A NEW BUSINESS MODEL FOR INTEGRATING TEXTILE/CLOTHING/LEATHER AND FOOTWEAR MANUFACTURING

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Textile, clothing, leather and footwear manufacturers strive to meet higher performance expectations, decreasing delivery times and stricter Environmental, Health and Safety (EHS) requirements within a global operating environment. Although these industrial sectors are part of the same supply chain and face similar challenges, no business framework has been developed for unifying common practises for their mutual benefit. A new business paradigm is presented where EHS requirements, Virtual Prototyping, Performance Evaluation, Production Organisation and Supply Chain management are treated using a collaborative platform, integrating footwear manufacturing with textiles, leather and clothing. The new platform aids this extended supply chain in managing these challenges, through a "Collaborative 3D Virtual Design platform", a "Knowledge Base" and a "Production Organisation Framework". The proposed business paradigm supports all phases of product life-cycle with respect to design and virtual prototyping, facilitating the selection of different production processes and appropriate partners from a wider supply chain pool. The paper gives an extensive analysis of all critical stages of the proposed business paradigm by following a footwear production scenario and concludes with a discussion of the anticipated benefits in time to market, improved supply chain partnerships, costs reduction, product innovation and hints for future work.

Keywords: footwear production, collaborative design platform, virtual prototyping.

CONTEMPORARY PRODUCT DEVELOPMENT ASPECTS IN THE CLOTHING, TEXTILE, LEATHER AND FOOTWEAR SECTORS

Clothing, Textile and Footwear (CTF) products range from one-piece single material items to multi-part multi-material assembly structures consisting of textiles, leather, polymer components, leather-board, wood-cork, metal, coatings and adhesives. Prior to end-product operations, several physical-mechanical and chemical processes occur in different locations around the world. All these sectors, along with leather tanning and retail, are strongly interrelated.

Modern CTF product development has to meet several challenges:

- Compliance with regulations and organizational Restricted Substances Lists (RSLs) on the presence and concentration of substances of concern;
- Reduced Environmental Chemical Emissions Factors;
- High end-user performance and comfort expectations;
- Short fashion cycles, tight delivery timeframes and fast prototyping;
- Managing a significant volume of previous design knowledge and technological options;
- Development and Production costs pressures;
- Complex Extended Supply Chain management with operations taking place globally and products launched to any market around the world.

Today, product development relies on Information and Communication Technology (ICT) tools to meet these challenges. In most cases these require specialists in design, testing, ERP or production planning to operate. This lack of improved interactive user interfaces does not facilitate adoption of the technology by the non-specialists. Inter and intra-organisational communication is further hindered due to interoperability issues. International standardized formats like IGES or STEP or collaborative platforms for CAD/CAM (Li, W.D., 2005) are poorly adopted by existing systems hindering data exchanging. On the other hand, the most successful business communication approach, based on XML technology, is that developed by the combined MODA-ML/SHOENET/E-BIZ TCF European project (Censoni et al., 2002; MODA-ML).

Modern CAD/CAM/CAE/PDM systems for solid items possess realistic dynamic real time simulation and visualization capabilities. This is not the case for goods that consist of non-solid materials such as clothing and footwear, due to modelling limitations. In clothing, simulation depends on mechanical properties data of non-stable non-solid fabrics and the anatomy of the wearer. Most specialized small and mid-sized firms involved in developing specialized CAD/CAM solutions can demonstrate significant progress, including the development of virtual mannequins. Footwear simulation is different because although a non-solid, it is a stable structure. The System Shoe (SYS) Add-On for the engineering CAD system SolidWorks® may open the possibility to use this popular system in the footwear industry (Garfani M., 2008) but has not become commercially available yet. In Virtual Reality, a field where clothing design has to demonstrate significant progress, the footwear industry has to show the VRShoe and MagicMirror modules (Vigano G., 2004). Most systems are constrained within local LANs or between companies operating the same proprietary software.

Concerning the management of Environmental-Health-Safety (EHS) aspects, besides the lack of ICT aids, a major drawback is the lack of a holistic and global approach to identifying relevant restrictions and limits, and managing these from early design stages. Existing legislation, brand specific RSLs and schemes such as Oekotex (for textiles, clothing), ConsumerSure (for leather) and Ecomark (CTF goods) are product and material oriented. Few approaches to process analysis with regard to substances of concern exist, a typical example being Bluesign®. A holistic approach for both material-product and process aspects has not been developed yet. What is also not existent is a global tool, to provide decision making features that cover combined requirements at any market in the world at any development and production stage.

