An exploration of the sustainable and aesthetic possibilities of 3D printing onto textiles as an alternative to traditional surface decoration, utilising cellulosic material

Abstract

Embellishment, in a fashion and textile context, can be considered an extraneous decorative process that has a significant detrimental impact on the environment. However, aesthetic and cultural theories, in addition to consumer appeal, show that it is a worthwhile endeavour. This project intends to address the ecological impact of the waste that can be caused by discarded, embellished textiles by creating a 3D printed alternative, utilising biodegradable cellulosic materials that may return to the soil as 'food'. The outputs were also tested for their strength of adhesion, in addition to their potential visual attributes.

Keywords

embellishment tradition 3d printing Tencel waste sustainability

Introduction

Textile embellishments are a small percentage of a finished product yet contribute a significant ecological impact. They can draw on the mining industry (metals for zips, poppers and electroplated studs for jeans) and the oil industry (plastic buttons, sequins and beads), with their associated impacts on global warming, land degradation, human health, air emissions and toxic contamination of water. In addition to this, at the end of a garments life cycle, in large scale textile recycling plants, items must be free of all trims to facilitate reprocessing. They can be difficult and labour intensive to detach or remain on the garment meaning that otherwise recyclable yarns or fabrics are passed by and sent to landfill.

According to Fletcher and Grose (2011), sustainably led innovation involves using renewable source materials and rapidly renewable fibres; materials with reduced processes such as water, energy and chemicals, fibres produced under improved working conditions for growers and processors and materials produced with reduced waste such as biodegradable and recyclable fibres from both consumer and industry waste streams.

From this standpoint, this research looks at alternative approaches to both the way that we embellish textiles and the materials used, concentrating on the renewable source materials of PLA (a biodegradable polymer derived from vegetable starch) and Tencel. This is a low-impact, regenerated cellulose fibre made from wood pulp. The raw cellulose is dissolved directly in an amine oxide solvent, substantially reducing pollution levels in water. It requires no bleaching prior to dying and is coloured with low chemical, water and energy techniques. 3d printing also offers an approach with little waste, which is less labour intensive than hand sewing. The full potential of this technique, in a textile context, is yet to be fully exploited.

Although 3D printing is occasionally used in a fashion context at this time, it is usually for ‘novelty’ rather than to approach any issues around sustainability in the textile industry. In addition to this, Tencel is utilised by several companies, including Marks and Spencers, H&M and Esprit, but they have not made enough of an impact to displace the use of more unsustainable fabrics such as cotton. This project intends to look at new ways to use cellulosic textiles and, potentially mixed with PLA, 3D printable materials to be used as embellishment *on* the textile.

This project utilises cellulosic materials in the form of woven, non woven and knitted Tencel (including powdered cellulose, all provided by Lenzing. The material to be 3D printed onto the Tencel (developed in Advanced Materials at Edinburgh Napier University as a separate project to this PhD) combines powdered Tencel and Polylactic Acid (PLA), a material 'made from sugars derived from agricultural crops.' (Fletcher and Grose, 2012 : 2012). While most composite materials are not ideal, PLA and cellulose both biodegrade in a way that provides eventual nutrients to the soil. In addition to this, 3D

printing is being used in a particular way, to provide the appearance of laborious hand printing and sewing techniques with the controllability of digital printing.There is no waste in the materials used in 3D printing – the equipment uses just what it needs and there is no water used in the process.

The embellishment and the material on the whole product would therefore be generally more sustainable for a number of reasons, as highlighted. Through this practice led investigation, there will also be emphasis on the technique's aesthetic appeal and the usability of the processes, so that it may be a real alternative to current provision and practices. This will be tested through observational methods looking at designer and consumer responses to prototypes and the new methods of embellishment in this study.

Literature Review – Ornament and Crime

As a response to many of the challenges in the relationship between fashion, textiles and sustainability, such as their impact on 'climate change; adverse affects on water and its cycles; chemical pollution; loss of biodiversity; overuse and misuse of non-renewable resources; waste production; negative impacts on human health and damaging social effects on producer communities' (Fletcher and Grose, 2012 : 13), it could be concluded that minimising processes that are not completely utilitarian, including 'embellishment', 'decoration' or 'ornament', would be a sensible reaction. The 'correctness' of minimalism and disdain for 'superfluous adornment' has been debated throughout the history of fashion and design, even before its unsustainable attributes were considered or understood. In his lecture 'Ornament and Crime' in 1910, Adolf Loos went as far as to say that 'the evolution of culture marches with the elimination of ornament from useful objects' and that it was 'a crime to waste the effort needed to add ornamentation, when the ornamentation would cause the object to soon go out of style'. Loos talked about the 'immorality' of ornament, describing it as 'degenerate' and its suppression as necessary for regulating modern society. (Loos, 1998) These tenets (and the phrase 'form follows function' by American architect Louis Sullivan in the 1930s) were followed throughout Modernism, by designers and schools including the Bauhaus. The influential Functionalist industrial designer Dieter Rams went further with his phrase 'less, but better' and in hisiconic 'ten principles for good design', he says that good design is 'as little design as possible'. (Rams, 2014)

