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Interactive learning tool in product development for injection moulding

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Abstract

This work is part of a methodological renovation project from Ingeniería de Fabricación Innovative Education Group, from University of Las Palmas de Gran Canaria. It has developed learning materials for courses in Manufacturing Engineering that can be used in several degrees. In this first learning material, it was decided to take a plastic injection mould as a teaching resource, and can be summarized into design and manufacture a plastic injection product whilst developing a teaching material aimed to explain the necessary stages to make an injection mould, as well as the manufacturing processes related to it. All this work has generated a lot of educational material for both laboratory practices and multimedia. Abundant information generated has been used to develop an interactive electronic publication. Finally this learning material has been chosen by the Publishing and Scientific Diffusion Service from this University, as a new line of work in publications of educational innovation.

Peer-review under responsibility of the Scientific Committee of MESIC 2015

Keywords: Autonomous Learning, Blended Learning, Interactive Learning Tool.

1. Introduction

The Group of Educational Innovation in Ingeniería de Fabricación (GIEIF) at the University of Las Palmas de Gran Canaria (ULPGC), emerges as a natural evolution of Procesos de Fabricación research group, and both are included within the Centro de Fabricación Integrada (CFI). The GIEIF has started a line of work for the

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development of interactive learning materials, which has its origins in the development of a project of educational innovation and methodological renovation for the design and manufacture of teaching resources. The basic objective is that these materials could be used mainly in the different subjects in the area of knowledge in Ingeniería de los Procesos de Fabricación, or other complementary to improve horizontal and transversal coordination in the new degrees.

In this project, it was decided to take as a first performance in this line of work, a mould of plastic injection as a teaching resource reference. The reason was that their development would encompass virtually all the thematic blocks in which many subjects of introduction to manufacturing engineering of several degrees are structured. Also all the materials and resources developed in the project could be used on more specific subjects, such as which address the advanced manufacturing processes and forming of plastic materials. In addition these are the main areas of work of the research group, so it already had a wide experience that it should take its teaching dimension.

It has counted with the participation of students of the new degree in Engineering in Industrial Design and Product Development. They are students who are endowed with capabilities especially suitable for the development of graphic materials attractive and well structured. These have shown also have sufficient skills to be integrated in multidisciplinary teams, even in advanced stages of the development of new products.

The main objective of this work is the exposure of the process followed for the development of this educational material, which has resulted in the development of an interactive electronic publication. This document has been produced in collaboration with the service of publications and scientific diffusion of the ULPGC, and has opened a new line of electronic publications of educational innovation.

2. Background

This educational innovation project called PIE2: Thermoplastic Injection-Additive Manufacturing, payed special attention to the implementation of new strategies and educational solutions, aimed at the adaptation of the teaching towards the European Higher Education Area (EHEA). Among them is the development of the teaching dimension of R&D projects, knowledge transfer, integration of teaching and research activities, and involvement of the industrial environment with teaching.

One of the basic objectives of this project was to facilitate the incorporation of new technologies that improve systems traditionally used for classroom teaching. With them it would be covered aspects that are hardly carried out efficiently in these sessions as: the use of graphic media, aggregation of contents, interrelation between concepts and use most of the benefits that facilitate transmission of information and support new media. These technologies are those of the scope of the current engineering work, and are essential to achieve the so-called digital competence. Other main objective of the project was the coordination of supplementary subjects within the same degree, as well as content common to different degrees in the area of knowledge in Ingeniería de los Procesos de Fabricación and related. This action fit within one of the lines of priority action of the GIEIF, which is the teaching coordination vertical, horizontal and transverse. It was thought to generate didactic material that could be used in many subjects, from different points of view and with different levels of depth.

This project was submitted to an internal call to the ULPGC to educational innovation projects, but was not granted specific funding. With the conviction that this project had great potential, the GIEIF decided to continue it by own resources of the research group. It was wanted to have the collaboration of students through the realization of projects end of career (PFC) of extinct degrees, and work end-of-grade (TFG) of the new degrees, from the beginning. The work was initiated through a PFC of the old degree of Industrial Design Engineering, oriented towards the definition of plastic product that they wanted to develop, and the preliminary design of the mould that would be used. There was continuity to this PFC through a TFG of a student within the first graduates from the new degree in Industrial design and product development Engineering. This gave a great impulse to the project and we will discuss about it in more detail in the following sections.

3. Methodology

As a starting point, it was decided to use as main theme of educational innovation project the injection process in plastic materials. This was due to the fact that this process is the most versatile and used in the manufacturing of

these materials in continuous development. In addition because rapid manufacturing of tools, Rapid Tooling, is one of the main lines of work in Fabricación Integrada y Avanzada research group. And also because it had the necessary resources to develop this project, in laboratories of CFI and Mechanical Engineering Department (DIM).

