Conference Paper

Shape Optimisation of a Snowboard Binding Highback. A Case Study of Generative Design Process Comparison

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Abstract

FEA software is traditionally expensive to purchase, takes a high level of technical skill and understanding and requires users to dedicate years to develop specialist skills. With the increasing popularity of more user-friendly, elementary software packages such as Fusion360, more cost effective and efficient processes can be developed and harnessed, especially by SME's and designers that don't have the ability to purchase expensive software packages. One particular FEA element that has recently begun transitioning from highly specialised to more readily available is 'generative design' and 'shape optimisation.' Shape optimisation has only been able to be utilised by large corporations with large research and development budgets. This case study looks at exploring and optimising the methods involved in generative design for product development and it's aimed at facilitating practises for small to medium enterprises (SME's).

The work described in this paper presents a study using a snowboard binding highback component which was reverse engineered using 3D scanning. A blank model, free of any discerning features was created from the scan and then used as the platform for the generative design phase. This process was completed using easily accessible software (Fusion 360) as well as high-end professional software (Ansys 16). A comparison between the two workflows analyses the resultant model outcomes and outlines efficiencies regarding processing time, technical skill, and latent difficulties of the entry-level process for generative design of the snowboarding high back.

This paper aims to demonstrate and describe an optimisation model for generative design and shape optimisation during entry-level product development.

Keywords: Generative design, Rapid Prototyping, Shape Optimisation, Snowboarding

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1 Introduction

This study looks at a generative design process that uses 3D scanning to capture an existing model to work from. The methods studied reflect that of an industry standard reverse engineering procedure (Otto and Wood, 1998).

Conventionally, every step of this process has involved very expensive tools (both software and hardware) that require a great amount of skill to use effectively. This includes expensive specialist 3D scanners and software packages. Generative FEA tools especially, have been operated by users that have made a career from this particular skillset. Due to the expensive and restrictive entry point to generative design, these tools have often been out of reach for small medium enterprises or start-up companies.

Recently (in the last 3 years), new simplified tools, such as mobile scanning apps (for smartphones) and simplified CAD packages (Autodesk Fusion360) have become available on the market. The industry is seeing a shift, with more small and medium enterprises having access to tools that were out of reach (in terms of cost and expertise required) in the past (Collins, Leen and Gibson, 2016). The methods explored in this research will compare new entry level tools and processes with traditional professional tools. The research will aim to demonstrate the usability of these new tools by measuring and comparing a set of comparable metrics in the time and cost involved in preparing. Software that was chosen for the study was selected as they are industry standard tools popular and well-known globally.

The findings of this research will help SME's to integrate and develop reverse engineering and shape generation techniques into their current product development processes. The research will be able to assist and guide designers in their development of work flows, giving them better insights into where resources should be allocated, whether through software purchasing or skills training in specific aspects of scanning, CAD modelling or shape generation.

The comparison between entry level and professional software will be performed by means of a case study. A snowboard binding high-back will be scanned and defeatured to create a blank model. Afterwards shape generation will be performed with the aims of minimising weight of the component while maintaining stiffness. At each stage accuracy, time taken and tool costs will be measured.

As 'generative design' is further refined and becomes more accessible to a larger variety of designers, both experienced and novice, it is important that these tools and processes are studied. Developing processes that are efficient and can easily be translated across a wide variety of fields will result in faster, cheaper outputs (products) that can be achieved with a much shallower technical understanding that is currently required.

Hence, the work contained in this paper aims to explore and optimise the methods involved in rapid shape and topology optimisation (otherwise known as 'generative design') in a single component design, using a particular piece of snowboarding equipment (a binding highback), as the working example. Specifically, the study will detail and analyse the design process in comparison between:

- Commercially available professional level software
- Entry level or freely available software

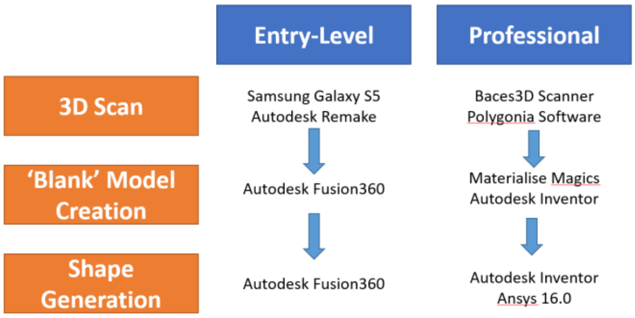

Figure 1: Indented Process flow* (Note: Inventor Shape generator was used in place of Fusion 360 in Shape Generation step).