Literature Review – Ornament and Culture

This research begins with the stance that to embellish, in a fashion context - particularly decorative print and structural embroidery techniques - are positive cultural and communicative devices, for designers and the public who choose to buy and wear such decorative items. Decoration can also add to emotional attachment between the owner and the garment and therefore extend its lifespan.

McRobbie (1998 : 6) defines fashion as 'the application of creative thought to the conceptualisation and execution of items of clothing so that they can be said to display a formal and distinctive aesthetic coherence which takes precedence over function'. This aesthetic factor is often the decorative elements added to the functional garment shape including printed motifs, patterns or embroidered shapes. If one follows the rationale that fashion and clothing are 'forms of nonverbal communication' and that fashion can be 'semiotically' read (Barthes, 1983) to 'make sense of the world and the things and people in it, that they are communicative phenomena; that they imply that the structured system of meanings, a culture, enables individuals to construct an identity by means of communication,' (Barnard, 1996 : 32) it would follow that 'symbols' and 'motifs', provided by print and embellishment, are among the most direct devices. Printed or embroidered motifs and added symbolic 'meaning' can, 'challenge or contest existing class and gender identities as a way in which people may transform their circumstances and conditions'. (Barnard, 1996 : 127)

Norman's research (2004 : 101), talks about the affirmative attributes of 'fun and pleasure' in design. This pleasurable, obviously 'prettified' aspect of fashion decoration can be seen as 'trivial' and 'irrelevant to serious minded persons.' (Wilson, 1992 : 34) Norman breaks down the 'fun' of aesthetic objects as being 'enticing by diverting attention; delivering surprising novelty; going beyond obvious needs and expectations; creating instinctive responses; espousing values or connections to personal

goals; promising to fulfil these goals; leads the casual viewer to discover something deeper about the experience thy would normally have with a designed object and fulfilling these promises.' (2004 : 114) Well designed embellished garments can create a combination of 'surprising novelty', that are 'useful and believe[d] to be beautiful' (Morris, 1880) and are treasured because of their personal meaning.

Literature Review – Ornament and Waste

Embellishment eschews 'novelty' and personal meaning, and, as it is natural for people to 'change their minds' and mediate their identities through their designed possessions, garments can, therefore, be discarded. It is this projects intention to provide a 'circular' solution, through the use of low energy processes and biodegradable materials where 'waste equals food' (Braungart and McDonough, 2008 : 92) This approach mirrors Braungard and McDonough's 'cradle to cradle' 'manifesto'. In their own project with a fabric that was 'safe enough to eat' (108), they said, 'as a biological nutrient, the fabric embodied the kind of fecundity we find in nature's work. After customers finished using it, they could simply tear the fabric off the chair frame and throw it onto the soil or compost heap without feeling bad – even, perhaps, with a kind of relish. Throwing something away can be fun, let's admit it; and giving a guilt-free gift to the natural world is an incomparable pleasure.' (109)

Literature Review – Tradition Versus 3D Printing

In the process of 'flocking', fabrics can be printed with glue then heat-pressed with flock paper. The flock adheres to the glue, creating as raised 'felt' effect glitter and foil can by similarly applied to produce special effects. (Udale, 2008)

The majority of printing inks are water based and much of the impact from processes involved in printing come from the disposing of inks and waste materials including rags, clean up materials, empty containers, used film and cardboard boxes. (Marshall, 2014) Along with this there is the water consumption used within the whole process and pollution from the fixation process. Due to the print residue it is more complicated to return the material back to a reusable state. (Marshall, 2015)

Other ways of adding surface decoration to embellished is by using beading and sequinning with 'beads made from glass, plastic, wood, bone and enamel" (Udale, 2008 : 108) It has been shown that the plastic used in beads have the potential of spending up to four hundred and fifty years in land fill without braking down. (Headifen, 2015) The negative impacts come from what the embellishments are made of rather then the process itself. Polyester thread is the main fibre used to attached the beads and sequins, however the base fabric is normally made of silk and cotton, then the beads and sequins are made of one of the above materials. (Udale, 2008)) This means a large amount of different fibres left at the end of the garments life.

