Dimensionless design: thinking outside CAD

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According to design consultancy PDD it is now possible to use traditional concept modelling techniques from outside the CAD world and still benefit from using modern technology

Received wisdom today has it that at the heart of every design to manufacture process is a fully defined mathematical database in the guise of a CAD model. Initial concepts - even those sketched out on the back of an envelope - are committed to CAD at an early stage, and from then on the central CAD model becomes the reference point for everything from rapid prototyping to final manufacture. But what if the product being designed does not naturally lend itself to a rigidly defined CAD model? Surely it must be possible to use traditional concept modelling techniques from outside the CAD world and yet still take advantage of modern technology? PDD certainly thinks so and for aspects of some design projects has even begun sidelining conventional CAD altogether.

Like most design consultancies, PDD has embraced the massive advances in design and engineering technology that have taken place over the past decade or so. An early adopter of 3D design software, PDD now uses solid modelling in its design projects as a matter of course. Indeed, one of the first steps in any design project is the move from concept to CAD. Here the designer can use the geometric modelling tools at his disposal to refine and perfect the design in virtual space before using the same geometry to generate a physical model for proof of concept. Once in physical form, the model is really put through its paces, material can be added or removed in an effort to perfect the design and - in theory at least - the resultant form can be recreated in the CAD environment for further refinement and eventual manufacture.

The weakest link

As Ben May, Head of the Development Centre at PDD, explained, however, there is a fundamental difficulty with this iterative design loop that introduces inherent inefficiency: "The weak link in the chain is feeding the design data from the modified model back into the CAD system. Unfortunately, this is fundamental: there's no point using CAD data as the basis for manufacturing if the data doesn't truly reflect the geometry that has been carefully honed through physical modelling and test."

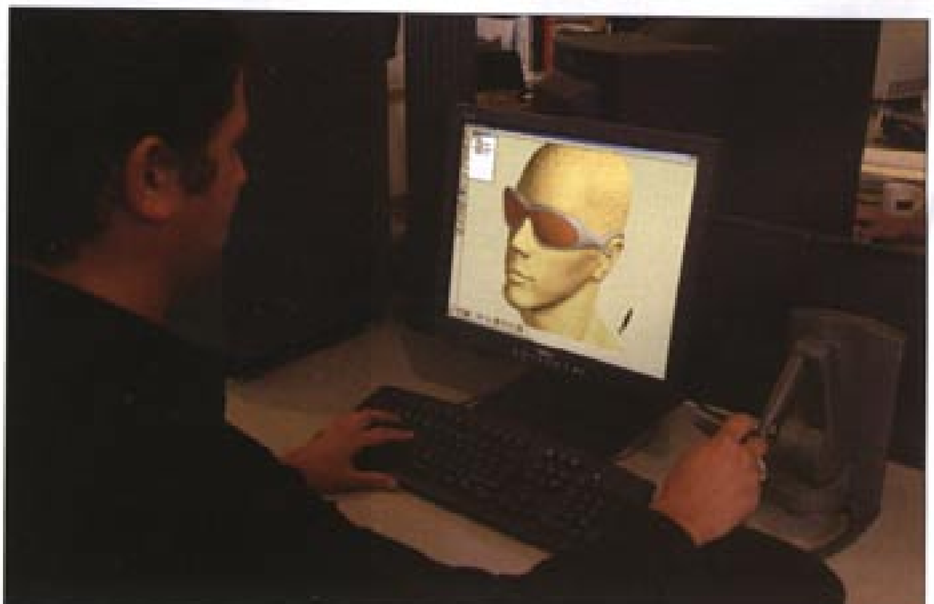
Until recently, the loop was closed at PDD by direct modification to the CAD model either though subjective tweaking or via metrology: accurately capturing individual points from the model using a CMM (co-ordinate measuring machine)probe. For designs based on relatively simple geometry these approaches are fine, but they do not offer a way of truly recreating the kind of freeform organic designs that characterise much of PDD's creative output. Direct CAD modification can only ever yield an approximation of the changes that were made to the prototype, and CMMmetrology only adds low-resolution point-cloud data that is fine for verifying the location of individual points - and therefore ideal for making sure a fixing feature is in the right place, for instance - but impractical for capturing every nuance a surface may contain.

"Things have moved on somewhat in the past couple of years," says PDD CAD Manager Philip Shade, "since we have invested in laser scanning technology that improves our data capture capability. But there are still fundamental difficulties with a system that relies on a fully parameterised CAD database when the designs we're creating do not necessarily fit in with that way of working."

Look and feel

PDD believes it is as close as it can get with currently available technology to eliminating the problems associated with making the transition from tactile model to CAD representation. As well as a 3D laser scanner for capturing more accurate surface data, its design studio also boasts SensAble FreeForm that uses haptic technology as a means of interfacing with the software. This not only means PDD's designers can get closer to the ideal of sculpting freely in virtual space, it also offers a convenient bridge between physical and digital models.

