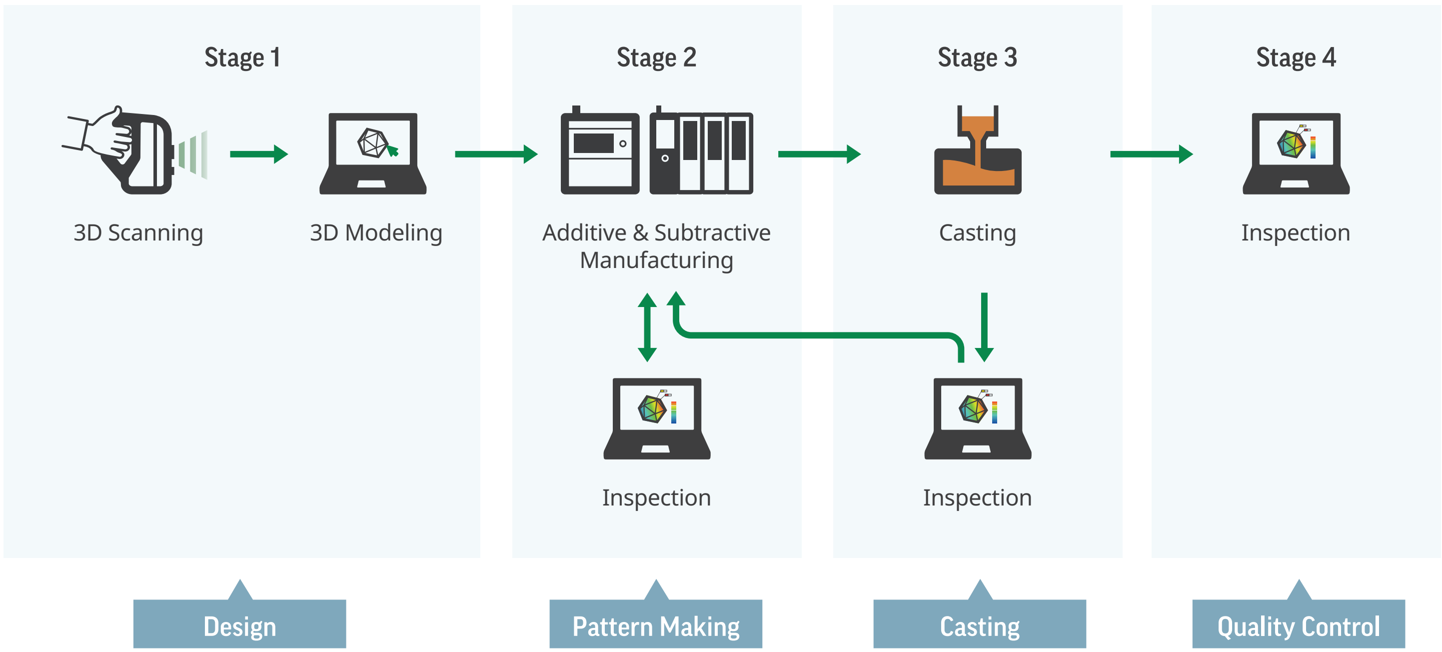
Multistage manufacturing can introduce uncertainty and process deviation which accumulate into end part results which are not accurate. Corrective investigations are challenging to perform unless a systematic approach is taken with the proper tools

SOLUTION

Artec 3D Space Spider scanner and Geomagic® Control X™ metrology and quality management software by 3D Systems

RESULTS

- Refining the additively manufactured, tool-less pattern process with 3d scanning and inspection nets improved results with minimum iterations (one)
- 27% reduction in cost with a 10% increase in total accuracy
- Close working relationship with a foundry, and analysis of the casting process nets finished parts which exceed foundry expectations with minimum iterations (one)
- 14% increase in end part accuracy
- Reduction in finishing cost with reduced secondary machining operations



Artec Space Spider is an ultra-high-resolution handheld 3D scanner that excels at precisely capturing small objects and complex details for dimensional inspection.

With plug and play operation, Space Spider scans objects easily, without complicated preparation and extensive user training, allowing customers to digitize parts anywhere. Artec 3D's proprietary "target free" algorithms allow the scanner to track the object by its shape and color alone. No need to apply targets to the object.

