CASE STUDY

Audi, BMW, DaimlerChrysler, and Renault Turn to PolyWorks® to Reduce the Time for CFD Analysis by up to 83%.

A CFD analysis empowered by PolyWorks offers a series of benefits simply not achievable with physical wind tunnel simulations, and gives specialists of the automotive industry unprecedented insight into fluid flow behavior.

Major car manufacturers have turned to PolyWorks' polygonal modeling technology to generate major cost reductions for their Fluid Dynamics analyses. Discover how PolyWorks' unique tools have enabled Audi, BMW, DaimlerChrysler, and Renault to reduce the time required to prepare a CFD-ready polygonal model from 7 days to 1 day...

Case Study Summary

Traditional Approaches

There are two traditional methods for conducting CFD analyses on physical prototypes:

- **Approach #1**:
  - Aerodynamic simulations are conducted through physical wind-tunnel testing of clay models.
- **Approach #2**:
  - The clay model is digitized using a non-contact 3D digitizer.
  - NURBS surfaces are created from the digitized points in rapid-surfacing software.
  - Surfaces are imported into CAD software for modifications.
  - CAD surfaces are tessellated and optimized.
  - Polygons are imported into CFD software for analysis.

Drawbacks of the Traditional Approaches

- **Approach #1:**
  - Physical wind-tunnel testing facilities are **rare** and **expensive** – Testing is **time-consuming**.
- **Approach #2:**
  - The complete process **takes up to 7 days of work** to obtain a model of acceptable quality for CFD.
  - The rapid-surfacing process alone takes **between 2 to 3 days**.
  - The complete process is **expensive** since it requires several iterations in various software systems.
  - This multi-step approach often involves several engineers from various departments, making the **workflow more complex.**
  - In addition, modeling in various systems increases the risk of **losing model accuracy**.

The PolyWorks Approach

The PolyWorks approach is quick and straightforward:

- The clay model is digitized using a non-contact 3D digitizer.
- The resulting point clouds are quickly aligned and meshed in PolyWorks to create a single polygonal model.
- All model editing is conducted in PolyWorks, including:
  - Feature curve reconstruction
  - Removal of unnecessary details
  - Insertion of CAD surfaces
  - Triangle reduction and optimization
- The polygonal model is imported directly into Exa's PowerFlow® software for aerodynamic simulations.

Benefits of the PolyWorks Approach

✓ The entire process takes **only 1 to 2 days**, compared to up to 7 days with other approaches.

> Faster product development

✓ A faster CFD analysis process allows engineers to **analyze more models** and to **explore more design possibilities**.

> More information during conceptual design

✓ Modifications to the model can be done directly in the PolyWorks environment – No need for additional software systems.

> Major cost savings

✓ PolyWorks' polygons are **CFD-ready** – Engineers' time is spent on results analysis instead of set up, data collection, and editing.

> More efficient CFD analysis

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Case Study

A Revolution in the World of Fluid Dynamics Analysis

Fluid Flow analysis is the study of how fluids, such as air, liquids, and gases move in and around solid objects, such as airplane wings, automobile bodies, or petroleum pipelines. Most major car manufacturers worldwide face fluid flow problems in their design work, such as air-flow over automobile surfaces measuring lift, drag, yaw, and friction. Typically, traditional fluid dynamics analysis are conducted through wind tunnel testing, an expensive and time-consuming operation that requires well-trained technicians.

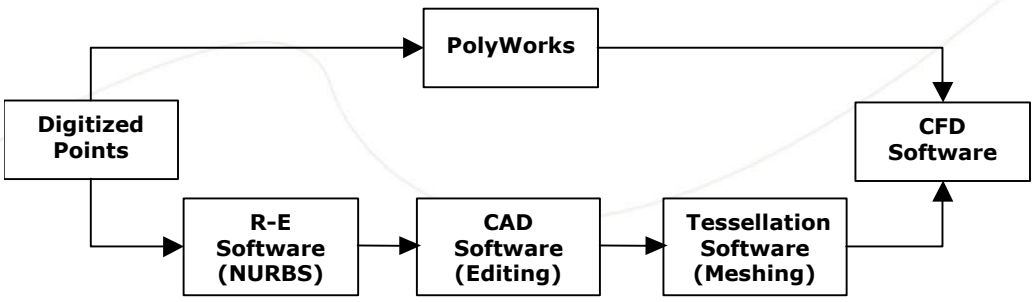
The emergence of 3D digitizing technology has revolutionized the way to analyze Fluid Flow by opening the door to "Digital Wind Tunnel Testing". The millions of data points captured by the non-contact 3D digitizers represent an excellent source of information for digitally simulating fluid flow, and replicating typical wind tunnel testing analysis at a fraction of usual cost and time.

