Delcam plc

PowerSHAPE & Parasolid™

More than the sum of its parts?

A White Paper

Delcam
2009

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The Problem

Computers are used to design, test and manufacture virtually every product we use. From the cars we drive, to the houses we live in, and the appliances with which we fill them. Most products are now so sophisticated that Original Equipment Manufacturers (OEMs) rely upon a supply chain of specialist component suppliers that is often five or six tiers deep. The key communication tool between these supplier tiers is the data file that forms the definition of the part to be supplied. However, designers use many different Computer Aided Design (CAD) systems to originate designs, each with its own proprietary data format. Ideally each supplier in the chain would have each of these CAD systems to accept native data files and the skills to use them effectively – but this is impractical especially for smaller suppliers. It is also the case that many suppliers want to communicate the shape of the components without revealing the intellectual property embodied in the native data file. In practice, many components are communicated to suppliers via files translated into 'neutral' formats, such as IGES [(1)] VDA-FS [(2)] and STEP [(3)]. Such translation is rarely perfect, resulting in errors that require substantial re-modelling in the receiving system.

According to a survey [(4)] conducted by Kubotek, 63% of subcontractors do *not* receive CAD data in their preferred format. The same survey goes on to state that the re-modelling needed to render the CAD data usable can add as much as 20% to overall business costs.

An earlier survey [(5)] on behalf of TenLinks Inc. concluded that while OEMs typically prefer to send data to their suppliers using 'neutral' formats, none of them would accept data back in those formats, insisting instead on receiving files in their own CAD system's native format.

The key requirement is therefore not simply data transfer, but full *interoperability*; data from one system must be immediately re-usable in another.

Over many years PowerSHAPE has been the premier system for manufacturing-focussed companies who need to accept data from many originating systems, often via translation, and modify it quickly, not only to fix translation errors but also to optimise the design for manufacturability, such as adding taper or modifying blend radii.

PowerSHAPE 2010, which incorporates Parasolid®, the industry leading geometric modelling component from Siemens PLM Software, is a major step towards true interoperability with many of the most popular CAD systems. Parasolid is the kernel on which more CAD systems are based than any other. These include IronCAD, SolidWorks, TopSolid, T-Flex, VisiCAD and Siemens PLM Software's own Solid Edge® and NX™ products. Many of the other CAD systems have import/export filters for Parasolid's native XT file format.

As such, these systems can exchange Parasolid XT files without translation and the inherent re-work such translation entails. Parasolid also adds a new level of sophistication to modelling operations such as blend editing and re-blending. Additional high value Parasolid-based editing functionality will be added to future PowerSHAPE releases.

This White Paper discusses how PowerSHAPE and Parasolid work together to deliver major productivity benefits. These include converting neutral format surface data and existing PowerSHAPE models with feature history into valid Parasolid models.

A Brief History of CAD

The first computer systems capable of drawing simple two dimensional (2D) shapes began to appear in the mid 1960s primarily as in-house products developed by the larger aerospace and automotive companies who saw potential productivity gains - especially when modifying or correcting existing drawings. The next level of sophistication came in the early 1970s with the development of three dimensional (3D) systems that aimed to define the exact shape of objects. Given the limitations of computer hardware and the cost of development, these systems tended to focus on narrow areas of design or manufacture that were of particular value to the developing company. At this stage two distinct technologies emerged: surface modelling and solid modelling.

Surface modelling represented the exterior surface of an object such as the aerodynamic surfaces of an aircraft or the aesthetic surfaces of a car using definitions such as Coons Patch [(6)] and Bezier curves [(7)]. Editing techniques allowed precise control of the shape and curvature of the surface which could be combined and intersected to create the shell of complex products such as the fuselage of an aircraft. These were particularly suited to machining complex surfaces, forming sheet metal and performing aerodynamic analysis. However, there was no definition of the substance of the design behind the surface. DUCT, the forebear of PowerSHAPE is a good example of this technology.

The solid modelling approach was based on boundary representation (b-rep) techniques which defined an enclosed volume from which every aspect of a real object could be calculated: volume, surface area, mass, center of gravity, moments of inertia and so on. Topology defined the connections between vertices and edges; edge loops defined faces. Geometry was then attached to add flesh to the bones: curves defined the shape of edges and surfaces defined the shape of faces. The computational requirements of b-rep modellers meant that the first generation systems were restricted to analytic shapes such as combinations of spheres, cylinders, blocks, cones and torii. Romulus, the ancestor of Parasolid, was the first commercial b-rep solid modelling kernel.

The advent of commercial CAD systems came as companies tried to sell their in-house technology to others, often to offset the increasing cost of development. As computer power increased, the capabilities of the different technologies began to overlap to create more general purpose systems. Today, few companies could justify the cost of developing their own CAD system and most commercial systems provide a mix of functionality that covers both surface and solid modelling.

PowerSHAPE is a highly-sophisticated surface modelling systems targeted at those who need to create, import and optimise surfaces for manufacturing, which entails creating a solid modelling representation of the parts. Parasolid is the leading solid modelling kernel used by many of the world's leading CAD systems. PowerSHAPE 2010 combines the respective strengths of these two premier products.

