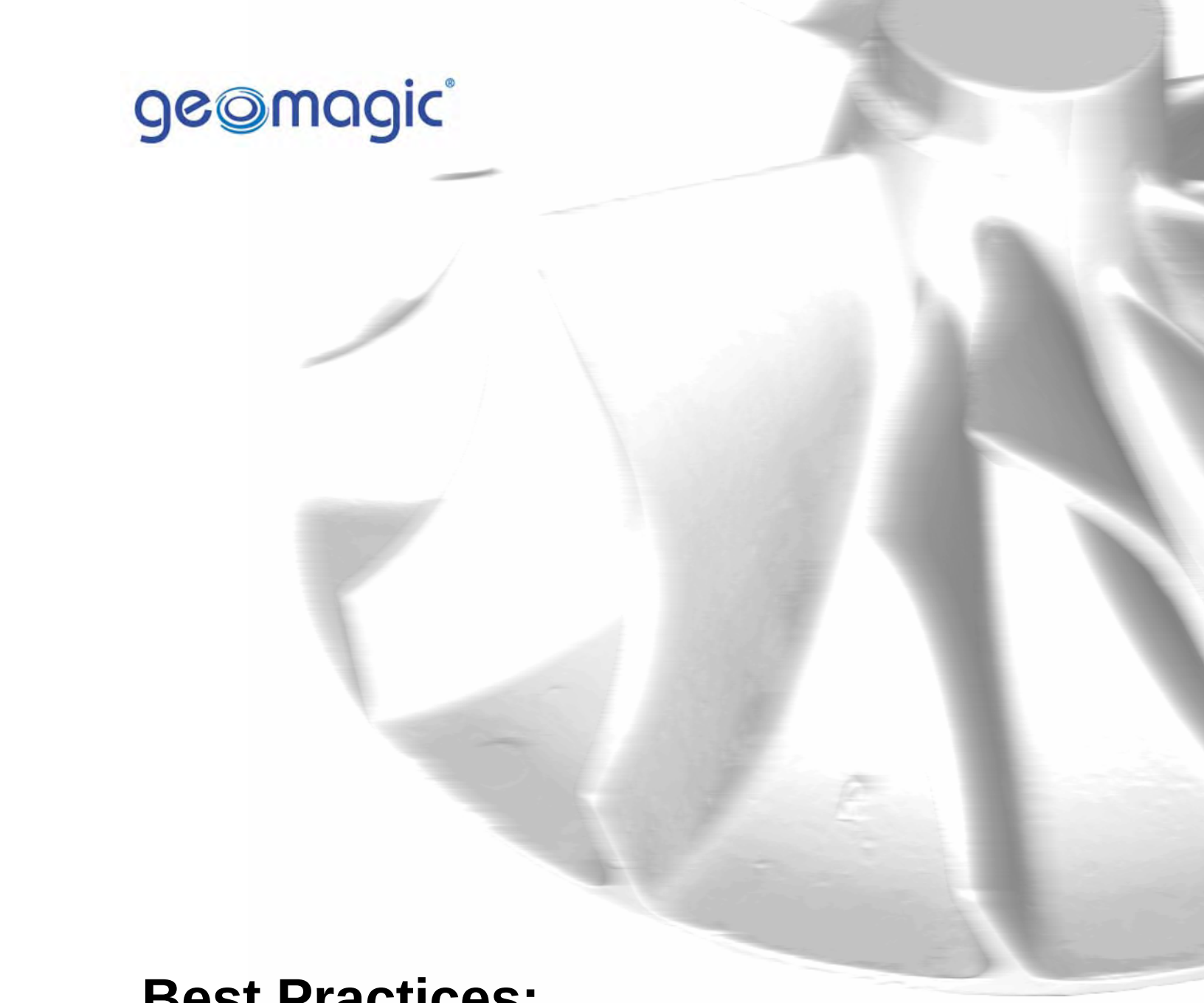


Best Practices: Parametric Design with Hybrid Modeling

David W. Bell, Geomagic, Inc.

Combining the best of measurement and modeling, Geomagic Studio can be used to complement existing CAD technology to produce accurate design models quickly and easily. This Best Practices document walks through an example of hybrid modeling utilizing an impeller to show how a native, parametric model of this complex shape can be created, and discusses the advantages of this approach versus traditional methods.