PolyWorks Empowers Digital Wind Tunnel Analysis

To perform powerful Digital Wind Tunnel Analysis, CFD software such as Exa's Power-Flow®necessitates polygonal models that meet strict requirements in term of accuracy, topology, size, etc. Not too long ago, several steps were required in order to prepare the model for CFD analysis, which could take up to 7 days of work. First, the digitized point cloud had to be transformed into NURBS surfaces using a reverse-engineering software system. The resulting surfaces were loaded into CAD software, and several editing operations such as feature re-construction and removal of unnecessary details were conducted. The CAD model then had to be tessellated using another software package in order to recreate a meshed model. Most of the time, this tessellated polygonal model would necessitate other modifications in order to meet the 100,000-triangle target required for CFD analysis.

"PolyWorks offers a straightforward approach which has changed drastically the preparation and optimization of the polygonal models for CFD analysis" said Dr. Hans-Peter Duwe from Duwe 3D Software in Germany. PolyWorks offers a wide set of polygon-editing tools that allows us to reconstruct feature curves, remove over-detailed features, and create closed polygonal models that can be used directly inside Exa's PowerFlow. All operations can be conducted within one software solution, which reduces significantly the time and cost of the Fluid Flow analysis" he continued.

Traditional Approach Versus PolyWorks Approach



PolyWorks advanced polygonal-editing tools let you directly create CFD-ready models

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CASE STUDY

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PolyWorks' Complete Toolkit for Optimizing the Polygonal Model of an Automobile

Create the Polygonal Model → **Edit the polygonal model for CFD**
- Reconstruct feature curves
- Fill all holes
- Remove unnecessary details
- Insert CAD surfaces
  - ✓ Underbody
  - ✓ Windows
  - ✓ Lamps

→ **Reduce and Optimize Triangles**

1. Create the Polygonal Model

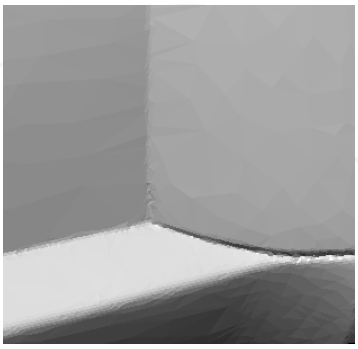
- Car designers create a physical model using clay or other similar composite. The size of the car prototype may vary from full size to 1/2, 1/4, 1/10 reproductions.
- The clay model is entirely digitized using a 3D digitizer.
- The multiple scans are subsequently aligned by photogrammetry (for a full-sized model) or using PolyWorks' unique best-fit method that quickly aligns scans using the geometric features of the object (for smaller objects).
- The aligned point cloud is meshed in PolyWorks and a highly accurate polygonal model is created with between 500,000 and 1,000,000 triangles and a tolerance ranging from 10 to 30 microns.

Original polygonal model after meshing the digitized point clouds

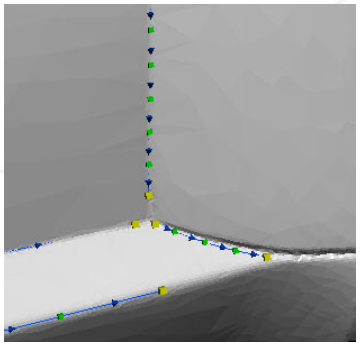
2. Edit the polygonal model for CFD

A) Reconstructing feature curves

- One of the most important factors which influence the air flow of a model is the quality of its feature curves. Since 3D digitizers cannot capture sharp edges with great accuracy, editing work needs to be performed for the reconstruction. PolyWorks offers a powerful tool that detects and tracks feature curves and best-fits theoretical sharp edges. After the sharp edge curves have been extracted, they can be extended and intersected to create corners.