PowerSHAPE

In order to provide a more tailored solution to the needs of customers, Delcam decided to split DUCT into two separate programs, allowing users to choose whether to purchase CAD, CAM or both. For design, DUCT evolved into PowerSHAPE, with the machining parts of the program becoming PowerMILL.

From its inception, PowerSHAPE's development had two key objectives. Firstly, the software must be easy to use, and use standard Windows paradigms for common operations. Secondly, and more importantly, the software must be capable of dealing with poor quality or incomplete data. The majority of PowerSHAPE's users are from the mould and die industries, with their core business being the manufacture of parts. These users, who are typically tier 2 or tier 3 in the supply chain, must be able to take design data from any source and create the tooling necessary to manufacture the part. In most cases, the tooling is considerably more complex than the design data, since it must also include the mating faces of the tool as well as all the mechanical components needed to eject the part after moulding.

By allowing users to rapidly change models using surfaces, PowerSHAPE proved to be an ideal tool for this type of work. In addition, specialist tools were added to locate the most common translation issues and repair them with minimal effort. In this way, PowerSHAPE users could get on with the work they needed as quickly as possible.

Parasolid

Parasolid is a solid modelling kernel designed to provide comprehensive functionality to applications developers of new and established Mechanical CAD (MCAD) applications. It is integrated into an application via calls to its Application Programming Interface (API) which comprises more than 850 functions developed with over 700 man years of expert effort. Parasolid's functionality has been shaped by working closely with the world's most demanding software developers and end-users to satisfy real-world modelling needs. This has led to a wealth of model creation, editing and querying functions, as well as high-level, application-oriented functions packaged to maximise modelling automation. A factor in Parasolid's success is the speed with which it enables developers to add sophisticated solid modelling functionality to applications, freeing them to add value in their specialised field. Over 2.5 million seats of Parasolid-based applications are in use globally and it is estimated that over 40% of all 3D MCAD designs are stored in Parasolid's native XT file format. The Parasolid team place great emphasis on quality and robustness. For example, over 1.25 million automated tests are run daily to monitor quality and performance during the development process.

A Comparison of Different Modelling Methods

Surface modelling in general, and PowerSHAPE in particular, is very tolerant of poor quality data. This often leads to carelessness on the part of designers, which can cause problems later in the production cycle. Solid modellers are considerably more stringent, and have very strict rules that must be adhered to, or modelling operations will fail.

Hybrid modelling systems have attempted to resolve the shortcomings of the two methodologies by effectively combining them. A hybrid modeller will therefore allow users to model parts using either solids or surfaces, or any combination of the two. However, such systems are either surface modellers that create solids from sets of surfaces, or are solid modellers that have had surface tools added. In either case, the tools that were not part of the original design of the kernel will never be as strong as if they had been developed from the outset. A solid modeller that has evolved from a surface modeller will never be as strong in solids as a system that was originally designed as a solid modeller, and vice-versa.

The Challenge

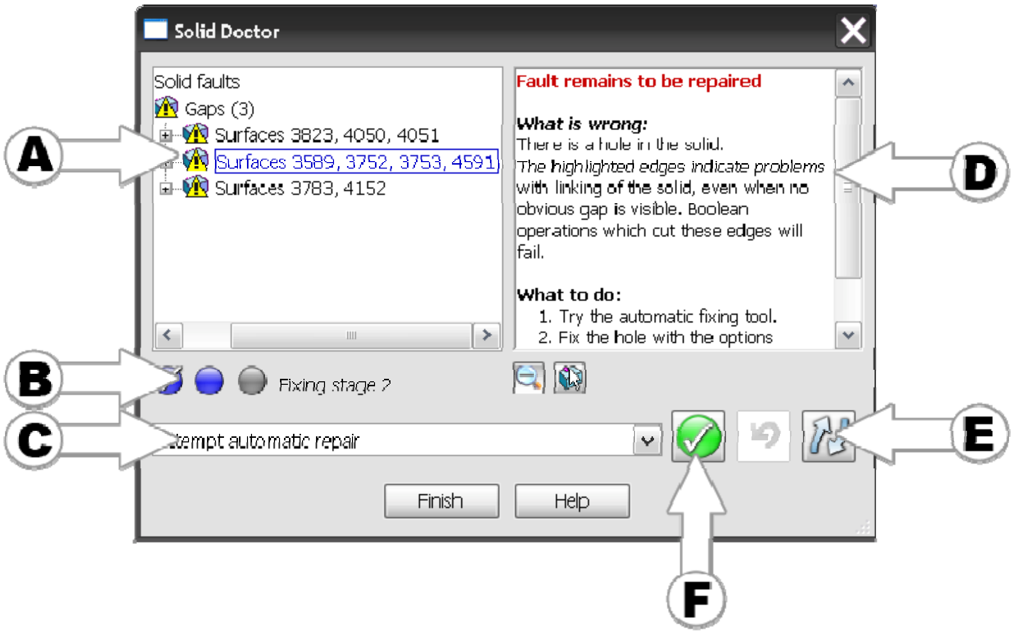
In a surface modelling environment, it is perfectly acceptable for surfaces to overlap, or for there to be gaps where they meet. Boundary representation (b-rep) modellers define a model as a closed volume. This requires a consistent topological structure which defines the relationship between vertices, edges and faces and consistent geometry that defines the curve of edges and the surface of faces to define the exact shape of the model. Together the topology and geometry must define an entirely closed, unambiguous and consistent volume. In order to achieve robust modelling of engineering components, Parasolid works to a precision of 10^{-8} metres (one hundredth of a micron). When importing surfaces, Parasolid has a number of strategies for sewing them together to infer the required topology and geometry. This includes optimising the model for future operations without changing the functional shape of the design. However, when the imported data is of low precision there are often larger inconsistencies in the form of gaps and overlaps of geometry that can be resolved automatically but are sometimes best resolved interactively by a skilled user to ensure that the functional design is not changed.