In contrast to this, using a 3D printer for embellishments could mean that designs are printed on demand without the need to build-up inventories of new products and spare parts. (Lipson, 2013) A 3D printing facility would be capable of printing a huge range of types of products without retooling—and each print could be customized without additional cost, unlike screen-printing in where new screens would be required for every design. (Shillito, 2013) Production and distribution of material products could begin to be de-globalized as production is brought closer to the consumer. (Lipson, 2013) Manufacturing could be pulled away from 'manufacturing platforms' like China back to the countries where the products are consumed, reducing global economic imbalances as export countries' surpluses are reduced and importing countries' (Lipson, 2013) reliance on imports shrink. The carbon footprint of manufacturing and transport, as well as overall energy use in manufacturing could be reduced substantially and thus global 'resource productivity' greatly enhanced and carbon emissions reduced. (Lipson, 2013) Reduced need for labour in manufacturing could be politically destabilizing in some economies while others, especially aging societies, might benefit from the ability to produce more goods with fewer people while reducing reliance on imports. Reduced need for labour in manufacturing could be politically destabilizing in some economies while others, especially aging societies, might benefit from the ability to produce more goods with fewer people while reducing reliance on imports. (Lipson, 2013)

Literature Review – Current Projects with Textiles and 3D Printing

At this point in the author's PhD research, there are several projects of note that look at 3D printing in a fashion and textile context. However, at this time, many projects look at the 'novelty' of the process rather than addressing the challenges of the industry and proposing tangible, mass producible solutions. Innovative projects that have caught media attention include Nike's 'Vapor Laser Talon 159 gram shoe' which involved a 3D printed, customisable nylon sole that was shown to improve athlete's performance. (Nike News, 2013) Michael Schmidt and Francis Bitoni's one-off 'fully articulated 3D printed gown, also printed in nylon by Shapeways, an open-access printing facility, gained widespread coverage. (Duann, 2013) Arguably, the first use of 3D printing in more 'mainstream' fashion and textiles was Richard Beckett's project for Pringle in 2014 where he used 3D printed 'laser sintered nylon elements' that were integrated into fabric (rather than 3D printed onto fabric). (Beckett, 2014)

Designers Meg Grant and Lynsey Calder (separately and together), have developed '3D printed, wearable origami' that involves PLA that is 3D printed onto several different textiles types (based on the applicability of the bond and flexibility of the ensuing print. Fabrics that were experimented with include iron-on interfacing (with the glue up side printed onto) and organza. (Calder and Grant, 2015) (see figure 1.)

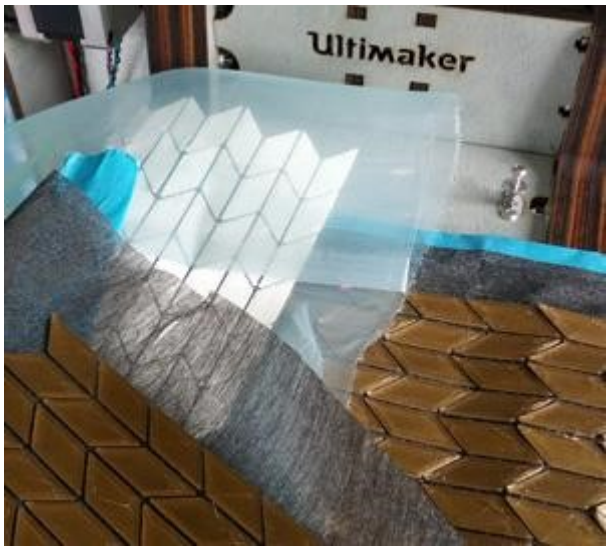

Figure 1. 3D Printed 'Origami' by Meg Grant, 2015.

Ziego Zamora's research also looked at the 'flexible bonds' that can be created between natural fabrics and digital objects with an emphasis on how, even at this time in the development of 3D printing, any printable file can become wearable. (Zamora, 2014) (see figure 2.)

Figure 2. 3D printing onto textile by Diego Zamora, 2014.