1- Polygonal model before editing.



2- Best-fitted sharp edge curves.

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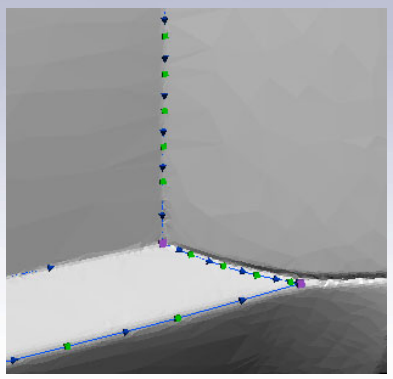
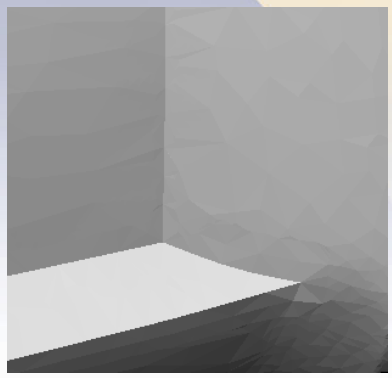


3- Curves are extrapolated and magnetized.



4- Curves and corners are inserted into the model to create perfect sharp edges and corners.

B) Produce a compact and watertight polygonal mesh

Here are the steps to create a compact and watertight model:

- **Filling holes produced during the digitizing phase**:
  - PolyWorks offers various hole-filling tools to close the surface of a polygonal model. For holes of small and medium complexity, users can rely on an automatic hole-filling method that smoothly interpolates curved sets of triangles within a user-defined 3D bridging distance.
  - For larger and more complex holes, users can create composite Bézier surfaces or NURBS surfaces on top of the polygonal model and insert triangulated surfaces that follow the curvature of the object.

- **Deleting unnecessary features of the model**:
  - The purpose of this operation is to keep the number of triangles as low as possible. CFD software such as Exa's PowerFlow are optimized to process polygonal models of up to 100,000 triangles. To reduce the number of triangles, users can remove unnecessary triangles on highly-detailed areas of the model, such as grooves, air traps, etc.
  - User can then use composite Bézier surfaces or NURBS surfaces to reconstruct polygons in these areas.

1- A curve is defined and inserted around the air trap under the front bumper.

2- The area inside of the curve is selected and deleted.

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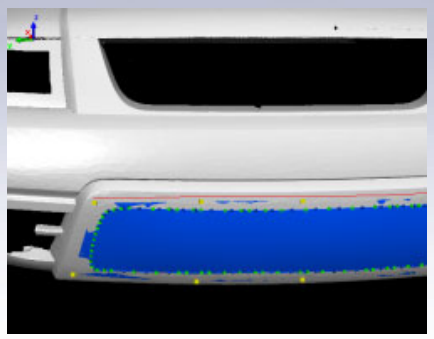
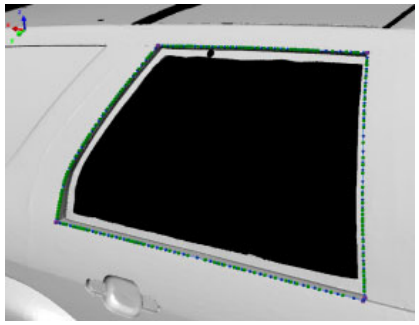


3- A composite Bézier surface made of three patches is fitted to the boundary of the hole.

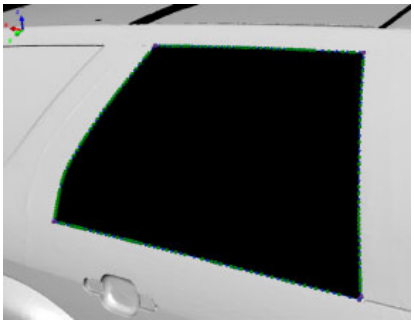
4- The Bézier surface is tessellated and the curved set of polygons is connected to the surrounding triangles.