2 Case Study: Parallel Generative design of a Snowboard Binding Highback

2.1 Background

Snowboarding is a sport that involves sliding down a hill on a board. A typical equipment setup commonly involves a snowboard, bindings and a pair of snowboard boots. At the elite end of the sport, there are many different styles and categories of riding (snowboarding), all utilising equipment with slight variances in performance properties (Loland, 2007)

Boards, bindings and boots are designed with varying stiffnesses. Commonly a manufacturer will specify a stiffness rating for a particular piece of equipment, generally on a sliding scale of 1 to 10 (10 been the stiffest) (Lib Tech, 2016). A brief overview is shown below, of different riding styles and the equipment properties desired for the respective style of riding.

- Big Mountain/Freeride: Hard and stiff boards, bindings and boots to allow for fast responsive turns and stability at high speeds.
- Racing/SnowboardCross (Olympic Sport): Hard and stiff boards, bindings and boots to allow for fast responsive turns and stability at high speeds.
- Freestyle/Slopetyle (Larger jumps and Big Air): Moderately stiff equipment to give stability during the landing of large jumps. However, some flex is still required to manipulate the board during aerial tricks/manoeuvres and while sliding on handrails and boxes.
- Freestyle Jibbing (define) /Rails: Very soft equipment generally preferred for maximum manipulation of the board. Soft boots and bindings are preferred to give a very soft feel and flex, allowing a snowboarder a more delayed edge response.

This study details the process involved in design and manufacturing of a specific component of the binding equipment, known as the highback. The highback is the rear part of the snowboard binding that acts as a lever when the rider turns, transferring the riders movements to the board. The component was chosen because it has the most influence on board manipulation, flexing as the rider transfers body weight.

(Trusnow.com, 2016)

The highback will be developed in parallel through the use of two different methods. The results and outcomes of each stage of the process will be analysed and compared in terms of cost, time taken, technical skills required and cost involved in equipment purchase and software licensing.

2.2 Methodology

The methodology used in this study involved three main steps as can be seen in figure 1. First, an existing market available Union Force SL (Evo.com, 2016) binding was dissembled. Reverse engineering was employed in an attempt to produce a virtual replica of the high back in the form of a 3D scanned model. The 3D scan was then manipulated and transformed into a working blank high back model, with all prominent features and contours removed. This model has been cleaned up to a generic shape that represents the design envelope of a large proportion of commercially available highbacks on the market. Using FEA and shape generation technology, the blank model was then optimised to achieve an optimal stiffness with minimal material and weight.

2.2.1 3D Scan of existing Highback Model

Entry Level Scan

A Samsung Galaxy S5 (Samsung AU, 2016) was used to capture a photo reel of images for processing by the software, Autodesk Remake. This type of 3D scanning is known as photometric scanning. In the case of Autodesk Remake the software processes the collection of images, using common data points to process and build a virtual 3D model (Autodesk ReMake, 2016).

An acceptable scan result was achieved through a process of 6 trial and error attempts. For the first scan, no preparation was performed before the photos were processed. The chosen binding highback had a black gloss finish, which made a difficult

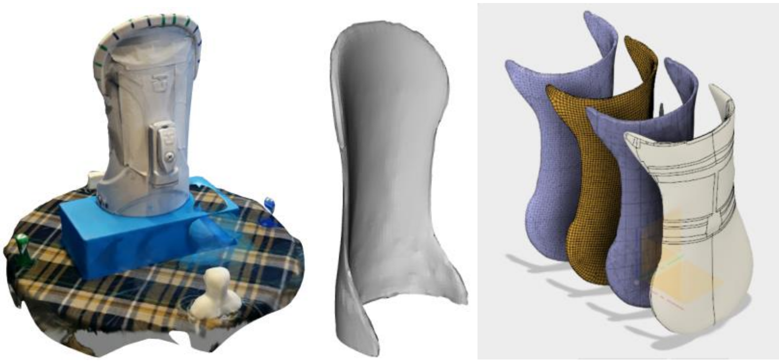

Figure 2: a) Raw Remake Scan Data, b) cleaned scan, c) 3D scan to solid body workflow.

scanning subject. To get an acceptable scan, a white chalking spray, Dy-Mark Flawcheck (Dy-mark International, 2016), was applied to the model.