Delcam chose to integrate Parasolid into PowerSHAPE to strengthen its solid and assembly modelling operations, both of which are fundamental to the design of complex mould tools. Also, the ability to read CAD models in Parasolid's XT file format directly from the most widely used CAD systems eliminates data translation issues in many cases, with immediate productivity benefits. However, Delcam was keenly aware that exisiting PowerSHAPE users would need an efficient upgrade path for models created in the existing kernel. To achieve this, the existing kernel and Parasolid co-exist in PowerSHAPE 2010 and Solid Doctor has been developed to make the transition smooth and efficient. Solid Doctor also provides a powerful methodology for handling data in IGES and other neutral formats, which is expected to be popular for many years to come.

PowerSHAPE's unique Solid Doctor examines a solid model, using Parasolid's own checking mechanisms which report inconsistencies in topology and geometry, divided into separate categories. For each category or class of inconsistency, Solid Doctor recommends the most appropriate course of action, including a possible automatic fix. The automated tools are typically different for each class of inconsistency, as experience has shown that what is effective in one case does not necessarily work for another. As well as the automated tools, Solid Doctor allows the user to extract affected faces or surfaces and repair them in isolation. The user has instant access to all of PowerSHAPE's surface editing tools and can choose to repair the surfaces, for example by changing their trimming, or to replace them. New surfaces can be created quickly and easily using PowerSHAPE's Smart surfacer which automates the process of creating surfaces from wireframe curves. Once the user is happy with the quality of the repaired surfaces, they are automatically incorporated back into the Parasolid model. This process continues until the user has resolved all the inconsistencies and created a valid Parasolid model. By allowing the user total control over how the part is repaired, even very poor quality or badly damaged models can be repaired quickly and efficiently.

The Solid Doctor

PowerSHAPE's Solid Doctor presents the user with a simple form that shows any inconsistencies in the model, as reported by Parasolid's checking mechanism, in a clear, concise manner. The Solid Doctor contains automatic tools to repair the most common inconsistencies, but also assists the user by recommending manual fixing methods should the automatic method not give the desired result.



A – Categorized list of consistency issues, displayed as an easy-to-read 'tree', clearly showing which surfaces need further attention. Issues are also highlighted graphically on the model and can be selected either from the tree or in the graphics window. The user may select issues individually, by category, or by normal Windows-style multiple selection (using Ctrl and Shift modifiers).

B – Parasolid's checking mechanism classifies issues by their severity, and this checking is carried out in three stages. Issues found at stage 1 are the most severe, but are typically repaired automatically. PowerSHAPE shows the current checking stage, giving the user a clear indication of the state of the model and how much further work is necessary.

C – Solid Doctor provides a dynamic pull-down list that allows the user to quickly select their preferred fixing method for the selected issue(s).

D – For the selected issues(s) Solid Doctor gives clear instructions for the recommended fixing method.

E – The ‘Re-check’ button checks the model again and refreshes the list of issues. This is typically used after several issues have been repaired.

F – Clicking the ‘Process’ icon runs the fixing method chosen at step C on the selected issue(s).

Case Study Using Customer Data

This case study or benchmark test will show the way in which PowerSHAPE creates a valid Parasolid model from an imperfect model imported using IGES. The resultant Parasolid model can be saved in XT file format and read directly into *any* CAD system that uses Parasolid as its kernel and many others that have XT import/export filters, with 100% reliability. The same starting file was also read into a leading Parasolid-based CAD system (System Z) to provide a direct comparison. All comparative timings for each stage of the process were made on the same hardware, a DELL Precision M4300 laptop with 3GB RAM and Intel Dual Core processor.

Time Savings

The initial model has 1,532 surfaces and is a moulded plastic cover for an automotive radiator.