Overview

> "It turns out that some product development and manufacturing problems can best be solved by simulation with computer models. Others are best solved by experimenting and capturing real results. Thus, a combination of the two approaches – in this case 3D modeling and 3D measurement, is more powerful than either alone."
>
> - Peter Marks, H*Capturing a Competitive Edge Through Digital Shape Sampling and Processing (DSSP)*H

Over the past decade, digital shape sampling and processing (DSSP) has evolved to complement computer-aided design (CAD) and product development with the power of 3D imaging. Since 1996 Geomagic software has helped thousands of customers convert 3D scan data into digital models for design, analysis, manufacturing and visualization. Geomagic applications lead the industry in reverse engineering solutions, and automatically generating NURBS surfaces from point cloud data. These models accurately capture and reconstruct the shape of a physical part, and are ideal for applications to:

- Capture physical designs and prototypes
- Reproduce legacy parts and tooling
- Replicate complex and organic shapes
- Prepare as-built models for CAE applications
- Enable mass-customization of unique components (dental applications, hearing aids, etc.)
- Preserve historical and cultural artifacts

Traditional CAD models are created by defining a construction sequence of 2D and 3D entities (features). Described as *prescriptive modeling*, CAD operators draw upon their skill and experience to create new designs by specifying the parameters of these entities to control the resultant shape of the object. The completed parametric model offers great flexibility for generating multiple variations, enabling design iterations and rapid experimentation with form and function. However, reconstructing a complex surface can be a struggle to balance time, effort, and accuracy. In some cases it may be virtually impossible to use a feature-based approach to reconstruct the surfaces due to the difficulty in identifying and quantifying the parameters which control the object's shape.

Challenging objects for conventional prescriptive modeling

In this document we'll show an example of using Geomagic Studio as a complement to traditional CAD part design in a process called *hybrid modeling*. With the strengths of feature-based modeling and the power of scan-based measurement, this solution provides the best of both worlds. Basic reference geometry, such as datums, curves, and primitive features, can be measured and extracted from the 3D scan data. These entities can then be imported into a CAD system to construct native geometry using the familiar tools and workflows product designers use every day. Using the automatic surfacing functions in Geomagic Studio, complex freeform shapes can also be captured and imported as NURBS surfaces. This approach will yield accurate and flexible results in less time than conventional modeling methods alone.

Example: Modeling an Impeller

In this example we'll scan and model an impeller wheel from an industrial equipment turbocharger using Geomagic Studio to extract datums, curves, and complex surfaces, and Pro/ENGINEER to construct a new parametric model.

Scanning the Impeller

This impeller was scanned using a GOM ATOS II scanner. The ATOS II is a "white-light" scanning system, which uses two high-resolution cameras to observe projected fringe patterns on the surface of the part. These patterns are analyzed to triangulate millions of points on the part and generate a point cloud.

> ***Tip#1: Plan ahead.*** Think about what aspects of the design need to be modifiable. From this develop a construction plan that includes the necessary parameters for your design.