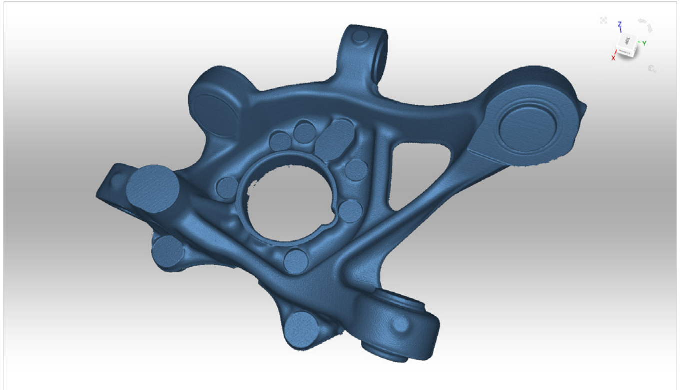


Figure 1: Artec Studio scanning software

Geomagic Control X from 3D Systems is an industrial metrology software which enables root cause analysis and correction for manufacturing, as a 3D scan – native software, Control X is an ideal solution for metrology with portable measurement devices. With Control X, more people in your organization can measure faster, more often, more completely, and anywhere.

The total solution provides unique insight into successful production in a complex manufacturing process. The result? Greatly improved overall final part quality, accuracy and repeatability.

Design

For this workflow example we replicated a real customer project, but generalized the details. In this case our customer was developing a specialized autonomous-driving light-duty vehicle. In order to speed time-to-market, a range of components and systems from vehicles on the market today were selected and combined to complete a working prototype. In this process they found a specific steering knuckle (1 each per) was of value to the project, and the customer needed to digitize and capture the design for further modification and production in a light weight material.

To begin work, the original casting was 3D scanned and reverse engineered. Artec Space Spider was used for rapid digitization, and the part was quickly and accurately modeled in Geomagic Design X using a unique hybrid modeling approach. Typically our customers will follow either an as-built (very accurate) or design-intent (dimension driven) modeling method. A hybrid modeling approach consists of combining both of those concepts to deliver a CAD solid model result that is a has both dimensioned features as well as a highly accurate NURBs surfaces. Using this strategy the model was completed in under 1.5 hours, and live-transfered to SOLIDWORKS as feature-based CAD.

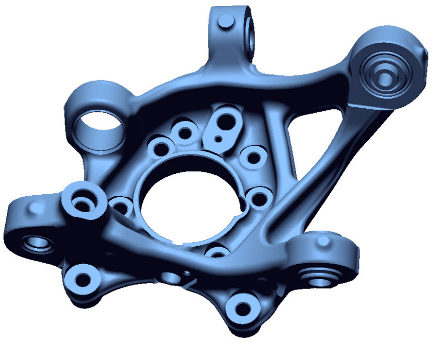


Figure 2: Original Part Scan

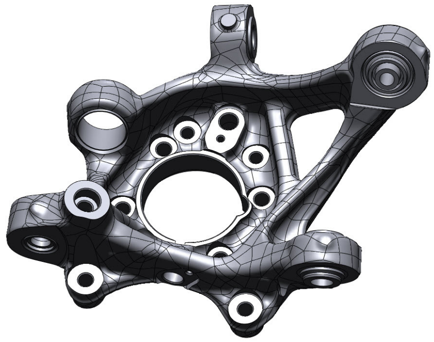


Figure 3: Hybrid CAD Model

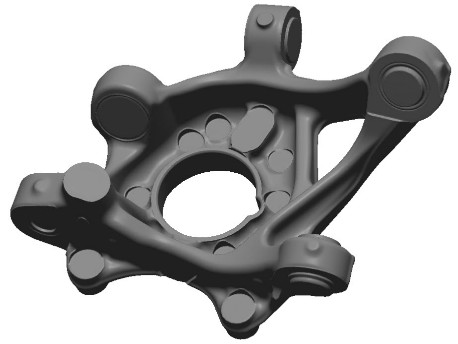


Figure 4: Defeatured Model for Print

Pattern Making

Additive Manufacturing has been used in aerospace and automotive applications to produce sacrificial casting patterns for decades. With recent advances in 3D printing, industrial-grade patterns can be printed in wax or polymer at significantly lower cost, which work seamlessly in the investment casting process. Today 3D Systems is seeing more distributed adoption of tool-less additive pattern making, and with that will continue to grow as the technology becomes more accessible, rapid, and precise.

For any additive process which involves heat energy in material deposition, or post processing, there is some amount of part warp and "settling" which can potentially occur. Parts which have significant mass, or significant cross sectional area will retain heat for longer than smaller or thinner parts.

