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A CONCEPT OF MANUFACTURING SYSTEM ENABLING THE CREATION OF CUSTOM-FIT PRODUCTS

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ABSTRACT
The ambitious scope of the European initiative CUSTOM-FIT, a Framework 6 Integrated Project, is to create a fully integrated system for the design, production and supply of individualized custom - products. Personalized and customized both to fit geometrically and functionally the requirements of the citizen for (initially) the medical & consumer goods sectors. In the paper the following subjects are described: projects' background, output descriptions, technical, scientific, social & policy objectives, description of work and the enabling technologies
Keywords: Rapid Manufacturing, Mass customisation, Time Compression Technologies

1. INTRODUCTION
A radical change in manufacturing is starting to occur (see Feenstra F., et. al., [1]). Rapid Manufacturing (RM) is based on completely new additive manufacturing techniques that produce fully functional parts directly from a 3D CAD model without the use of tooling (as reported from Wohlers T, [2]). This offers the potential to change the paradigm of manufacturing, service and distribution with opportunities for producing highly complex and customised products. CUSTOM-FIT is an industry led FP6 Integrated Project co-ordinated by Delcam plc, initiated by TNO Industrial Technology and Loughborough University. The partnership covers the complete vertical value chain from fundamental research, design and simulation up to the incorporation of a complete system, including end users.

The consortium is made up from broad base of some 32 partners (of which 35% SME) from 12 countries forming a complementary set of roles with their own individual expertise in the field. The proposed CUSTOM-FIT management includes a General Assembly, a Management Board, a Scientific and Industry Board and 8 Work Package Committees. The social aim of CUSTOM-FIT is to improve the quality of life by providing products to the citizen optimised to their individual geometrical shapes and requirements. This will improve the performance & comfort and at the same time reduce injuries (Alcaniz M., et. al., [3]). The current production technologies are not able to automatically manufacture one-of-a-kind customised products and Custom-Fit is therefore the pioneer in using knowledge based (Rapid) manufacturing techniques. Specific objectives of the project are summarised as:

1. Technical & Scientific Objectives: *Capturing of data* (f. i., Scanning, colour capturing), *Processing of captured data* (Input of all captured data, representation of graded structures, integration of non- geometrical requirements), *Design of product* (algorithms for neutral format and translator, mathematics and method to represent and design graded structures within a geometry and to transform subjective non-geometrical requirements into objective requirements), *Manufacturing of the product* (materials to be processed Ti&Co alloys, engineering plastics, bio-

compatible polymers, adjustment for processing other materials, manufacturing speed 25% faster than competitive manufacturing speeds), Final verification of product (CEN, ISO).

2. Social & Policy Objectives: *Profound and credible know-how* of the impact of the CUSTOM-FIT technology on supply chains, citizens, the economy and the environment (Porcar R., et. al., [4]), *Several operational training programs* on the implications of CUSTOM-FIT technology for the consumer, A design philosophy, *Direct dissemination* to 15% of all relevant bodies, *Successful commercial exploitation*, Four successful case studies by the industrial partners.

Although customisation of products (Hague R., et. Al., [5]) has been recognised as having important commercial potential for many years it has generally been limited to relatively superficial cosmetic variations such as the choice of product colour. The additional cost associated with customisation has been a major barrier to its wide spread adoption. The development of the fully integrated CUSTOM-FIT technology as a process will enable the determination of rapid product requirements, CUSTOM-FIT product design and tool-less rapid manufacturing (Wimpenny D.I, et. al., [6]).

2. CUSTOM-FIT EXAMPLES

Some examples have been selected as test cases for the project and will illustrate its goal (some of them are presented in figure 1).