The scan also included jagged edges around the holes as can be seen below. These holes were undesirable in the creation of the blank model as it would require further post-processing to fill in and correct. Matt textured masking tape was applied to cover over these holes. Other small holes and gaps were filled with putty.

Following scans were still showing an amount of distortion that was not true to the original model. To resolve this the following steps were taken:

- The lighting was modified so a soft diffused light source, in the form of an overhead fluorescent tube light. This light eliminated any sharp shadows that may have been causing distortions (Gupta et al., 2011)
- A patterned material, as seen in Figure 2a, was laid on the scanning table. This aided in the creation of more recognisable common data points.

Matte textured, multiple coloured locate items were placed around the model. Lines and dots of different colours were added to curved contours (Figure 2a). Again, these steps were performed to aid in the creation of more common data points.

2.3 Professional 3D Scan

A Kreon Bases 3D Laser scanner (Kreon Technologies, 2016) was used to scan the professional-level model. The laser scanner creates a virtual 'point cloud' of the model, which can then be processed into a series of faces to create a 3D CAD model. Difficulties were encountered in scanning the black gloss surface of the model. Chalking spray and tape was used to prepare the highback for scanning due to the gloss surface finish of the product, this was done for both professional and entry-level methods.

A considerable amount of training and practice was required to be able to perfect the smooth steady passes required to produce a quality point cloud with minimal noise. Internal curve geometries and the undersides of the model were very difficult to scan without bumping the model or moving its position. Many attempts had to be aborted due to the scanner operator bumping the scan table. Even the slightest movement would cause the point cloud to be undesirably offset, rendering the data useless.The end result was a model that had a very rough triangulation and required considerable post processing to clean.

2.3.1 Creating a Blank Highback Model

Entry Level Software

Primary model processing involved cleaning away unwanted scan data, the filling of small holes and gaps in the model as well as STL smoothing operations in Autodesk Remake. required focusing on small areas (around 10 mm diameter circular areas) to identify any peaks and troughs that needed smoothing by comparing to the physical model. Inbuilt Remake error checking was successfully used to detect and correct any floating particles, gaps or triangle intersections/overlaps.

Secondary processing was performed using Autodesk Fusion360. Initially an attempt was made at wrapping and pulling a surface around the STL exported directly from Remake. However, due to the complex curve geometry of the model, this resulted in many pinch-points at the top and bottom of the geometry, which could not be corrected by the normal means of vertices welding. A normal vertice weld at these locations would break the guide curves of the model, resulting in model collapse.

An alternative method was engaged which evolved creating a mesh directly from the Remake model. Through series of trials, it was found that exporting the model as a texture-less OBJquad model at 8000 quads was the highest resolution model that was able to be exported to Fusion360. The OBJquad could then be inserted and converted to a mesh body. This newly formed mesh was then converted to a T-spline body and then a BRep face model, with a final conversion to a solid body. Lastly, two holes were added where the high back is fastened to the binding baseplate, and a boss feature was added to the back to act as the rear support.

Professional Software

Primary processing was conducted using the scanners proprietary software, Polygonia (Kreon Technologies, 2016). Faces were created from the point cloud to form a 3D CAD model (STL). Secondary processing involved smoothing, noise shell removal and cleaning the model using Materialise Magics software (Materialise, 2016). Magics processing was conducted with an expert user who has had many hours experience and professional training. The end result was an export body that when exported as a .STP or .IGS filetype could be used in simulation software.