In 2015 3D Systems introduced the 'Fabricate' application which involved a series of ready made designs by Cubify (triangles, spikes and squares that could be [printed into 'special fabric' that would then be sewn or glued onto items of clothing. (Kira, 2015) (see figure 3.)

Figure 3. 3D printed garment utilising designs by Cubify, 3D System's printer and Fabricate application, 2015.

Methodology

This project has been set out to provide an alternative to surface design techniques including screen printing, flocking and embellishment techniques including embroidery, applique, beading and sequins. The initial secondary research looked at the features of the embellishment techniques in comparison to 3D printing onto textile.

At this point in the research, the *reasons* for looking into 3D printing utilising cellulosic materials as embellishment have been adequately established and so a test was set up to determine if 3D printing onto Tencel fabrics could perform as well as traditional embellishment, looking at safety standards in the apparel industry.

Primary Research

The following images (figures 4 – 6) show the initial experiments with PLA 3D printed onto Tencel (with woven drill being visually the most successful). The author experimented with designing software for the Ultimaker 2 3D printer (Cura) to create a shallow print of several millimetres high. To enable the strength tests to take place, 'dots' were printed onto the textile that could be gripped by the machinery.

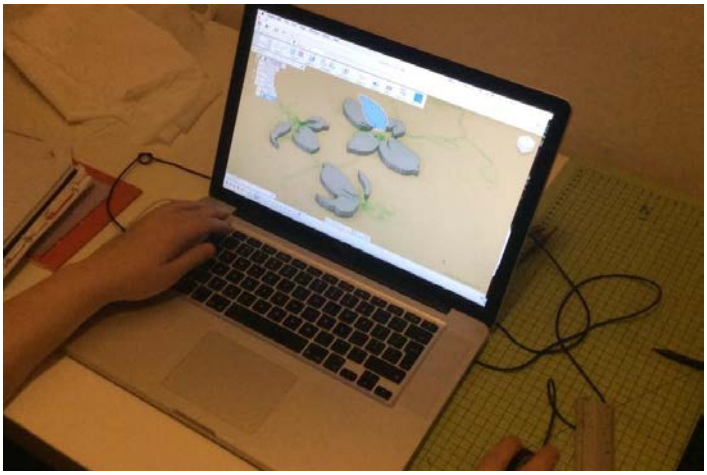

Figure 4. Designing process for the 3D printer, Kirstie Burn, 2016

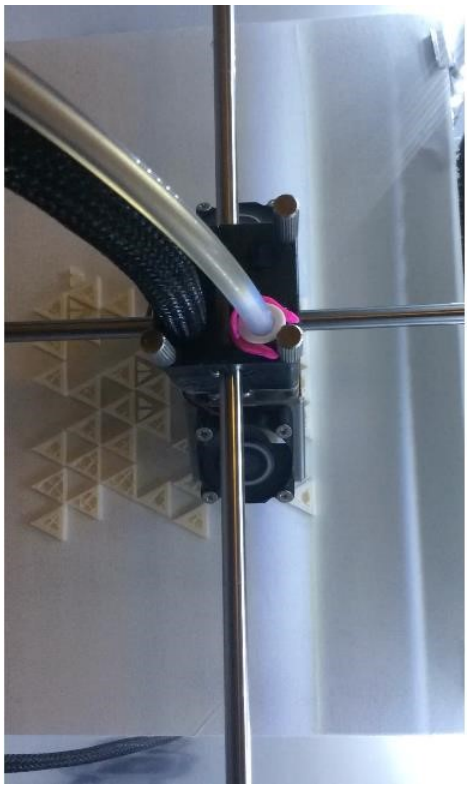

Figure 5. 3D printing onto textile, Kirstie Burn, 2016

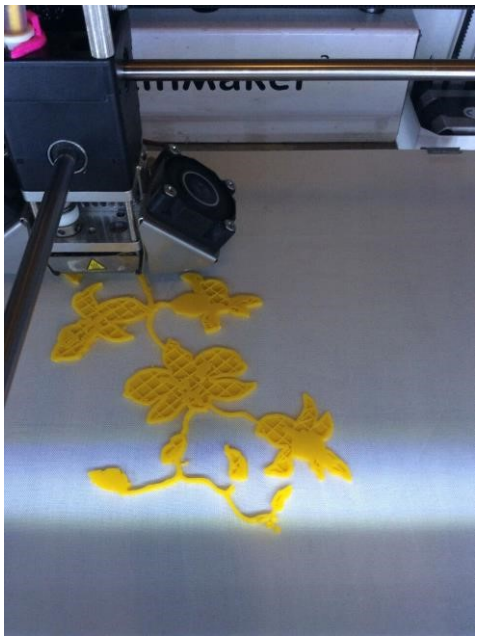

Figure 6. Floral design development for 3D printer, Kirstie Burn, 2016

Peel Tests

Although the foregoing provides the motivation for its use, if 3D-printing is to be applied in the proposed context, it is important to establish that the technique produces a satisfactory bond between the printed embellishment and the textile. For this purpose, a series of peel tests were carried out on samples of PLA 'buttons' printed onto four different Tencel textile structures; drill, plain woven, knitted and non-woven.

