HAPTIC – A NEW ADDITIVE MANUFACTURING TECHNOLOGY FOR FOOTWEAR, APPAREL AND ACCESSORIES APPLICATIONS

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ABSTRACT: A new additive manufacturing technology for industrial mass production of footwear, apparel and accessories branded as "Haptic" will be introduced. Applying traditional non-digital screen printing technology for additive manufacturing, a totally new approach of footwear manufacturing was implemented successfully in 2015 at Huafeng Textile Group in China. Production was scaled up from zero to 500000 pairs of sport shoes per month early 2015 and strong growth leads to rapid extension of capacity. Multiple benefits such as freedom of design, soft and comfortable seam-free footwear uppers and efficient and sustainable production processes lead to high market acceptance. Using high-solid water-based chemistry allows application of high film thicknesses. Layer by layer various level thicknesses can be applied and attractive new footwear designs can be achieved. Further development needs will be discussed such as moving to full mass customization by changing to digital additive manufacturing methods and achieving higher thickness 3D textures by efficient automatic application methods. Beside of new application technologies for additive manufacturing of "Haptic" there is a strong need for material development as full compliance to chemical safety and full performance requirements for sports footwear have to be met.

INTRODUCTION

Today manufacturing of textiles for sport footwear, apparel and accessories happens in long supply chains with multiple hand-over processes from one supplier to the next in the chain. Every hand-over process bears risks for quality control, delays of lead time, complex supply chain management processes and poor accountability on quality. Looking specifically at sport footwear the upper materials are often made out of various materials cut and stitched together. Stitching obviously creates high manual labor cost. Seams and stitching lines along the material joints are limiting freedom of design. Therefore sometimes instead of stitching processes hot pressing of TPU films is the preferred solution. However, that still creates large loss of material due to cutting waste and often ends up with stiff and less comfortable upper designs. In addition TPU film can only be used for larger area surfaces and fine lines or small dots cannot be achieved.
Within this article a new method of manufacturing footwear upper components is introduced. This method creates a new freedom of design while improving the supply chain in regards to speed, quality, efficiency and sustainability. The new method of Haptic coating is based on additive manufacturing.

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ADDITIVE MANUFACTURING VIA SCREEN PRINTING

Most people associate additive manufacturing today with modern digital 3D printing processes. Following the idea of printing 3D objects layer by layer a new method of screen printing was developed. This method is obviously not as advanced as modern digital 3D printing technologies but allows mass manufacturing of value added textile products in an additive manufacturing approach. It can be easily implemented in standard factory environments and workers can quickly be trained to use this technology. The difference in fact is only that instead of a computer controlled digital process automatic or manual screen printing processes are utilized to deposit coating layers on top of a textile substrate. Whereas a standard screen printing process only adds a colorful decorative print the Haptic approach adds multiple layers of coatings on top of each other. Doing that step by step a coating thickness of 0.5 – 1.5 mm can easily be achieved and the thickness is only limited by the numbers of applied coatings. Usually a transparent base coat is applied first building up the basic coating thickness. On top of the thick base coat thin color coats are applied resulting in the final visual appearance. In addition to color other Haptic effects like soft touch or rough touch effects can be created. Applying different screen designs and coating the different designs on top of each other multiple level 3D structures can be achieved.

Figure 1. Mulit-level Haptic coating on polyester mesh

DESIGN FEATURES OF 3D HAPTIC COATINGS

Haptic perception and 3D texture

Haptic perception, the feeling created when touching something, is mainly driven by the macroscopic and microscopic 3D textures of a surface. Macroscopic textures can easily be achieved with the multi-layer screen printing technology described above. Depending on screen

design various shapes and geometries can be created in addition to 3D height of the levels. When you touch it you feel the 3D texture. In addition the microscopic texture of the top coating layer is created by the chemistry and the coating formulation. Microscopic textures create feelings like soft touch, sandpaper touch or rough touch. The hand feeling when touching a product creates a Haptic perception to the person touching and often strongly influences people's buying behavior. Therefore it is most desirable for modern design to emphasize Haptic perception in addition to color design.

Color

Product design obviously is not only about the Haptic perception and usually at first contact customers focus at the visual appearance of a product. Haptic coatings can be manufactured in all different uni-colors, metallic and anodized effects, flip-flop color shifting effects and many more special effects attracting the eye of customers. Color design adds on to the 3D texture design and the overall freedom of design.

Gloss

Sometimes products should not be overloaded with color achieving a more elegant appearance. By keeping to one-color-only designs but instead changing the gloss of surfaces at different 3D levels exciting modern effects can be achieved. And for sure also various colors in various gloss levels could be combined on one product.

Figure 2. Haptic perception, color and gloss variations of Haptic 3D coatings

CHANGES IN SUPPLY CHAIN VIA ADDITIVE MANUFACTURING

Classical Tier-2 to Tier-1 model

A typical supply chain set-up for manufacturing sports footwear contains Tier-2 material suppliers and Tier-1 footwear factories. Usually many Tier-2 suppliers deliver their material such as fabric, TPU film, logos, molded parts, etc. to the Tier-1 factory where the material is cut and prepared for the final assembly process usually done via stitching or hot pressing. However, this well established supply chain model fails in delivering short lead times, easy supply chain management and in many cases quality accountability is difficult to obtain as so many Tier-2 suppliers are involved. Therefore at Huafeng a new model of component manufacturing was developed utilizing the Haptic 3D additive manufacturing approach.