Prosthesis are external attachments (nose, eye, ear, arm and leg), used as substitute due to the defects caused by birth defects, accident or cancer. For an amputee traditionally the socket is made using a negative and positive plaster model. The negative reproduces the stump topology and is produced by wrapping a plaster bandage around the stump. The positive is made pouring liquid plaster into the negative model. When the plaster becomes hard, it needs to be skilfully and correctly shaped for the socket's construction. Often several fittings are required before sufficient comfort is achieved. The new CUSTOM-FIT approach will be to scan the stump first, model the socket using new CAD techniques that will model variable graded materials and produce the socket with the LMT.

Implants include cleft pallet patients, trauma and amelioration (jaw bone fracture) of the dental base of the jaw, hip replacement and bone replacement for cancer patients. The aim within CUSTOM-FIT is to reduce the lead-time and investment in labour of conventional methods of manufacturing by using new knowledge based manufacturing methodology.

Helmets protect the user against injuries. By applying the RM a technology helmet that are custom made to improve fit and so reduces the risk of Traumatic Brain Injury (TBI) will be produced. The inner cushioning will be designed to fit the rider's head. This optimised fit will also increase the comfort and therefore improve the safety by reducing tiredness and improve attention in traffic. Furthermore, a customised inner cushioning will allow the possibility of integrating spaces for integrated communication devices. This kind of integration of added functionally will be produced as a part of the signal component product.

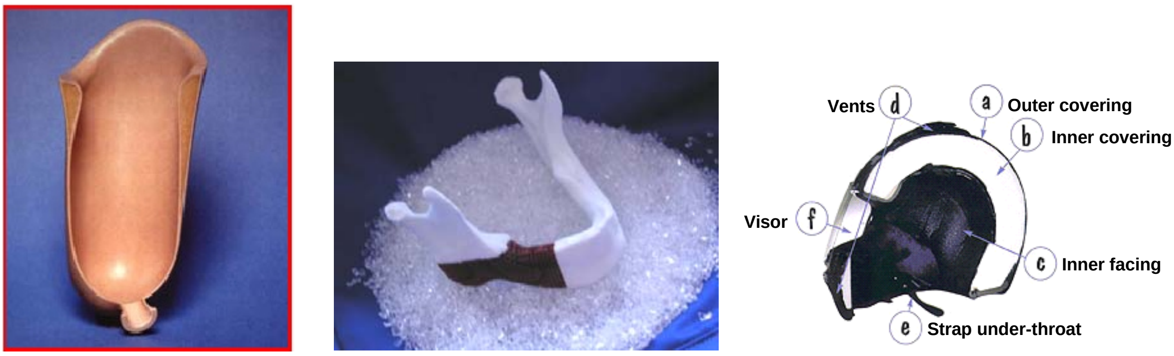

Figure 1. Prosthesis socket, implant and helmet

3. RAPID MANUFACTURING PROCESSES, MACHINES AND MATERIALS

The technological aim of CUSTOM-FIT will help transform the manufacturing sector of Europe into high-tech industries. This will be achieved by developing and integrating a completely new and breakthrough manufacturing process delivering unrestricted geometrical freedom with graded structures of different material compositions. Four basic methods of production have been identified as potential machining techniques for Rapid Manufacturing purposes. All of them are potentially capable to depositing graded material to create single functionally graded components; all are currently in a development phase. In each case the research organisation is partner of CUSTOM-FIT, and will place their expertise at the consortium's disposal; then the most suitable parts will be used to establish a best of all worlds' new CUSTOM-FIT process.

High Viscosity Jetting (Loughborough University) is based on displacing a small drop of a high viscosity printable material to a desired location on a substrate. The HVJ process consists of a single jetting unit scaled to a block of multi-jets controlled in parallel to deposit the layer of a desired pattern. The jet units are controlled by the jet pressure, the distance from the substrate and the length of the jetting pulse. The system will have the potential to be the first true generic manufacturing process, enabling polymers, ceramic and metals to be processed with the same basic approach.