Action	PowerSHAPE	System Z	Comments
Import IGES file	22s	128s	System Z converted the surfaces to solid on import. No secondary process is necessary.
Convert to solid	67s	N/A	PowerSHAPE auto-fixes typical faults as it creates the solid.
Diagnose Faults	5s	11s	PowerSHAPE reported 9 consistency issues that required attention. System Z reported 706 surface issues and 3 gaps.
Automatic Repair	12s	235s	At this stage, 2 consistency issues remain that must be repaired manually in both systems.
Total Time	**106s**	**374s**	

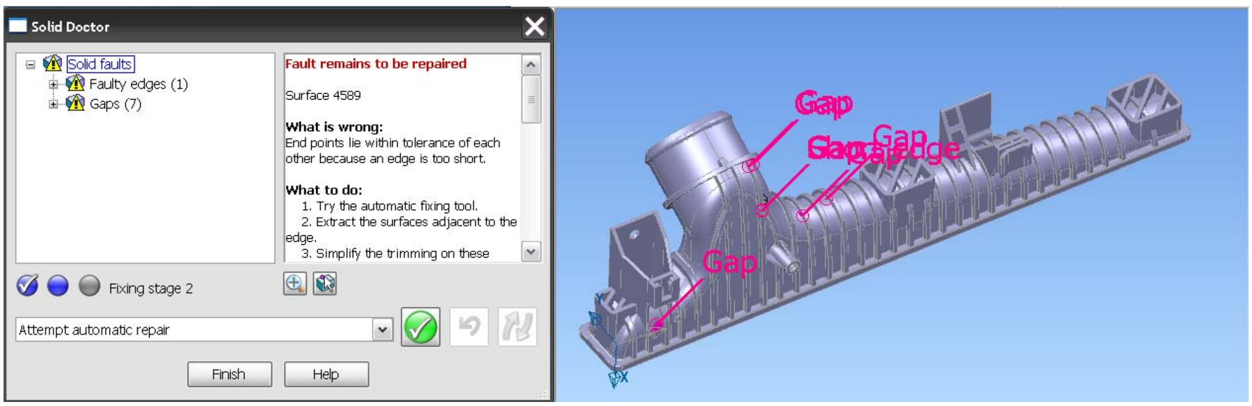
IMPORTANT NOTE:

The remaining two consistency issues needed to be repaired by the user, using whatever tools the software provides. Because the remaining issues in this example are both *surface* problems, they require a strong surface modelling solution for their repair. The Solid Doctor allows the user to access *all* of PowerSHAPE’s surface modelling tools during the repair, including the unique Trim Region Editor that allows surfaces to be re-trimmed interactively.

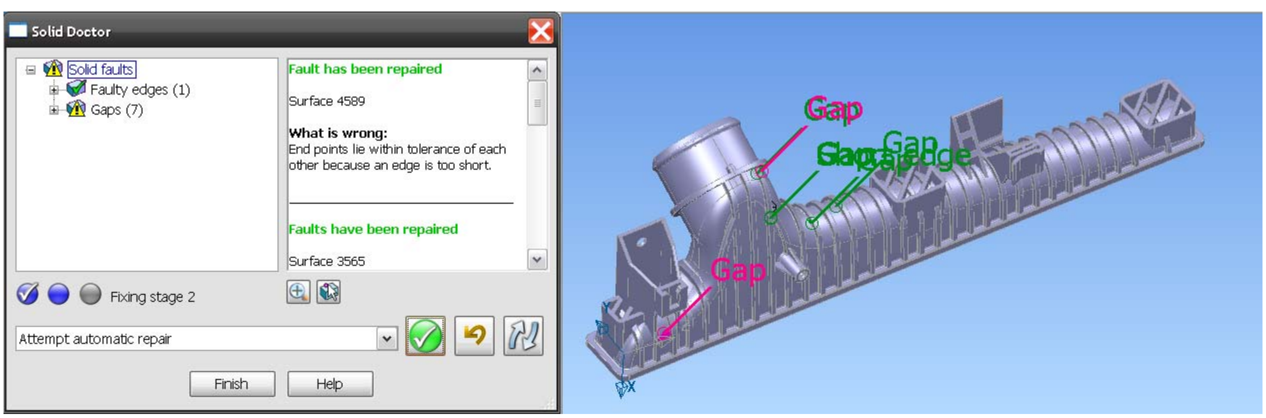
In this particular example, each of the remaining issues could be corrected in less than 30s using PowerSHAPE. This gives a total *maximum* time of less than 4 minutes to create a valid

Parasolid model, compared with a time of over 6 minutes using System Z to achieve an unfinished part, a time saving of more than 40%. While a time saving of less than 2 minutes may appear insignificant, it should be remembered that this is a simple model, containing only 1,500 faces. A typical mould tool can contain in excess of 10,000. A reduction of 40% in the time taken to repair such a model so that it can be returned to the originator represents a substantial cost saving. It should also be remembered that during the life-cycle of a single part there can be several revisions, each of which may require the same amount of re-working on both import and export. The cumulative cost saving for a large and complex project will therefore be considerable.