Product developers address Performance/Comfort prediction at an early stage. In textiles there has been considerable research and several classic mathematical models, non-deterministic models, neural networks and other techniques have been developed and documented. For 3D products multivariate analysis and Finite Element Analysis have also been applied. The apparel and textile industries have made steps towards supporting product design from the engineering point of view (Wang and Yuen, 2005; Choi and Ko, 2005). Mao et al. (2008) presented a CAD based system allowing thermal functional design on a virtual human body. Although, the footwear sector still lags behind the developments in the textile and clothing sectors, a shift towards more end user oriented engineering is observed (Boer et. al. 2004) and new concepts for customizing footwear are developed (Leng and Du, 2006; Luximon et al., 2003). In clothing, with improved and refined models and algorithms, simulation and animation are realistic and fast and mechanical properties of virtual prototypes can be assessed (Breen et al., 1994; Eberhardt et al., 1996; Baraff and WitKin, 1998; Choi and Ko, 2002; Cordier et al., 2003; Fontana et al., 2005). With respect to "Shoe Virtual Engineering and Performance Evaluation" a system has been developed by Azariadis et al. (2007, 2010) that supports important comfort functionalities. However, this novel system is still not integrated with external material databases sharing, under this way, material data and properties with TC industry.

The existence and access to materials databases is important. Within different design solutions for clothing, some limited datasets exist but it was only during the Leapfrog project, for textile based apparel, when extensive libraries were developed and became available to product developers (LEAPFROG). Another important aspect is access to knowledge related to process path options and historic information for different product concepts. This has been addressed through the Extended Smart Garment Organisation module of the Leapfrog project for clothing (LEAPFROG) and through the Standard Extensible Shoes Factory Data Model of the DOROTHY project on footwear multi-site multi-nation production systems (Pedrazzoli P., 2009). DOROTHY also addresses the issue of capture, retrieval and reuse of product data.

Having an understanding of these issues and the challenges for product development teams in the Clothing, Textiles, Leather, Footwear and their extended Supply Chain sectors, this paper presents a new business framework based on ICT technologies that facilitates product development integration within these sectors.

THE PROPOSED BUSINESS FRAMEWORK

Most footwear manufacturers follow a traditional product development approach:

- Review of design and market demand information. Basic design concepts, shaped by customers providing specifications and design parameters, are created;
- Performance aspects of the end product are defined either in very detailed form (specifications) or in broad terms (often attribute based);
- EHS requirements related to the end product for the market and user group concerned are identified;
- Potential candidate materials are considered and then those are identified that will actually be used in the development process. Sufficient data on EHS and performance/comfort related properties of these materials is obtained;
- Sample quantities are obtained for production and, possibly, testing purposes
- The processes to make the product are established and the production of the prototypes is organized;
- Prototypes are produced for several different product options;
- These are subjected to testing, field trials and the results evaluated;
- Further evaluation of supply terms, costing and pricing for each prototype takes place, involving the extended supply chain;
- The optimum prototype(s) in terms of legal, technical, supply chain and financial considerations are selected and submitted to the customer for approval;
- Based on the results of evaluation at each stage and through communication within the extended supply chain, the design, materials and processes may be changed;
- The final step is production of the new product.

The proposed concept is a Business Process Re-engineering approach using ICT enablers facilitating exploitation of Knowledge and Virtual Prototyping. By overcoming some of the constraints of ICT tools, in particular, interoperability, ease of use and visualization-simulation issues, the above-mentioned framework could evolve as follows:

- Basic design concepts are created. ICT allows for quick exchange of enquiries, quotes, graphical and non-graphical information between interested parties;

- Performance aspects of the end product are defined and captured, in either detailed or attribute form, using online tools;
- EHS requirements related to the end product for the market and user group concerned are identified very quickly from databases;
- Potential candidate materials are searched on Materials Libraries or the possibility to have custom made materials supplied is investigated on-line. Decision making tools indicate candidate materials that meet Performance and EHS requirements, thus eliminating testing;
- Virtual Prototypes are created from different combinations of selected candidate materials. These are visualized-simulated and their Performance/Comfort properties calculated quickly through complex mathematical tools running under a simple Graphical User Interface. Only the optimum virtual prototypes are selected. The number of physical prototypes that need to be produced is reduced dramatically;
- Material requests for prototype production can be made on-line;
- The processes and production organization aspects to make the product are established;
- Only a few prototypes are produced and subjected to limited testing, field trials and evaluation, as well as demonstration to customers;
- Information regarding supply terms and cost can be exchanged very quickly and accurately online;
- On approval from the customer, production may commence.