C) Inserting CAD surfaces

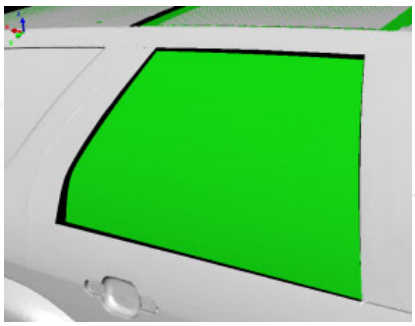
- Parts from an existing CAD model can be inserted to fill elements, such as the under-body, wheels, windshield, windows, and lights.
- Bézier surfaces and NURBS surfaces can be used to fill the areas for which no CAD is available.



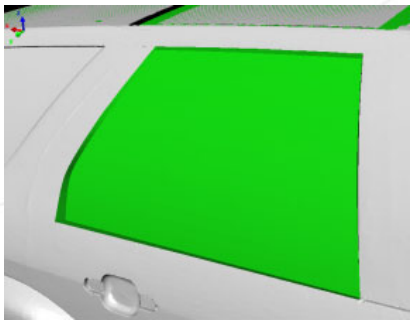
1- A curve is defined and inserted on the boundary of the window.



2- The area inside of the curve is selected and deleted.



3- A tessellated surface obtained from a CAD model is inserted.



4- The tessellated surface is connected to the surrounding triangles. The model is now watertight.

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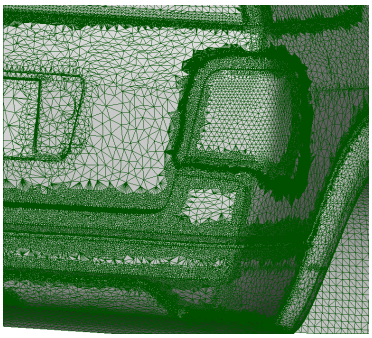
3. Reduce the number of triangles and optimize triangle orientation

PolyWorks adaptive meshing technology enables the creation of "intelligent" polygonal models, preserving high resolution over edges and fillets while creating larger triangles in flat areas. To comply with Exa PowerFlow's strict requirements, a polygonal model should:

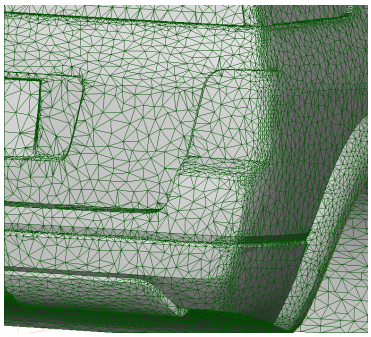
- Contain around 100,000 triangles
- Not contain any triangles with bad aspect ratios (height/base)
- Have triangles whose orientation follows the curvature of the object.

PolyWorks offers advanced techniques to prepare a model that meets these requirements. Users can:

- Set the reduction parameter as a target number of triangles.
- Use a maximum edge length to prevent the creation of large triangles with poor aspect ratios.
- Specify the edge detection angle for preserving feature lines.
- Invoke a mesh optimization algorithm that aligns the triangle edges along the curvature flow.



Edited model of 1,000,000 triangles before reduction and optimization.



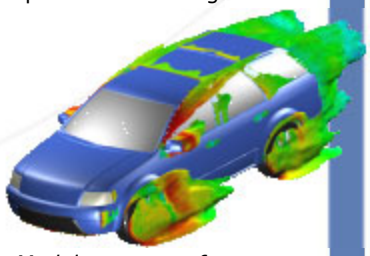
100,000-triangle model with triangle orientation following the curvature of the object

Raise the CFD Analysis to Another Level with PolyWorks

Finally, an optimal polygonal model is exported by PolyWorks as an STL file to Exa's PowerFlow for thorough CFD simulation. PowerFlow transforms the polygonal model into a mesh of *Voxels* to describe the solid surface, and calculates how particles are allowed to move and collide with each other and with the solid surface over a real-time period. A PowerFlow CFD analysis empowered by PolyWorks offers a series of benefits simply not achievable with physical wind tunnel simulations, and gives specialists of the automotive industry unprecedented insight into fluid flow behavior.

Benefits from using PolyWorks to optimize CFD analysis:

- ✓ **Minimizes the time for model preparation, which frees more time to better analyze results**
- ✓ **Provides more information during conceptual design**
- ✓ **Opens the doors to faster product development**
- ✓ **Brings superior quality products to market**
- ✓ **Generates major cost savings**



Model courtesy of Ford Motor Company

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