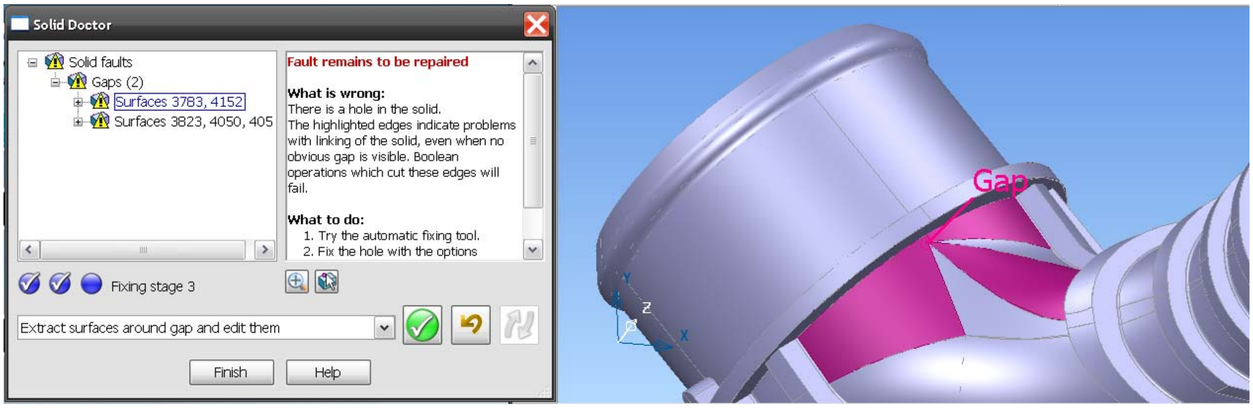
PowerSHAPE Solid Doctor Workflow



Solid Doctor checks the solid for consistency issues and displays them in an easy to understand tree, and also marks their locations graphically on the model. Issues are divided into separate categories, each of which has an automatic fix and a recommended alternative strategy. The user can select individual issues either from the tree or graphically on-screen. This allows the user to tackle issues in whichever order, and by whatever method, they feel most appropriate.

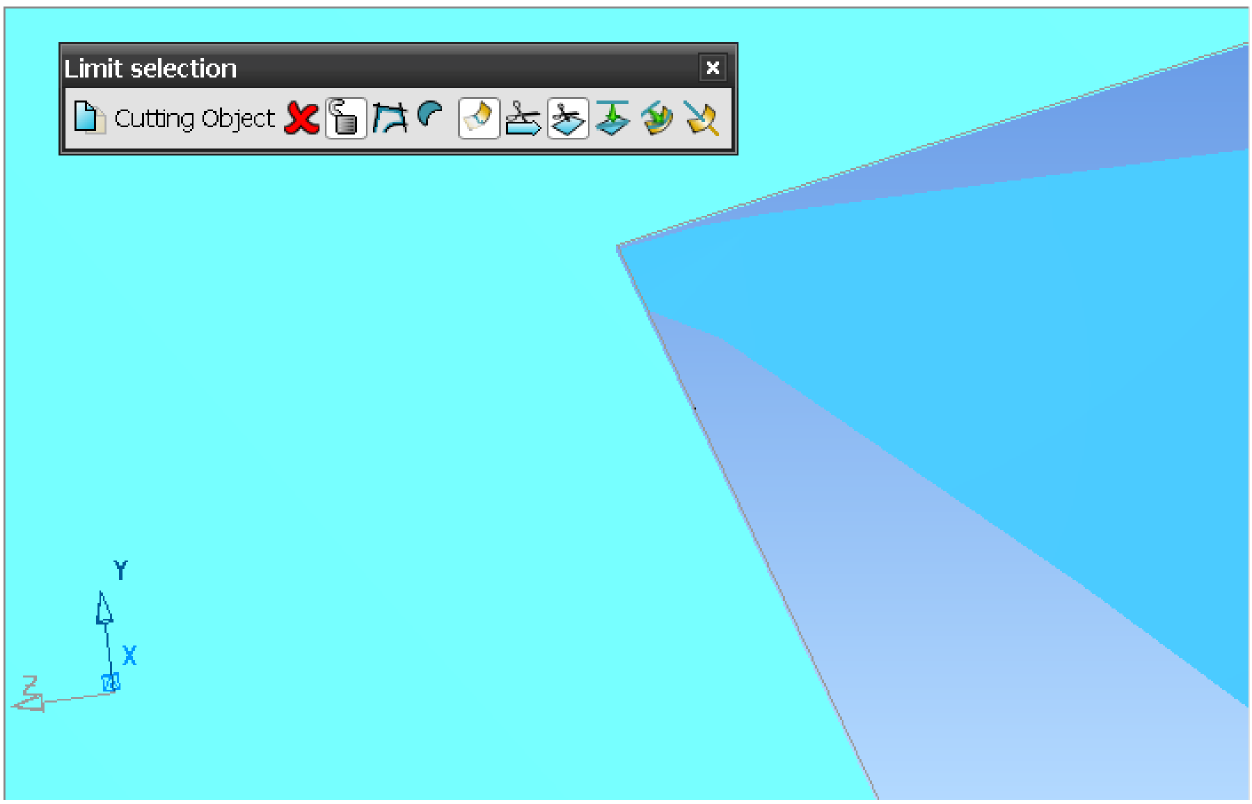


After automatic repair, issues that have been attended to are clearly highlighted, both in the graphics window and the tree, for ease of identification.