Based on this knowledge we tested two printing methods with the goal of having the lowest possible cost of printed goods, and have the highest level of dimensional stability. We tested a completely solid wax printing method as well as a thin shell/ sparse wax infill method, prepared by 3D Sprint build client software and printed on the Projet MJP 2500 IC system which produces wax casting patterns. From prior experience we found that a 2 mm shell with a 50% sparse infill ratio produces high-quality stable parts when printing relatively large parts.

After post processing and cooling time, our two patterns were scanned with the same Artec Space Spider with relative ease. The unique shape of the parts, green wax color, and slight dulling and whitening effect of the post process allowed our scanning technician to smoothly capture the models using Geometry + Texture tracking.

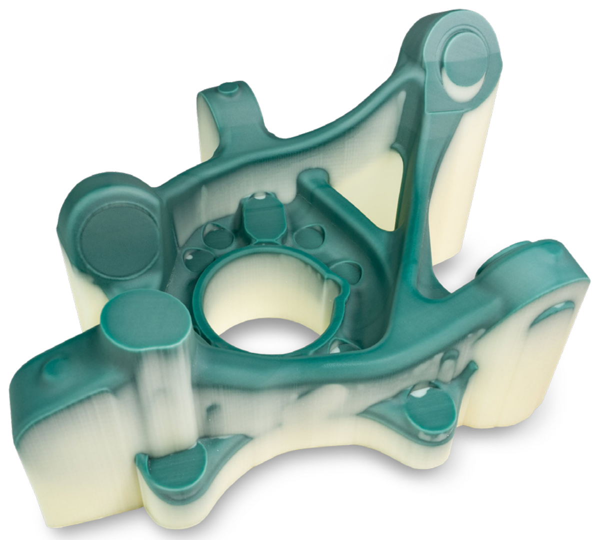


Figure 5: Unfinished 2500 IC Print

Figure 6: Example Cross Section of Sparse Infill Mode on Projet 2500 IC

Using Geomagic Control X we imported our 3D Sprint Build file directly and inspected each part in its exact print orientation for the inspection routine. Knowing that we would be scanning our subject part iteratively to improve our process, we were able to set up one detailed inspection project and duplicate it several times while maintaining the entire process development history in a single Geomagic Control X file. When scans were complete, we simply dropped each new stl file into the Control X project and the evaluation process automatically took over, resulting in high quality, repeatable reports.

We found that generally all areas with machining offsets were within the casting tolerance, but the more freeform areas presented trends outside a tight tolerance band. We believe this properly correlated our assumptions that large cross section areas retain heat and potentially change shape when cooling.

Our comprehensive analysis for this stage helped up draw some conclusions that 3D printing with the wax pattern was not only more cost-effective but also more dimensionally-compliant after post processing.

- ~ 35 % less part material used in the process
- ~ 27 % material cost reduction
- ~ 10 % increase in overall compliance with tolerances (using 3D Comparison)
- Solid part did not pass our tolerance threshold
- Infill Part passed our tolerance threshold.
- Additionally, further investigation showed that long term dimensional stability at room temperature was improved over the solid part.

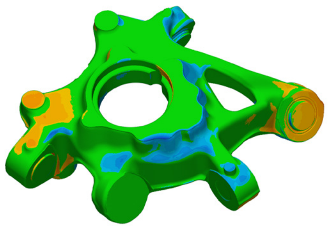


Figure 7 Analysis: Solid Wax Pattern

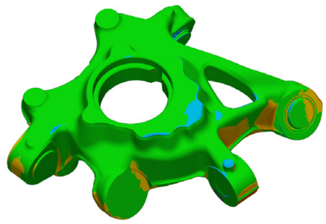


Figure 8 Analysis: Wax Pattern with Infill

Casting

Investment casting is a trusted manufacturing methodology dating back 5,000 years and established in global industrial manufacturing for the last few hundred years, since the dawn of the industrial revolution.

Today, the casting process is quite mature and repeatable, well-known and covered by simulation software to help reduce the chance of internal part defects. With an experienced foundry partner, and minimal effort on the customer side, it's possible to deliver additively manufactured patterns and produce parts which are free of internal defects and generally exceed commonly held process tolerance expectations for casting

Customers who actively participate in testing of the result and process iteration can expect to achieve significantly higher quality output when tuning their part geometry, due to the stability of the casting process itself.