A mould as a tool of the process may be related to the content blocks of many subjects of this area of knowledge. In the subjects of fundamentals of the manufacturing processes, it may be related to metrology through the geometric specifications of the product and the mould components. Injection can be considered a process of melting and moulding, and thus can be analysed the capabilities and limitations of injection compared with other processes in the same area of conformation. The injection mould components are: plates, guides, ejector pins, and others; they are obtained through processes of deformation and cutting, and machining processes of removal material. The moulds by themselves are mechanisms, which can become quite complexes, where different joining and assembly solutions of its components are used. Finally figures or major cavities of the mould, are usually generated using advanced manufacturing processes to achieve the required geometrical complexity. In the more specific subjects can be related to the programming of numerical control machines for milling and electro discharge machining (EDM). It can also be covered rheological analysis and simulation of the injection process. Additionally it can be addressed additive processes for manufacturing prototypes or inserts for major mould cavities or cooling system.

From the beginning was raised collect all possible audio-visual material from the different activities to be developed. Besides, the different resources that would be generated in the process of product development would be used in labs, to reinforce and complement the theoretical content of different subjects that could make use of them. This methodology could be applied to any type of product, but it was decided that it would have a clear identification with a self-developed product. It was decided to carry out a product that would take implicit the visual identifier or logo symbol of the ULPGC, and after assessing various alternatives finally was set at a promotional element type keychain. This could be used by the institution to give as a gift in events such as: congresses, conferences, seminars or others; or simply to give students of first registration. This product was originally formed by a main body, and two additional parts were assembled allowing include identifiers of the events and the organizing unit of the ULPGC. Once evaluated this preliminary design it was decided to redesign it to incorporate an element of digital information storage. This was the starting point of the TFG that gave birth to the development of interactive learning materials. It may include information deemed appropriate about those events, within the memory chip type COB (Chip On Board) integrated. This product also has the added value of being developed, and manufactured with the available resources by the Centro de Fabricación Integrada of the ULPGC.

Based on the preliminary design, the main objective of the TFG was the partial redesign of that product to include a memory of digital storage, Fig. 1. It was complemented by the design and development of a plastic injection mould of modular typology using inserts interchangeable, it allowed its manufacturing through available resources by research group, Fig. 2.

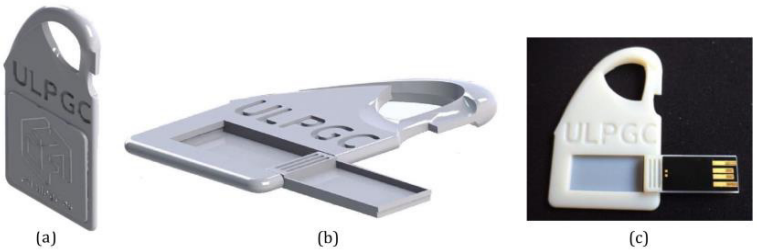


Fig. 1. (a) Preliminary design; (b) final redesign; (c) functional prototype.

To develop of this work was necessary to use CAD tools for modelling parts to be injected, and a whole mould and metal inserts that would form the major cavities. The tools for the manufacture of these cavities using the EDM process were also designed. Subsequently the assembly of different components and systems of the mould analyses were performed. They were carried out simulations of the injection of these parts using CAE tools, in order to achieve a viable and feasible design. Once the final design was almost closed, an additive manufacturing technology

was used to perform a functional prototype, Figure 1. This allowed us to identify some elements of improvement in design, both from the functional to a more simple and economical manufacturing standpoint. After the incorporation of these amendments, the final design was closed, and could move to the manufacturing phase.

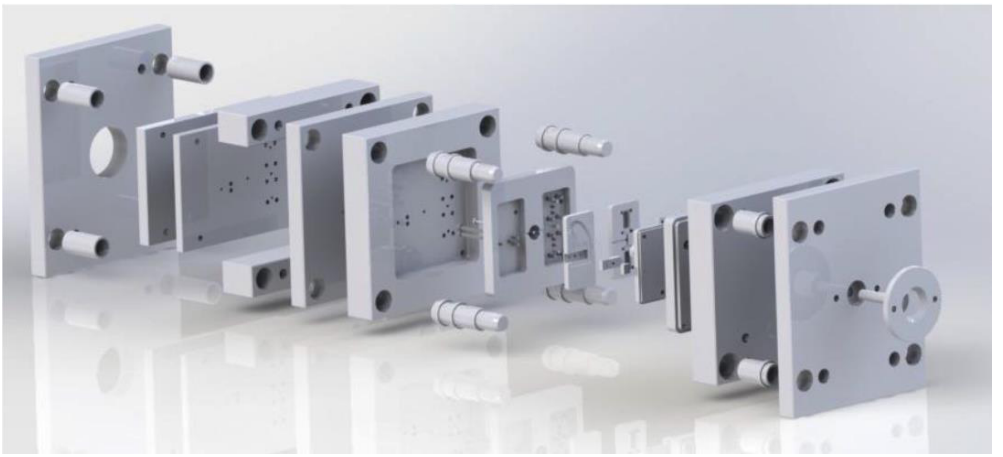


Fig. 2. Mould exploded view.