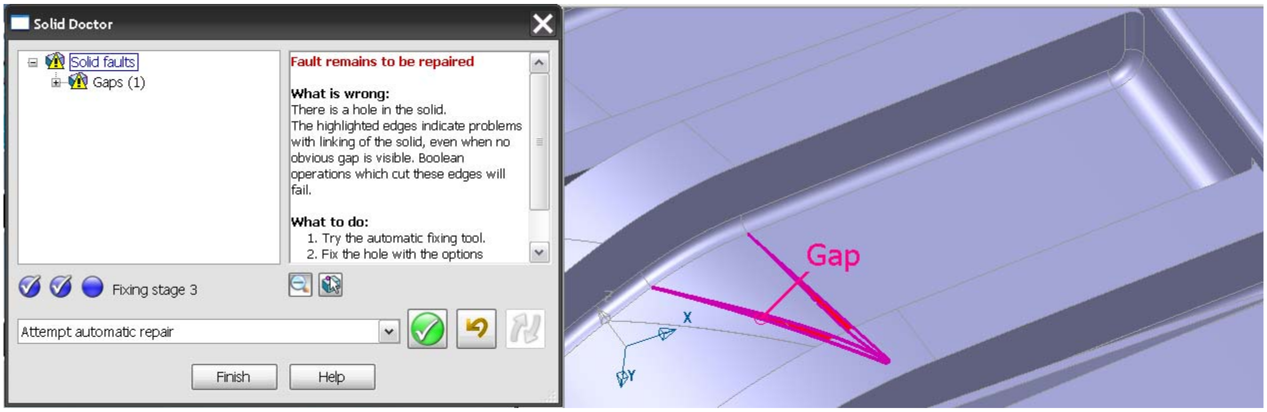


The surfaces that form the region requiring attention are extracted from the solid, and edited manually.

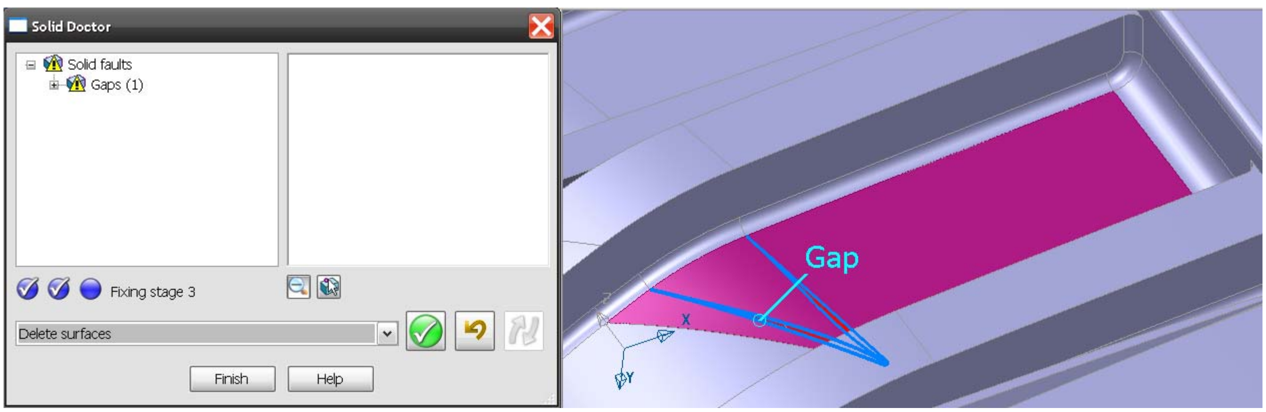
In this example, the surface on the right has not been correctly trimmed, and there is an overlapping region.



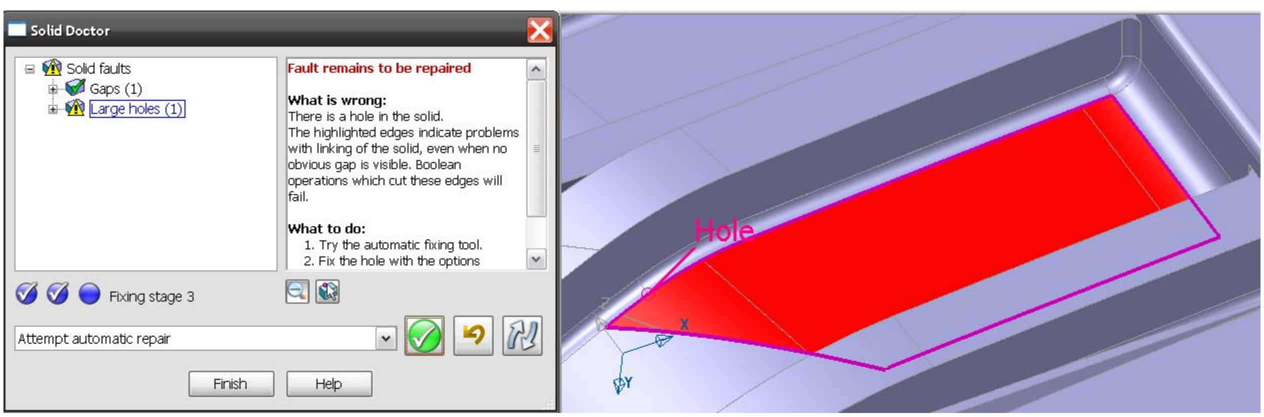
This inconsistency is repaired by re-trimming the overlapping surface to its neighbour. The two surfaces are ‘sewn’ back into the Parasolid model.