The FreeForm Concept solution is a touch-enabled system that gives designers a quick, easy way to develop realistic 3D conceptual designs. By creating a robust linkage between conceptualization and engineering it accelerates the transition from sketches to model, thereby shortening the product development cycle. The system output includes photorealistic renderings, files for rapid prototyping,



PDD's design studio uses SensAble FreeForm, a touch-enabled system that gives designers a quick, easy way to develop realistic conceptual designs in 3D

and selected 3D formats for downstream processes.

Shade adds: "By using the laser scanner and its associated software to digitally capture the changes to the form of a model, PDD can rapidly decimate and refine this data before reading it back into the CAD system to use as a template for modifying the original parametric geometry. This means we can reflect changes made to the physical model far more faithfully and accurately than we could before."

So far so good: the iterative loop from CAD to model to laser scanned point cloud and then back to CAD is efficient in its way but it still inevitably relies on some level of compromise when it comes to representing freely modelled surfaces in terms of a discrete set of geometrical modelling operations, however sophisticated they may be. But in some cases the advantages you may get through having a fully defined CAD representation are outweighed by the imperative to be faithful to the physical model.

Getting a head

The issue came to a head (as it were) during a project PDD undertook to design and prototype a limited number of custom-fit inners for motorcycle crash helmets. Armed with scan data for a number of individuals' heads, the external geometry of a helmet and a further scan to show how a correctly fitted helmet sits on the head, PDD was able to construct a series of surfaces in virtual space that matched both the internal surface of the helmet and the shape of the head inside. Both these were essential if the helmet lining was going to fit and function properly but while the external surface of the lining could be created using standard CAD techniques, the same could certainly not be said of the inside.

"The helmet project really brought home to us the importance of being able to work with a combination of freeform and parametric geometry," said May. "Certain design features, and of course the fact that the linings had to fit tightly inside the helmets, relied upon the kind of fully constrained geometry that CAD is so good at; but the whole concept of custom-fit helmets would have been compromised if we felt we had to have the same level of geometric control of the interior. There are some situations when parametric CAD geometry is simply not appropriate."

The helmet project was a huge success and encouraged PDD to push the boundaries of 'dimensionless design' by completing a major design project without recourse to conventional CAD at all. "We were commissioned to design a new pair of scissors for Acme United Corporation, a long-standing client of ours," explains Graham Lacy, Development Director at PDD. "Since this was a product whose success would depend on the human interaction we wanted our designers to concentrate on perfecting the form of handles and grips form without having to feel constrained by conventional CAD-based rules."

The first attempt at the design of these scissors was based on an extrapolation of a detailed 2D concept sketch and incorporated a photographic detail from an existing pair of scissors to ensure the hinge mechanism would be in line with the client's other products

A cut above

Going straight in at the deep end, PDD used its haptic device to sculpt an initial shape in virtual space. This first stab at the design was based on an extrapolation of a detailed 2D concept sketch, a throwback to the days when initial concepts were carved out of foam blocks with sketches pasted onto them. PDD also incorporated a photographic detail from an existing pair of scissors to ensure the hinge mechanism would be in line with Acme's other products. The SensAble geometry was then taken directly to PDD's CNC machine to produce a foam model for physical testing. This initiated a series of iterative loops during which the model was ergonomically tested and hand modified, rescanned and cleaned up in the SensAble environment and then recreated as a prototype foam model - without once being constrained in CAD space.

"The speed of both the scanning and the CNC machines means we can get through iterative design loops much faster," said May. "This would be impossible if we had to spend time translating the changes we make with a scalpel and some plasticine into the language of CAD. So not only did we end up with a design that was not compromised creatively, we were able to perform more iterations getting it just right."

"In the case of Acme we took this to a natural conclusion by briefing the toolmaker with visuals and physical prototypes rather than a CAD database - many toolmakers are now accepting STL (stereo lithography) or even visual data as an input," explained Lacy. "We certainly wouldn't do that every time - you need a toolmaker relationship you can rely on - but it shows how far you can go with dimensionless design."

A winning combination

PDD is certainly not advocating dimensionless design for every project, but it does see a future for it in sculptural or amorphous design-rich areas such as brand characterisation, anatomical interfaces, ergonomic or body-worn products and toy design. The main advantages are a freedom from the shackles of parametric modelling and an associated faithfulness to the integrity of a physical prototype.

"A fully defined CAD model is great if your priority is being able to communicate with your toolmaker in China," says Lacy, "but you then have all the parametric baggage associated with trying to create an organic shape using geometry. Dimensionless design combines the advantages of traditional tooling methods with the integrity of CAD, but for the first time with speed, control and ease of communication."

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