Metal Printing Process (SINTEF, Norway) is aimed at developing the equivalent of a high- speed photocopier that produces three - dimensional objects from powder material. Layers of powder are generated by attracting the metal or ceramic powder to a charged photoreceptor (PR) under the influence of an electrostatic field. The attracted layer is deposited on a building table where it is consolidated. More photoreceptors will be used to sequential deposit different powders in the same layer. The process is repeated layer-by- layer until the three-dimensional object is formed and consolidated.

Multiple deflection continuous jet process (TNO Industrial Technology, The Netherlands) is similar to a standard ink-jet system but it can currently use fluids with viscosities of approximately 300 mPa/s (at jetting temperature). With this system a continuous stream of droplets is produced, the separate droplets are then electro - statically charged and deflected to form the desired pattern. Because of the higher achievable viscosities, stronger end products can be produced. Since it is a selective deposition technique it is possible to use several types of materials within the same product.

"Upside down" 3D printing process (De Montfort University, UK) is based in a polymer powder that is positioned precisely where it is required by the selective application of a temporary binder/electrostatic charge. Excess powder is removed and the material that has been deposited is fused together. This process is continuously repeated adding building and supporting materials until the desired functionally graded object has been completed.

As mentioned, in CUSTOM-FIT we face to a big problem since RM does not really exist at the moment and RP processes are currently being used for Rapid Manufacturing with the problem that these machines have not been designed for these finished applications. Consequently they produce parts with poor or variable surface finish, tolerances that are difficult to maintain and the repeatability of the processes is often poor with very little real time adaptive control. Also, when manufacturing small volumes of prototypes the removal of support material is not a major issue but this will become so if there is a need to produce hundreds of thousands of parts in a short time. The speed of current layer manufacturing processes is a major issue with conventional manufacturing processes with injection moulding being 10 to 1000 times faster in material throughput.

The build envelope of current processes has been a problem but with the inclusion of Materialise as a partner who is producing very large stereolithography machines this problem is expected to be overcome. RM offers a significant opportunity for new materials (especially nanomaterials and composites) to meet the demands for controlled porosity and graded materials. As a part of the project new nanomaterials and composites will be developed and tested to meet the requirements of functionally graded components identified in the proposed aforementioned test cases.

Nanocomposite materials consist of nanometer-sized inorganic particles dispersed in a polymer, and are an important upcoming new class of materials. The combination of nanocomposite materials with the use of additive manufacturing processes, such as the proposed here, opens up a whole new horizon in component manufacture, as materials tailored to have different function can be deposited directly at the location where they are needed. In this Integrated Project, research will be performed in the application of nanomaterials needed for the specific products that will be made by the CUSTOM-FIT process.

5. CONCLUSIONS

The ability to produce customised products, which are matched to the specific needs of an individual, is expected to have a major beneficial impact on the quality of life of European citizens. CUSTOM-FIT, an Integrated Project is identified as highly ambitious with corresponding breakthrough and potential impact and therefore it is requiring an enormous effort and drive to achieve the objectives. The carefully selected consortium with a balanced partnership with complementary expertise in different sectors and geographical spread provides the project with a sound basis to be successful.

This IP has the ambition to develop and integrate this system in order to enable complex customised products to be produced from unique combinations of (nano-scale) materials without the need for dedicated production tooling. Products will be directly produced from 3D computer data without human interference. This will be undertaken in the fields of computer science & engineering (to capture the human geometry and to design the Custom-Fit products), material science (invention of sustainable nano-materials & processes), business re-engineering and logistics (brand development, supply and demand chains).

Rapid Manufacturing (RM) is defined as “the use of an additive manufacturing process to construct parts that are used directly as finished and functional products or components”. Since RM is not existing yet and currently the state-of-the-art involves only Rapid Prototyping technologies, which are focussed on single pieces for evaluation purposes but not being suitable as end products. Only in some applications RP can be applied to make functional parts but this is more “RP+” than mature RM. The intention is make a step change with RM and overcome basic limitations as f. i. speed, accuracy, finish and costs all of which restrict present uptake up of the technology.

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