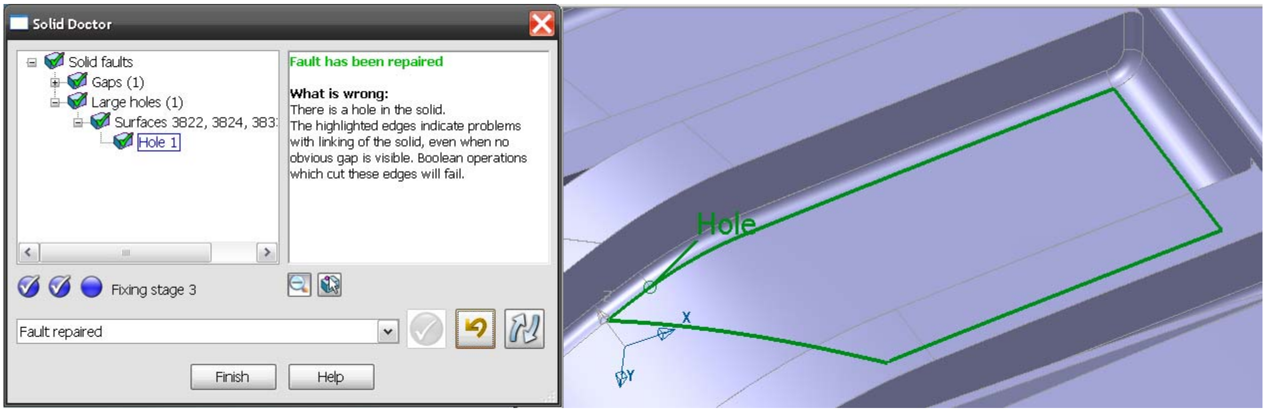
The final inconsistency is caused by a degenerate surface (possibly as a result of a translation error).



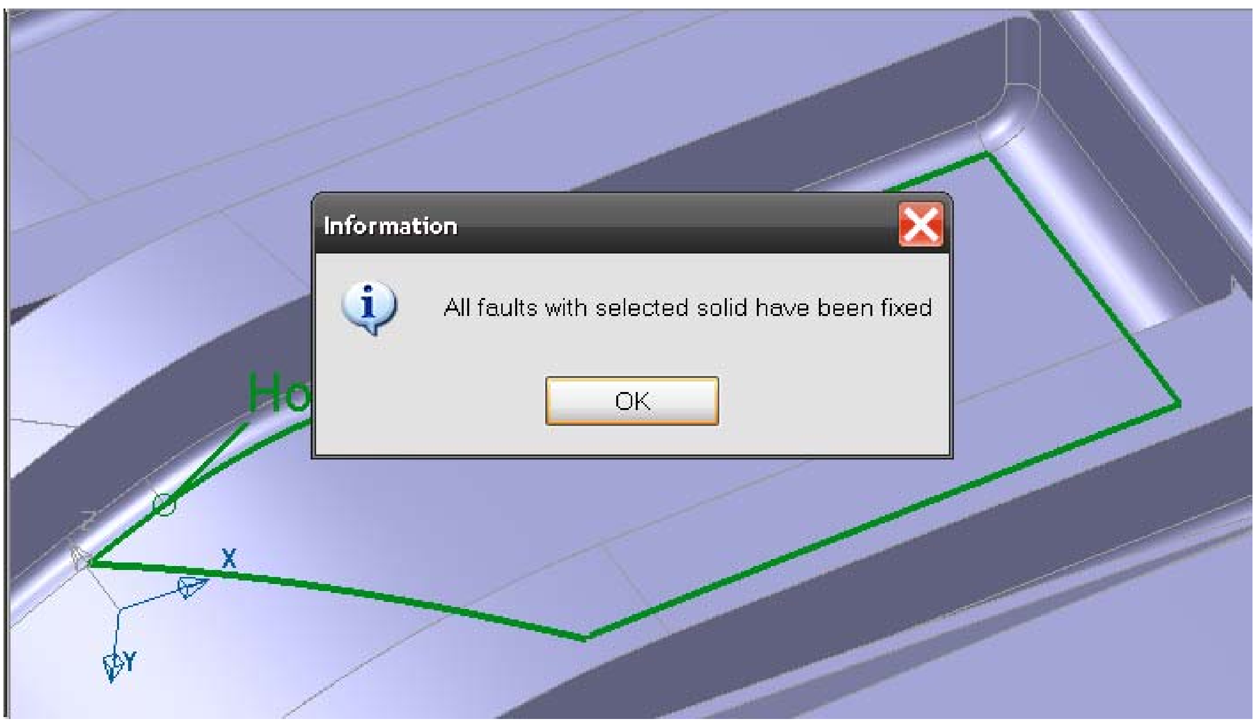
The user selects the inconsistent surface and its neighbours.