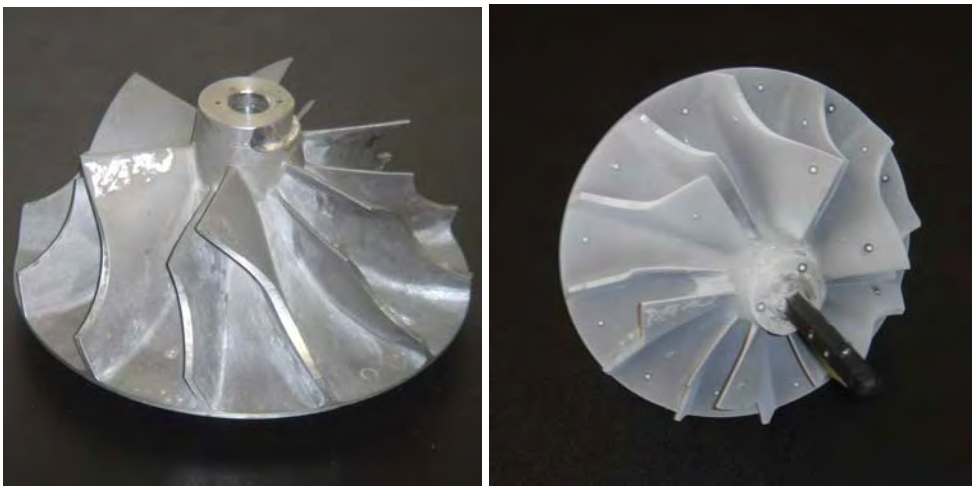
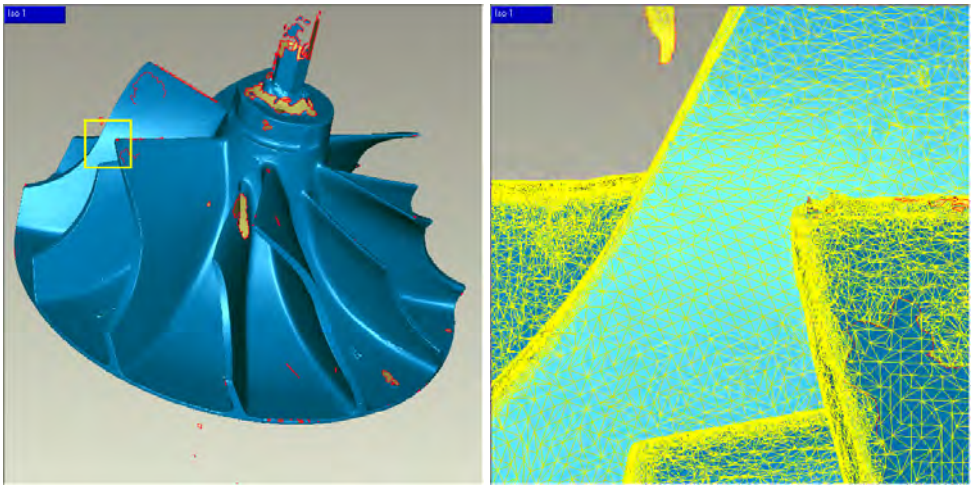


Photo of impeller, prepared for scanning with registration stickers.

Due to the shiny surface of the part, a powder coating was applied to reduce the reflectivity which would interfere with the projected patterns. The complexity of the shape requires that multiple scans be taken from many different positions to provide line-of-sight to all of the surfaces of the impeller.

To aid in the alignment of the scans, an array of registration targets were also placed on the object. Using a technique known as photogrammetry, the centerpoint of the registration targets is automatically detected from the high-res camera images, and the unique result of the collection of visible points as seen from any position is sufficient to provide enough information to align each scan.

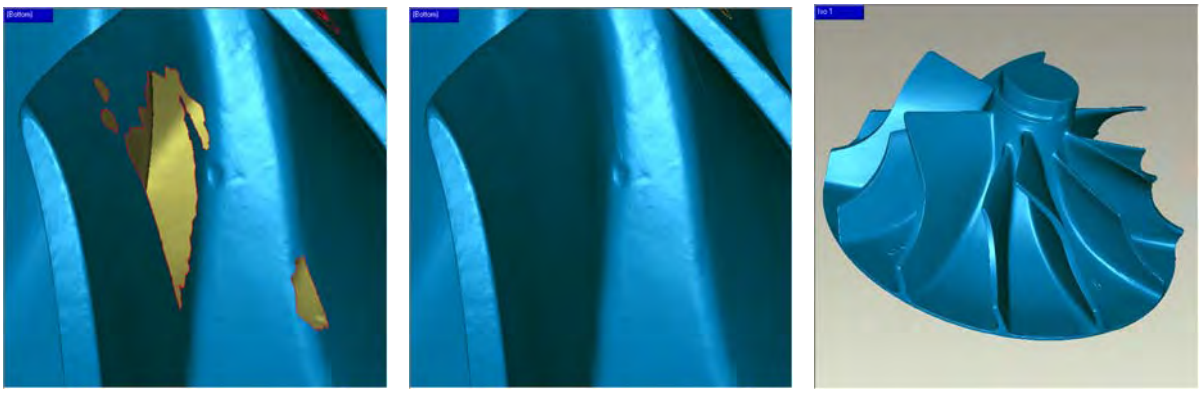
Over 15 million points were captured from more than 20 scans, which were then aligned and merged to create a polygon model.



Raw STL data from scanning system

Cleanup and Repair

After importing the scan data as an STL model, the next step is to clean and repair the data using Geomagic Wrap (a module of Geomagic Studio). Typical cleaning procedures include removing extraneous data, noise reduction, decimation, filling holes, and repairing intersections. In this example the entire polygon model was repaired. However, in many cases it will only be necessary to clean portions of the model that will be used during the parametric reconstruction process.