The printed buttons were nominally 10mm in diameter by 5mm high, and attached to the textile over the full area of their circular base. The samples were set up individually in a Lloyd Instruments LRX 01/2005 pull-testing machine (see figure 8), using suitable grippers, and positioned axially such that the peel angle was 90° as the traversing peel line coincided with the button diameter. This was done to ensure that the maximum force would be measured as per the standard right-angle peel test. Five individual samples of each were tested in order to give a measure of the consistency of the process. The results are shown in Table 1, and presented as box-plots in Figure 7.

Table 1: Maximum peel force measured for all samples.

Tencel drill	Tencel plain woven	Tencel knit	Tencel non-woven
13.65	12.55	31.71	6.35
13.55	9.48	17.30	8.52
13.82	8.98	18.91	5.56
14.21	7.39	25.05	7.12
13.31	3.16	24.16	6.27

Figure 7: Box plot of peel forces by textile structure

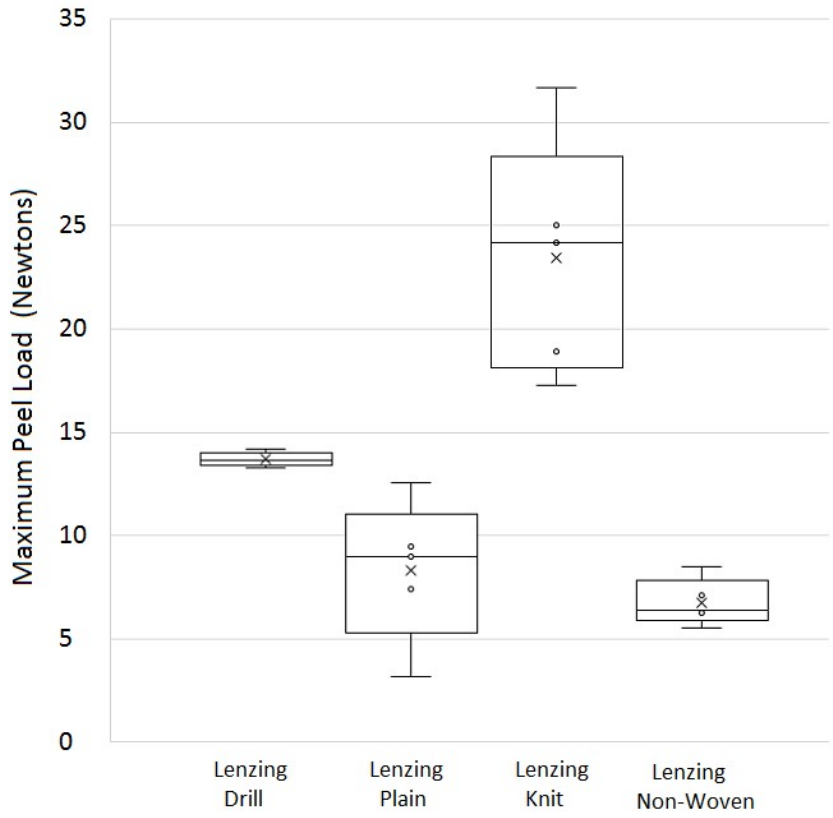

Figure 8. Peel test equipment and 'button' samples, 2016

It can be seen that the textile structure has a significant effect on the strength of attachment. The strongest bond achieved was with the knitted textile, but this also exhibited the most variability. The reasons for this are not immediately clear, but may be because of the multiple fibre orientations presented at the textile-polymer interface, in contrast to the bi-directional nature of the woven fibres, largely parallel to the plane of the bond. Whilst this may lead to an expectation that the random orientation of the fibres in the non-woven textile would lead to an even stronger bond, this is not evident in the peel test results. Inspection of the samples post-test, however, reveals that the bond remains intact and the failure mode is that of the textile tearing.