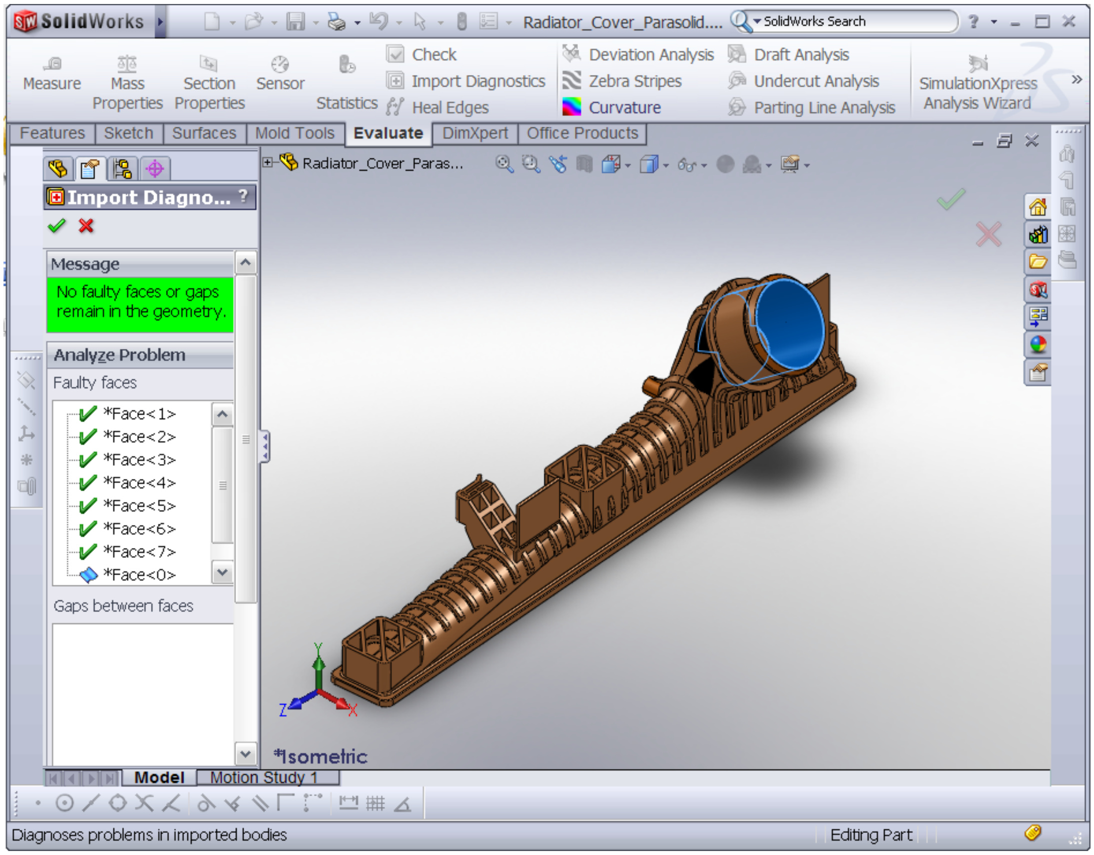
The surfaces are deleted from the solid, leaving a large hole.



The hole is filled with a trimmed NURB patch, giving a smooth result.



The solid model is then re-checked, and found to be valid.



As a final test, the model was saved in Parasolid's XT file format and then imported into SolidWorks. SolidWorks' own 'Import Diagnostics' checking reported it was a valid model and further work on the design could continue immediately.

Application

As has already been discussed in this paper, reliable transmission of design data is crucial to any organization that is part of a supply chain. If the individual links in the chain do not use the same CAD system, data translation issues can cause significant bottlenecks, leading to lost production time and significantly increased costs. Although it might appear that the ideal situation would be for every organization to use the same software, this is impractical for many reasons. Different users have different needs and requirements, and no single CAD system can fulfil them all. Further, suppliers would need to purchase many different CAD systems and learn to use them all effectively, to do business with several OEMs who did not all use the same design software. This would not be commercially viable.

PowerSHAPE, with its unique Solid Doctor, neatly bridges the gap, by providing a cost-effective solution to the demanding needs of any organization that requires the ability to reliably read CAD data from any source. PowerSHAPE's unique surface modelling tools, in conjunction with Solid Doctor, allow users to rapidly repair even significantly damaged models.

PowerSHAPE, alongside Delcam Exchange, can read native CAD data directly from all major CAD systems and now Parasolid XT files from:-

• AutoCAD • CATIA • Computervision • Cimatron (IT & Elite)	• IDEAS • Inventor • Pro-Engineer • Rhino	• SolidEdge • SolidWorks • Unigraphics NX

In addition, PowerSHAPE and Delcam Exchange can read and write data files in all 'neutral' formats, such as IGES, VDAFS, and STEP.

Thus, PowerSHAPE provides a complete data transfer and repair solution, enabling fast and reliable conversion from any CAD source to perfect Parasolid file, leading to reduced time to market and significantly lower production costs.

References & Further Reading

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