Geomagic: hole filling and repair to complete the polygon model.

Extract Curves and Datums

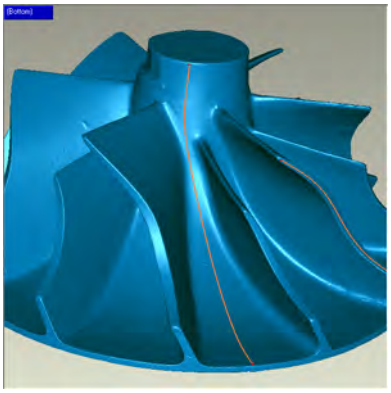
One of the first tasks in the CAD process will be to model the hub of the impeller. The shape of the hub can be reconstructed by detecting the center axis of the impeller, defining the hub profile with an extracted curve, and then generating a surface of revolution with the curve revolved about the axis.

> ***Tip #2: Name all reference entities.*** In Geomagic and your CAD system, name each entity as it is created. This good housekeeping technique will reduce confusion and make things dramatically easier if someone other than the original modeler needs to modify the part. You can also effectively use CAD layers to organize the data elements and avoid display clutter from large numbers of features such as datum planes, surfaces, etc.

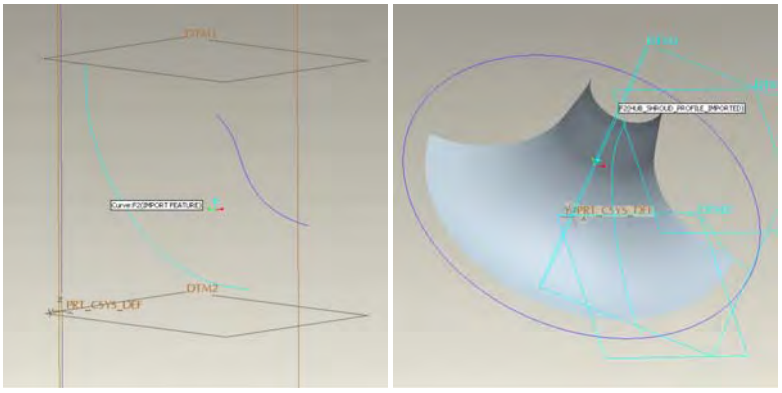
The axis can be found by selecting the outer perimeter surface area of the impeller. This area should be perfectly cylindrical by design, and will generate a stable datum axis. An alternative would be to use a selection of the hub surface area to calculate the axis from the rotational surface.

The next step is to create the profile curve which will define the shape of the hub. In this case a simple planar cross-section curve cannot be extracted, as the presence of the blades interferes with the cross-section of the hub. Fortunately we can draw upon all of the tools in our CAD system, and use another approach: a variable section sweep. We can generate the surface by “extruding” a half-

circle along the hub axis, and control the diameter of the half-circle with a non-planar curve extracted from the hub surface.



Geomagic: creating curves



CAD: importing curves and creating a variable sweep surface

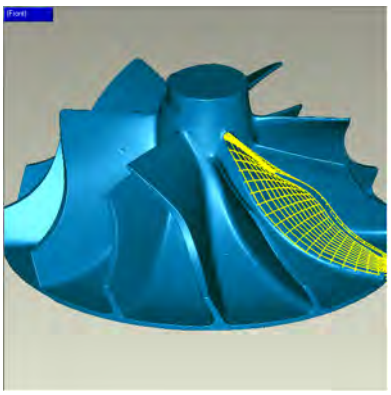
The bottom surface of the impeller (not shown) does not have any obstructions from the blades, so a simple planar curve can be extracted and used to create a surface of revolution.

To create additional parameters for controlling the shape of the surfaces, consider using the orthogonal edge boundaries of the swept surfaces to create new, idealized curves.