Taking all the above into account, a new framework is proposed in this paper, which is developed under the ENVIRO-TEX-DESIGN project, and consists of all those supports needed to make a real business case feasible and in particular:

1. A “Collaborative 3D Virtual Design Platform” providing users with information and tools as well as an integration framework for the whole platform. It is based on:

- An easy to use collaborative 3D work environment enabling real time interaction between partners. It aims at capturing emergent customer demand in terms of style, comfort as well as health and safety;
- Dynamic real time simulation/visualisation and virtual prototyping capabilities, thus enabling quick decisions on product options. The entire Graphical User Interface (GUI) is web-based limiting the need for purchasing proprietary software by an end user;
- Web-Services enabling a 24H access all over the world.

2. A new knowledge environment based on datasets and on the customer demand/specifications, which interacts with 2D and 3D CAD systems and it is linked to the collaborative platform. Four of these data sets are used on two major components available on the collaborative platform:

- The EHS Decision Making Toolbox that includes:

- EHS requirements defined through customer-producer dialogue, the purpose/usage and geographical market of the product;
- EHS constraints provided by the local/regional regulations. It is the first tool with a global approach to managing EHS aspects for multiple markets;
- A substance and an environmental impact data set linked to both material and process data. This is the first tool integrating product and process EHS management;
- EHS recommendations at design stage along with a 3D visualisation of chemical and toxicological distribution. This is a unique feature not developed before.

- A Performance Evaluation Module that includes:

- Unified material libraries (material characteristics) for the textile, leather, clothing and footwear industries, allowing quick interrelations between these sectors;

- State of the art behavioural models (based on the Interactive Matrix concept for Textiles and Clothing and enhancing the novel VSTB system (Azariadis et. al., 2007, 2010) that calculate performance and comfort aspects of textile, clothing and footwear products through an easy to use interface;

- Graphical visualisation capability for the calculated performances indicating, for the virtual prototype, the level of compatibility compared to expectations.

3. A “Production Organisation Framework” that includes:

- A partnership-extended supply chain network based on a database of suppliers and their products and online forms for communication;
- A Data Sheets generator based on historic process data enabling automatic generation of production data sheets through retrieval of available knowledge, as well as data capturing tools for storing knowledge for future use.

IMPACTS OF THE NEW BUSINESS FRAMEWORK

The proposed business framework integrates the sectors of textiles, leather, clothing and footwear. This facilitates the access of footwear manufacturers, in particular, to the vast pool of textile sources. It also facilitates the involvement of non-specialist purchasing persons from the retail/institutional sectors in development work. The widening of the Supply Chain, combined with the use of Materials Libraries and ICT Virtual Prototyping tools is expected to increase product innovation, since developers will attempt to investigate new production options and material combinations.

The most dramatic impact, though, may come from the use of Virtual Prototyping itself. The number of required physical prototypes required may be reduced dramatically, thus, cutting costs related to materials, setting up equipment, production of samples/prototypes and subsequent testing and evaluation. Due to extensive use of ICT solutions, communication between supply chain partners is also faster, which combined with reduced physical prototyping requirements causes the time to market to decrease.

Significant savings are also achieved through improved compliance to EHS requirements from the stage of material selection, to organizing production and launching the product onto the market. The costs of non-compliance are significant and any material or end-product failure to EHS testing may erode expected profits.

IMPROVEMENT AND FUTURE WORK

The new Business Framework will be assessed through a Footwear Business Case within the ENVIRO-TEX-DESIGN project. The results will determine the extent to which the framework is feasible with the modern technological advances.

The holistic (material-product and process) approach to EHS assessment for any market around the world is innovative and unique. Environmental assessment is based on the Chemical Emission Factors. Future work could also include carbon footprint, process emissions, water usage and other measurable environmental aspects.

The use of Virtual Prototyping and Performance Evaluation by applying powerful advanced techniques, through simplified GUIs is the main change facilitator in the framework. Using the power of modern ICT and through developing improved behavioural models, it is expected that many properties of end products can be assessed without resorting to physical testing. These models need to be improved to be more accurate and to cover a wider range of properties (e.g. colour fastness).

Acknowledgments

This work is carried out under the EU funded project "Virtual Collaborative Design Environment - ENVIRO-TEX-DESIGN", FP7, Project No. 213903.

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