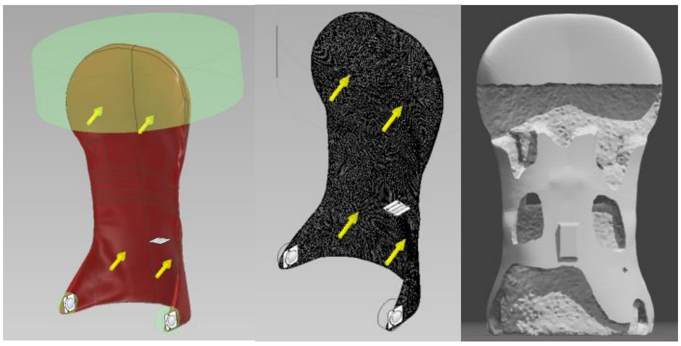

Figure 3: a) Shape Generator Constraint setup, b) fine mesh generation, c) resulting shape model.

Due to a formatting error, the original file could not be used for analysis. Future work would involve applying the loading conditions and constraints of a snowboarder in motion to the part in a simulation environment such as Ansys 16 (ANSYS, 2016).

2.3.2 Shape Generation of New Models

Entry Level Software

At the time of writing, Autodesk Fusion 260 had not yet released their shape generation update (Autodesk, 2016). In place of this, the shape generator within Autodesk Inventor was used instead, on the basis that many Fusion 360 tools are based on Autodesk Inventor tools. Using the shape generator tool, two pin supports were added at the fixation highback points and a roller (frictionless) support added at the rear. Settings allowed a material to be selected and a target was set at 'maximise stiffness' while attempting to reduce weight by 40%.

An applied force of 600N (Kondo, Doki and Hirose, 2014) was applied to the face that makes contact with the snowboarder's boot. It was observed that some small faces that wrapped around to the opposite side of the body did not allow for optimal force application (as seen in Figure 3a). Future work would see further face refinement to rectify this issue. To avoid inappropriate thinning at the top region of the highback, a 'Preserve Region' or avoidance box was applied to this area. Fine mesh settings, using elements of less than 1 mm was used, resulting in a processing time of 7 minutes.

The resulting generated shape can be seen below in Figure 3c. Future work would involve utilising this shape to refine the model, creating smooth, solid body based on the geometries created by the software. As can be seen, interfaces at areas such the preserve region boundary and newly formed cut-outs need further modifications to produce a realisable model ready for prototyping.

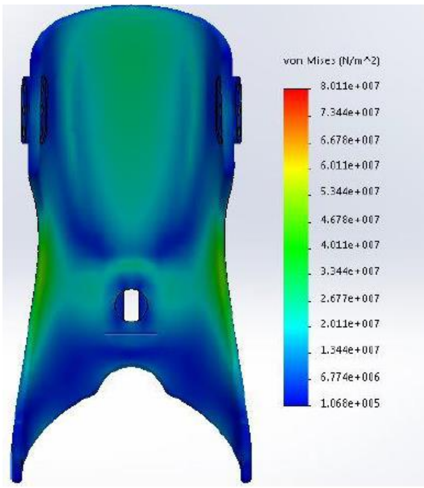

Figure 4: Ansys 16 Stress Analysis simulation of a similar highback model.

		Scanning Accuracy Measurements			
	Physical Model (mm)	Entry Level Scan		Professional Scan	
		Measured (mm)	% Difference	Measured (mm)	% Difference
Top Centre Thickness	7.00	6.80	2.86	9.95	0.71
Middle Side Thickness	4.00	3.33	16.75	4.20	5.00
Bolt to Bolt Interior	98.50	97.03	1.49	98.70	0.20
Overall Height	222.00	215.00	3.15	218.00	1.80
Average % Difference			**6.06 %**		**1.93 %**

Table 1: Scanning Measurement Results.

Professional Software

In this particular instance, the body was not able to be inserted into Ansys for simulation. A similar result from a previous study can be seen below. In the below case, a similar situation was setup in Ansys 16 and the resulting stress analysis of the part can be seen. This result can be used to add cut-outs and remove material at areas of the model that have low-stress concentrations. The blue x-shape in figure 4 below is identified as an area of the model that can benefit from material removal without affecting performance.