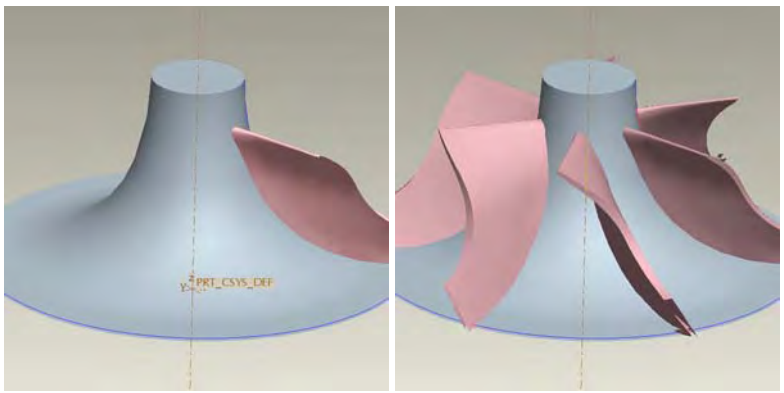
Tip #3: Create reference geometry on a per-feature basis. Extract and model features one-by-one. Similar a conventional CAD design practice, construct the model from the ground up, checking at each step that all construction elements are valid and no design constraints have been violated.

Combining Free-Form Surfacing

In the impeller shape, the most complex element of its design is in the blades. These surfaces are difficult to measure or define with basic parameters. Using the power of NURBS surfacing in Geomagic Studio, the blades can be quickly surfaced and imported as IGES or STEP features.



Geomagic: NURBS surfacing



CAD: importing blade surface and patterning

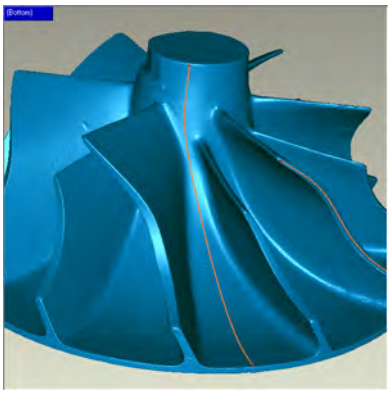
After a single blade is imported, it can be replicated (or "patterned") around the imported datum axis to create multiple blades on the hub surface. The entire import and pattern process is again repeated with the second splitter blade. Rather than define the spacing between the blades as a direct angular measurement, a parameter is defined that relates the angular spacing to the total number of blades. This will allow us to easily change the number of blades while preserving an appropriate blade spacing.

After incorporating the blade surfaces into the solid model, a parametric radius is defined at the surface intersection. This radius can be adjusted at any time in the future. Again we can draw upon the wealth of tools in the CAD system to define many other blends, including variable radius and rolling ball.

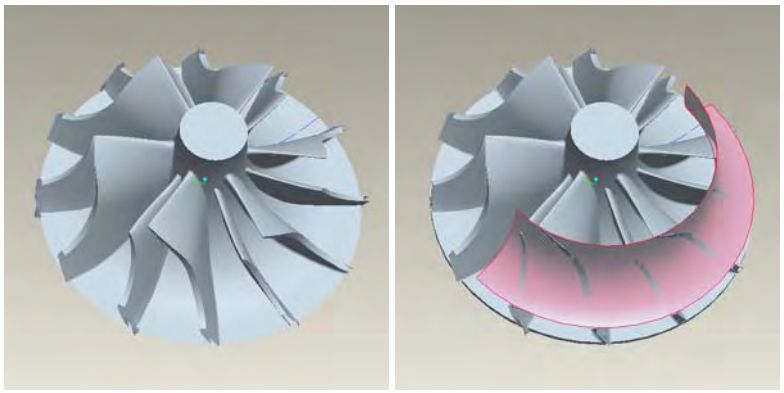
Tip #4: Use surfaces rather than solids. Surface features do not have to be closed and are therefore less restrictive. Using surfaces will provide more flexibility and minimize the total feature count, avoiding unnecessary cuts and reducing regeneration times. Once the surface model is complete, you can create a solid model from the quilted surfaces.

Trimming and Blending

After all of the blades have been positioned, additional datums and curves are defined to perfect the contour along the outer surfaces of the impeller. Again a non-planar profile curve is extracted from Geomagic Studio, and a variable section sweep is used to generate the surface to trim the outer surface of the blades.



