3D scanning of artistically-derived GFRP tooling for the production of parametric manufacturing drawings of tub shower products

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Introduction

Computer aided design (CAD) models are an integral part of modern engineering practices. The use of 3D models for design have enormous impact in the reduction of uncertainty associated with component sizes, interference, assembly and other logistical aspects. Hence, there is a tendency for modern engineering firms to use 3D modeling as a core part of their workflow, in order to reduce uncertainty, costly errors and increase productivity and repeatability. However, there are limitations associated with incorporating CAD into the design and manufacturing stages for some engineered products.

Tub shower stalls (example shown in Figure 1) are increasingly common commodity products, with many major manufacturers producing $300 million per year in the North American market alone. In many ways, manufacturers describe these products as part of "art", in that the methods to produce tooling for the product shape are done by hand and under discretion of technicians. With this lack of design and drawing control, products are subject to variability, inconsistency and costly reworks when the loosely specified structures need to be reworked as per a customer's orders.

Figure 1: Example tub shower stall

The highly compound-curved nature of these products makes them difficult to originally model and design, hence the current use of technician artistry. In this industrial project, a procedure has been developed to reverse engineer artist-derived tub shower products, which can be imported into a 3D CAD environment using novel 3D scanning technology. The workflow developed is shown in Figure 2.

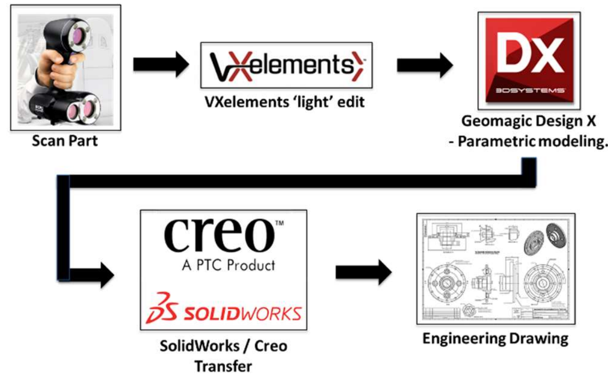

Figure 2: Workflow employed to import 3D CAD models of complex tub shower geometry

In addition to the logistical work associated with the workflow development, scientific work was completed on how to best capture the tub shower parts using 3D scanning, by analyzing the residuals in the 3D positioning data of the scan, which describes the error and uncertainty in the system [1,2].

Test Procedure

A full-scale (1.5m x 2.5m x 1m) glass-fibre reinforced polymer (GFRP) tooling was borrowed from an industrial partner, prefacing a full scale-up effort and integrating this process into standard company practices. An example of the tooling is shown in Figure 3, where the tool also has positioning dots placed on it, for point cloud mapping of the surface.

Figure 3: GFRP tooling initially scanned

In order to help reduce the errors associated with scanning such a large and featureless object, surface treatment and analysis of the scanning software Jacobian matrix for quantifying residuals was necessary. For the former, Figure 4 shows different materials applied to the GFRP tooling.

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Figure 4: Application of wax, developer paint, flour and other materials to the GFRP surface.

In choosing the final surface condition (polished GFRP with semi-transparent thin-film Nylon sheet overlaid), the residuals of scans were observed and minimized. The residuals are normally calculated using the Jacobian matrix shown in Equation 1, where the process parameters such as x_1 (intensity of the reflected light at the centre of the scan beam), x_2 (the integer value of the normal distribution scan mean), x_3 (the standard deviation of the reflected light intensity along the length of the scan beams), x_4 (intensity of the background noise/light) and t (the length of the scan beam) [3] can be experimentally and parametrically determined via a robust DOE approach (e.g., Taguchi method [4]), in order to minimize that error for this challenging application.

$$J(\mathbf{x}) = \begin{bmatrix} -e^{\left(\frac{-(t-x_2)^2}{2{x_3}^2}\right)} \\ -x_1 \dfrac{t-x_2}{{x_3}^2} \cdot e^{\left(\frac{-(t-x_2)^2}{2{x_3}^2}\right)} \\ -x_1 \dfrac{(t-x_2)^2}{{x_3}^3} \cdot e^{\left(\frac{-(t-x_2)^2}{2{x_3}^2}\right)} \\ -1 \end{bmatrix} \qquad \text{Eq. 1}$$

This approach was taken to maximise the overall accuracy of the process, needed to scan and parametrically define the surfaces of these products. Figure 5 shows the in-situ scanning of a GFRP mould using a handheld Creaform VIEWscan point-cloud portable scanning unit. By using standard positioning dots, in addition to the treated surface, the tracking software that constructs the 3D space for the point cloud, was more accurately able to do so and in turn reduce errors and time-intensive rework to fix such scan errors.

Figure 5: GFRP surface being scanned in-situ.

The 3D point cloud was post-processed in VXelements software and imported to DesignX to be made into a parametric model, before being transferred into CREO 3.0 via DesignX's Live Transfer function. The relative conformance between the scanned model and parametric model was observed, as shown in Figure 6, where the red and blue sections of the 3D model indicate regions that deviate beyond 0.25-inches.

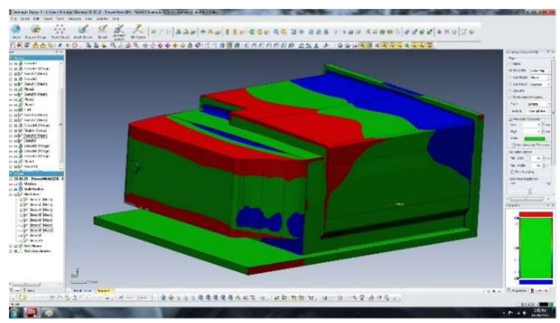

Figure 6: Error analysis between 3D point cloud and parametrically generated surfaces

Results

The procedures generated were successful in addressing the industrial partner's needs. The experiment was scaled up and a total of 90 tools are to be scanned, turned into parametric 3D models and transposed into manufacturing drawings. These will then be used for the more effective and controlled manufacturing of future GFRP tub shower products.

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