	Software and Hardware Costs ($USD)			
	Entry Level		Professional	
	Software	Hardware	Software	Hardware
Scanning	$315[A]	$350[B]	NA[C]	$75,000[D]
Model Prep	$280[E]	NA	$20,000[F]	NA
Shape Generation	$280[E]	NA	$20,000[H]+	NA

Table 2: Software and Hardware Costs.

Scan Processing Time		
Entry Level		Professional
Photo Scan Time	Model Generation	Scan Time
5 mins	8 mins	50 mins

Table 3: Scan processing time.

2.4 Results and Discussion

When comparing the two scanning methods, the entry-level scan proved to be much cheaper, faster and truer looking result. The metrics used to come to this conclusion were:

- Time: A usable scan was obtained within 5-minutes using the entry level method, compared to over 1 hour using the Kreon scanner, which still required further processing. Modelling time was not measured as it was heavily dependent on user skillset and experience.
- Cost: Costs of tools used was recorded as in Table 3. A Samsung galaxy smartphone is in order of magnitudes cheaper compared to a professional scanner such as a Kreon Baces arm scanner.
- Accuracy: Table 1 shows scanning results which compare the physical model scanned to measurements taken from the virtual models. Four points of measurement were chosen at different points of the binding. The overall height, the distance between the bottom bolt holes and the thickness at two locations. A geometric percentage difference of 6% was recorded on the entry level scan compared to 2% on the professional scan.

While not a quantifiable measure, considerable user expertise was required to take a scan to a solid using the professional Kreon scanner. However, entry level technique was very user-friendly and still resulted in a satisfactory result.

It is reasonable to assume that most SME's have access to modern smartphones with quality built in cameras, such a Samsung Galaxy, which can be purchased for less than $1000 USD. This is in comparison to the Kreon laser scanner that retails at $75,000 USD.

Taking a photo reel for scanning with the Samsung Galaxy took 5 minutes and very little technical skill, with scan generation in Remake taking less than 10 minutes. In contrast, achieving a scanned model with the professional scanner took a considerable amount of technical skill, training and roughly an hour to achieve a result that was lesser in quality (in terms of model geometry, not accuracy), to the entry-level scan.

Blank model preparation in Fusion360 took many hours and an experienced understanding of surface and mesh modelling. Many issues were encountered such as selecting appropriate mesh sizes and following the appropriate conversion steps without collapsing a model guide curve resulting in model collapse. The end result had a number of small surfaces that could have been further optimised to aid in better FEA/shape generator results.

On the other hand, a trained Materialise Magics operator can perform the same operation in less than 2 hours and achieve a blank model that was ready to have FEA and shape generation processes applied. While it's difficult to make a statement as to whether one software package was better than the other, the Magics software produced a usable result faster when operated by a trained user, however the license cost is an order of magnitude higher, than the Fusion360 subscription which can be licensed annually for $280 USD (Autodesk.com, 2016).

Shape generation using the Autodesk Inventor function was straightforward and involved following a workflow of setting up constraints, applying a mesh and running the simulation with a set of pre-determined targets (weight reduction and maximising stiffness). It is anticipated that a user with a foundation knowledge would be able to perform the required operations to generate an enhanced model. However, as the result was uncleaned, having many partial holes and jagged edges and interfaces, further model refining would be required.

3 Conclusion

The processes outlined in this study could be easily translated into other areas of sports and consumer product design in general. Overall it was inconclusive whether one process (entry level vs professional) was unconditionally better than the other. It was found that recent advances in scanning and modelling technology have made what was once expensive (both in equipment and software costs) and highly technical process, much more accessible to SME's. This brings a need for further studies into techniques and processes to aid in the evolution and widespread acceptance of these technologies in sports industries that could benefit from its application.

Further work will involve:

- Further optimising the blank models in terms of face and mesh properties to aid in the generation of better shape generated models.

- Shape generated models that are currently very primitive will also be processed further to make fluid, organic and aesthetic parts.
- Setting different parameters as desired by different modes of snowboarding. (e.g. a light highback with minimal stiffness for park riding)
- Physical prototyping using 3D printing allowing end-user testing on a snowboard binding in real-life snowboarding situations.
- Exploring the use and development of the same techniques, in other pieces of snowboarding equipment as well as wider sports related applications.

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