New Model via Component Manufacturing

The basic idea of improving the supply chain in regards to speed, efficiency and quality was changing from a materials supplier to a component supplier. A vertical backwards integrated manufacturing set-up at Huafeng Textile Group allows quick and easy access to raw materials for the next production step. Now with the forward integration into component manufacturing the Tier-2 textile supplier usually supplying rolls of textile to Tier-1 moved downstream closer to Tier-1 and brand. The enabling technology for the downstream integration was the newly developed 3D additive manufacturing technology Haptic. This technology can be easily applied to textiles just after manufacturing rolls of textile material and value is added directly at the textile manufacturer. Further production processes such as hot pressing or reinforcements and final cutting of the semi-finished upper component allow a flexible and timely supply to the shoe assembly factory. The finished component is shipped out from one supplier only simplifying the supply chain and leading to full accountability on quality. In addition an effective manufacturing process is created with less labor cost, huge freedom of product design, and high degree of sustainability. Specific contributions to more sustainability will be discussed in the next paragraph.

Figure 3. New Business Model of Component Manufacturing with Haptic Technology

SUSTAINABLITY CONSIDERATIONS

Additive manufacturing is a modern process with high material efficiencies. Adding material where it is needed and only there leads to less material consumption, less waste and less cost. With the Haptic technology no cutting waste will be generated and does not need to be disposed or recycled.
In addition the chemistry used for the Haptic process consists of fully water-based high solid PU polymers. These PUD systems allow application of high coating thickness with lower number of layers due to less shrinkage during drying. As there is only little water to be dried off the drying time and drying energy is reduced compared to standard PUDs. And finally, as Haptic PUD is fully water-based there is no smell of solvent in the factory, there is no health risk because of inhalation of evaporated solvent and there is no fire risk to the factory (Bayer). All these facts contribute to a safe and healthy workforce manufacturing top quality products.
Although the Haptic technology reached mass production stage for sport footwear in 2015 many ideas how to improve the technology remain for further research and development. Based on the above described experiences the next chapter will describe the future path of Haptic technology.

DEVELOPMENT NEEDS FOR NEXT GENERATION ADDITIVE MANUFACTURED TEXTILE PRODUCTS

Automation

Rising labor cost and high demands on quality management ask for ever more automation within production environments. This also applies more and more for footwear and apparel manufacturers and not only for the high-tech electronics or automotive industry. As described above Haptic 3D coatings are today applied by screen printing processes. These processes can easily be automated and in fact for decorative printing automatic screen printing is a standard technology today. However, for the 3D additive manufacturing approach new challenges appear and need to be mastered. Due to changing material high after each screen printing step machine adjustments for pressure and speed of printing need to be done carefully. Drying times and temperatures between each application process need to be carefully adjusted. This is especially the case when climatic conditions change e.g. from summer to winter or from very high humidity tropical weather to dry winter climate. Currently first automatic Haptic additive coating lines are installed at Huafeng in China and engineers work on minimizing defect rates and fine tuning the process for best and most consistent results. Automatic 3D additive screen printing is close to full implementation in mass production. However, the market is already asking for the next generation of automation, the fully digital 3D printing.

Digitalization

It would be highly desirable to apply Haptic 3D coatings on footwear and apparel textiles with fully digital methods. This would not only allow automatic production but also full mass customization applications. Today small production runs are still limited because of screen making and change of screens in production. In future creation and selection of design could be done via software on the computer and could then be quickly and seamlessly transferred into a digital production machine online. Main challenge today is the materials used for 3D digital printing. So far our tests did not lead to samples suitable for footwear applications. Usually adhesion of 3D printed material to fabric are poor, most materials are not very flexible and will break during practical use and some UV curing materials rise toxicity concerns when used in products with skin

contact. In addition to full compliance to mechanical and chemical safety requirements the application technology should also allow printing various colors including attractive eye catching metallic colors on one product at the same time. Application technology also needs to achieve speed and efficiency that it can replace screen printing and move from sample manufacturing to full scale mass manufacturing of million pairs of shoes. Product designers also ask for ever more advanced 3D designs requiring new application technologies.

Enhanced 3D Textures

Modern digital 3D printing methods allow manufacturing large scale 3D objects. Haptic coatings today in comparison only deliver thin 3D textures of maximum 1.5 m height. Changing from manual screen printing to automatic and digital 3D additive manufacturing should allow creating 3D textures of several mm height. 3D printing technologies can easily achieve that today but the material requirements for footwear or apparel applications cannot easily be met. Again, there is a strong need for developing the right printing materials together with a high speed application process.

Material Development

There are plentiful material requirements for footwear, apparel and accessories application. Basically every serious sports of fashion brand have their own standard about performance and chemical safety. In addition industry standards such as Oekotex® (Oekotex) or the new roadmap to ZDHC (ZDHC), where various brands join together for improving their supply chain and manufacturing practices are implemented. Following table shows some performance lab test requirements to be fulfilled for sports footwear:

Table1. Performance lab tests for footwear applications

Test Standard	**Requirement**
Rubbing fastness	No damage
Washing	No delamination, no damage
Migration fastness	4-5
Hydrolysis test	No damage, no delamination
Flexometer test	No cracking
Martindale abrasion	No damage

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