The woven drill samples are notable for the consistency of the bond strength, albeit at little over half the mean strength of the knitted samples. Such consistency would be needed should the process be adopted on a production basis. The reasons for the outstanding performance in this regard is the subject of further enquiry. Furthermore, that the bond strength of the printed polymer approaches that of the textile itself in some cases is supportive of the potential viability of the technique. However, further work is to be carried out to investigate a variety of other polymer/fabric combinations.

Conclusions

This research project has involved a multi-disciplinary practice, theory and product engineering team and because of this, the applicability and worth of the project has been thoroughly investigated before the initial lab tests were undertaken. Embellishment itself, as a process, could be considered extraneous in a climate that looks to ways that products can be made in a 'leaner and greener', more minimalistic way. However, taking as inspiration Braungart and McDonough's theories on circularity, that waste can be 'good' if it becomes 'food', and the availability of PLA and cellulosic materials, this project proposed the tackle the challenge of fashion waste in a new way. At this time, there are some projects that look at how 3D printing can be applied in the fashion and textiles industry, primarily as an exciting new aesthetic process. This project, however, wishes to address and answer a problem in fashion and the strength

initial strength tests undertaken show that 3D printing, as an alternative to traditional embellishment techniques, utilising Tencel and using PLA bioplastic, can be a feasible, usable material.

Reference List

Barnard, M. (1996) Fashion as Communication, London, Routledge.

Barthes, R. (1983) The Fashion System, Paris, Farnar Straus and Giroux.

Beckett, R. (2014) 3D Printed Knitwear – Pringle of Scotland AW 2014 [online] http//:www.richardbeckett.com/pringle-3d-fabrics.html [Accessed 30.07.2016]

Braungart, M. McDonough, W. (2002) Cradle to Cradle, Re-Making the Way we Make Things, London, Vintage Books.

Calder, L. Grant, M. (2015) The Pop Up Workshop [online] Available at http://thepopupworkshop.wordpress.com/tag/e-textiles [Accessed 30.07.2016]

Duann. (2013) Reveaing Dita Von Teese in a Fully Articulated 3D Printed Gown, [online] Available at http://www.shapeways.com/blog/archives/1952-revealing-dita-von-teese-in-a-fully-articulated-3dprinted-gown.html [Accessed 30.07.2016]

Fletcher, K. Grose, L. (2011) Fashion and Sustainability : Design for Change, London, Lawrence King Publishing.

Headifer, R. (2016) Plastic Litter [online] Available at http://www.plasticwastesolutions.com/plasticlitter [Accessed 30.07.2016]

Kira. (2015) Project Runway and 3D Systems Present 'Fabricate' 3D Printed Wearable You'll Actually Want to Wear [online] Available at http://www.3ders.org/articles/20151016-project-runway-3d-systemspresent-fabricate-3d-printed-wearables.html [Accessed 30.07.2016]

Lipson, H. (2013) Fabricated : The New World of 3D Printing, London, Wiley.

Loos, A. (1998) Ornament and Crime, Paris, Ariadne Press

Marshall, J. (2015) Sustainability in Screen Printing [online] Available at http ://www.printwearmag.com/features/sustainability-screen-printing [Accessed 30.07.2016]

Marshall, J. (2015) How to do Eco-Friendly Screen Printing [online] Available at http://www.ryonetblog.com/eco-friendly-screen-printing [Accessed 30.07.2016]

McRobbie, A. (1998) British Fashion Design : Rag Trade or Image Industry ?, London, Routledge.

Morris, W. (1974) The Beauty of Life : An Address Delivered at the Town Hall Birmingham in 1880, London, Bentham Press.

Nike News. (2013) Nike Debuts First-Ever Football Cleat Built Using 3D Printing Technology [online] Available at http://news.nike.com/news/nike-debuts-first-ever-football-cleat-built-using-3d-printingtechnology [Accessed 30.07.2016]

Norman, D.A. (2004) Emotional Design : Why we Love (or Hate) Everyday Things, New York, Basic Books.

Rams, D. (2014) Less but Better, Cologne, Die Gestalten Verlag.

Shillito, A.M. (2013) Digital Crafts, London, A&C Black.

Udale, J. (2008) Basics Fashion Design, London, AVA Publishing.

Wilson, E. (1992) Chic Thrills : A Fashion Reader, London, Pandora.

Zamora, D. (2014) Diego Zamora PhD Candidate [online] Available at http ://www.designinaction.com/research/individual/diego-zamora [Accessed 30.07.2016]