Geomagic: defining curves



CAD: trimming the outside with a variable section sweep surface

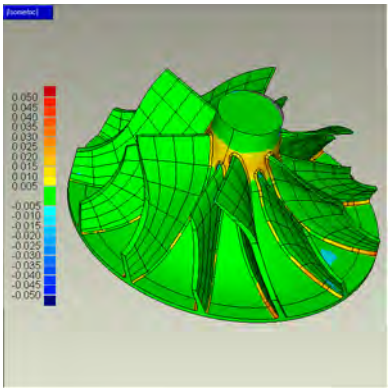
A cylindrical surface is generated to trim the outer surface of the entire impeller. This cylinder is centered on the extracted datum axis, and its diameter can be measured by constructing a 3D Feature cylinder from the polygon surface. After trimming the outer

Tip #5: Merge incrementally. Do not wait until the very end to try and merge all of the various surface features at once, as a failed merge becomes difficult to identify where alterations must be made.

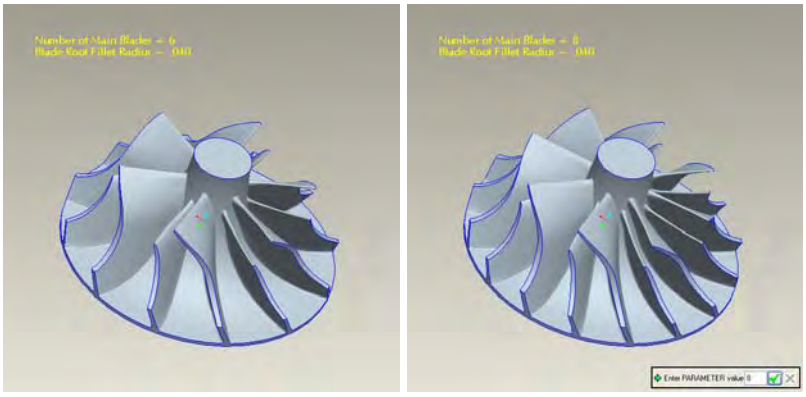
cylinder, we can be assured that our design has produced a perfectly centered and symmetric impeller.

Final Result

The final model meets all of the design parameters, and is verified to be a closed solid. Using Geomagic Qualify we can compare the final CAD model to the original scan data to verify its accuracy.



Geomagic Qualify: accuracy check



CAD: modifying the number of blades parametrically

Through the methods described we have full parametric control over the shape of the hub surface, the radii of the blends, and the number and spacing of the blades. The complete process, including scanning, repair, and modeling, required less than one day to complete.

Advantages of Hybrid Modeling

Leverages your existing 3D investments. Today's CAD systems have invested thousands of man-years to create highly-evolved systems for digital design and creation. Rather than invest and learn in another CAD system, you can leverage your existing modeling system – and the skills of your CAD users and experts – by augmenting these tools with the 3D measurement and rapid surfacing capabilities of Geomagic Studio.

Creates new designs in less time. When compared to traditional CAD techniques, the hybrid measurement and modeling approach can greatly reduce the amount of time required to replicate an existing design. In some cases the hybrid approach can be completed in a matter of hours as opposed to days or weeks using conventional techniques.

Produces native parametric CAD Geometry. Using the strengths of the CAD system, various aspects of the design can be parametrically driven by numerical values or other constrains such assembly mating conditions. Many file I/O translation issues are avoided, as the core of the geometry has been produced within the user's CAD system.

Accurate results. Freeform surfaces can be generated from point clouds containing millions of sample points. This technique can reproduce subtleties in surface structures that would otherwise be lost. The process is also highly repeatable, as acquisition of scan data is less operator-dependent than typical measurements performed by hand.

Summary

Hybrid modeling combines digital shape sampling and processing with the power of computer-aided design to provide an innovative solution for parametric reverse engineering. Today's CAD systems will continue to serve as the nexus of 3D digital design and creation, and Geomagic's tools for measuring 3D scan data and modeling complex surfaces are the perfect complement to the wealth of existing functionality in CAD systems. Resulting in native, parametric models produced quickly and accurately, hybrid modeling infuses new capabilities into existing CAD investments and leverages existing workflows and user knowledge to push the envelope of digital design.

Geomagic is a worldwide software and services firm headquartered in Research Triangle Park, North Carolina (U.S.A.), with subsidiaries in Europe and Asia and distributors worldwide. Geomagic is the market leader in digital shape sampling and processing (DSSP) with a vision of mass customization, technology innovation and business performance. Geomagic software enables customers to accelerate product development cycles and ensure quality at every step. More than 5,000 professionals use Geomagic software and services across diverse industries including automotive, aerospace, medical devices and consumer products. They benefit from unprecedented time savings, short learning curves, increased productivity and simplified processes.