Shrinkage or Contraction Allowance

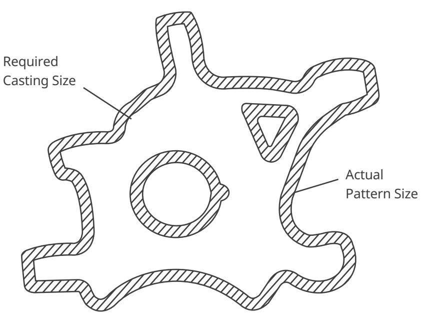


Figure 9: Shrinkage or Contraction Allowance

Shrinkage is a known result of the casting process and typically a foundry provides some guidance to customers in order to compensate for the known shrinkage for a specific material, for a part size defined by bounding box. Due to the complexity of geometry and compounded by the physical casting process, it is common to see non-uniform shrinkage with most parts. As a result casting can generally be regarded as a "loose tolerance" process.

During the casting processes for our steering knuckle we investigated a shrinkage rate that would be suitable for our model and material. After consulting with the casting facility a 2% uniform scale was recommended to produce an accurate part. To investigate the effect that 3D scanning and a precision scale factor can have on end-part accuracy we produced a wax pattern with a 2% scale factor as advised, and supplied it to the foundry

Further inspection on the returned castings was performed to verify if the uniform scaling factor conformed to expected tolerances. Following the generalized foundry specification it provided a part which was definitely inside our partner's stated achievable accuracy for a part of roughly. However, closer inspection with the Cross Section compare tool in Control X indicated some obvious areas where better application of the precision scale factor could meaningfully improve the overall accuracy of the finished part.

This Cross Section Silhouette comparison with tight tolerance band clearly shows outer borders with blue coloring, and inner borders are showing orange and red coloring. The outer profile is confirming an "undersize" condition where the actual part boundary is inside the reference boundary. The inner profile is showing that center cylinder feature is dimensionally smaller than intended, but appearing as outside of the reference feature. This indicates that the total silhouette shadow of the part has a scale difference which can be corrected by increasing the scale factor, printing, and casting again.

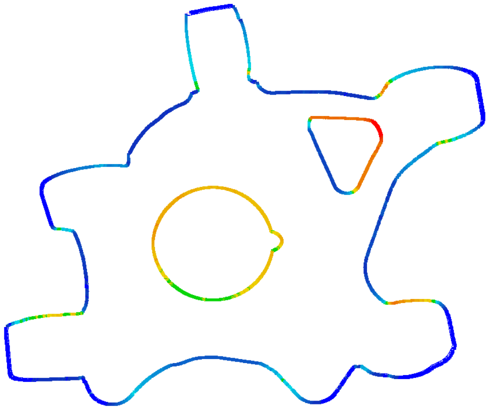


Figure 10: Analysis Cross Section of Scale Error

Previous casting process improvement investigations have given us some insight on relative adjustments from recommended standard values that we can apply, and a second wax pattern was printed with a non-uniform scale factor of 2.2%, 2.3% and 2.7% in X, Y and Z respectively, and supplied to the foundry.

With a final inspection on the precision compensated pattern we were able to draw some conclusions about the pattern-to-part process:

- The precision scaled pattern provided results which exceeded foundry expectations.
- Overall dimensional compliance of the scale corrected part increased by ~14 %.
- At least one major machining operation could be avoided with the increase in precision.
- Total overall part production cost was reduced.
- Future analysis is needed to see if further precision can be applied to generally reduce machine operations.

Figure 11: Final Cast Part

Conclusion

Efficiency is key in maintaining profit and reducing waste in human cycles and manufacturing cycles. With Artec 3D Space Spider, and Geomagic Control X we were able to improve the total overall quality of our manufactured part, by analyzing each stage of our process, with the minimum possible tuning cycles and iteration. Reducing iteration and guesswork, saving time and money, and faster time to market are key benefits of using a total solution for high quality 3D Scanning, and Scan-native Industrial Inspection software.

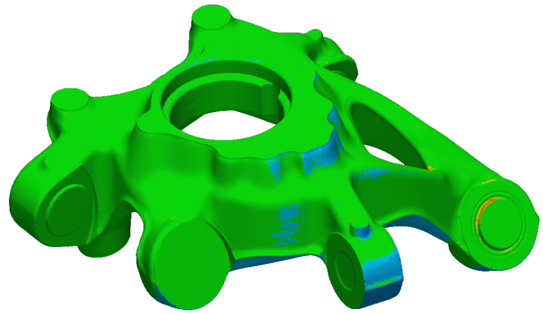


Figure 12: Analysis of Final Casting