It was decided to manufacture a mould prototype, with the upper part of the geometry of the product, in order to validate the proposed solution. In turn allow more precise planning of the required manufacturing processes as well as to identify its critical points. It was necessary to manufacture some of the electrodes for EDM that were required, Fig. 3. It was used a vertical machining centre Ibarmia VCM 1000 available in the laboratory of Tecnología Mecánica of DIM. This old equipment had undergone a change of numeric control to the new FAGOR 8065, and these works also allowed checking functioning and adjusting some systems of the machine. Next it was performed programming and simulation of these machining by CAM tools, and they were finally executed in this machining centre. First a plastic material for easy machining was used to generate a prototype of these tools, which allowed us to identify some problems of manufacturing thatwere corrected for final machining. The definitive tool was held in high purity electrolytic copper for use in a CNC machine of EDM, available in the laboratory of Fabricación Flexible of CFI.

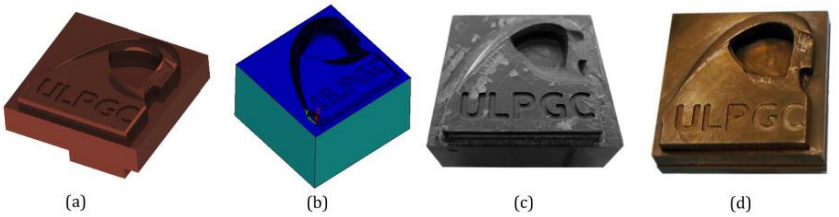


Fig. 3. (a) Electrode model; (b) machining simulation; (c), machining test; (d) final electrode.

There were 2 sets of electrodes, 4 in total, in order to achieve the final geometry in two types of surface finish that would highlight and achieve an aesthetic effect in different areas of the part. Also some EDM tests were performed to define the most suitable process parameters, and adjust positioning, orientation, and the electrodes penetration by using optical measuring equipment in the laboratory of Metrología Dimensional of DIM. Prototype mould plates and cavities were machined with the EDM machine ONA BD300 available in the laboratory of Fabricación Flexible of CFI. Additional machining for the sprue, runners and gate were finally completed in plates.

When plates were finished, they were mounted in the structure of other mould available by the group, to make first injection testing in injection machine from laboratory of Tecnología Mecánica. It was necessary to carry out an intense work of adjustment and testing on this renewed old equipment, due to some problems on this machine, limiting its application to this prototype mould. Finally, it was possible to perform these tests of injection and injected parts that have allowed validating the adopted solutions of design product, Fig. 4.

(a) (b) (c)

Fig. 4. (a) Prototype mould; (b) pre-serial injection; (c) end part injected.

This work described above was done by a working group of the GIEIF that joined a student doing her TFG, under the project of educational innovation. The abundant graphic information generated was used to generate the multimedia teaching material. This material consists of an interactive PDF file where all phases of the project of this product development are collected, and which students can use of autonomous way from its subject virtual classroom, Fig. 5. Are included a lot of images, videos, and even two interactive graphics window, one for the product itself and another for mould. It can be analysed in detail each and every one of the components, using visualization, measuring and sectioning tools of this module.

(a) (b)

Fig. 5. Original training material pages.

4. Results

This initial teaching material was presented to the Service Scientific Publications and Diffusion (SPDC) of ULPGC, to evaluate the feasibility of it publication. It was valued very positively by managers and presented to the Editorial Council of the SPDC, which has considered it appropriate to start a new line of interactive electronic publications in educational innovation. Raised various alternatives for this publication as documents in format of browsers, and links to multimedia repositories of contents were evaluated. It was decided finally to maintain the interactive PDF file format, so that all content is in a single file that could be used without a web connection. This teaching material was generated initially intended for internal use by lecturers in the area of knowledge, and was not raised to be published. That is why it was necessary to make an adaptation of formats, a better structuring of content,

and complement some sections. There was also a major constraint referring to the size of the file, which should be a dimension less than 20 MBytes, to facilitate distribution and its use in platforms Moodle type.

(a) (b)

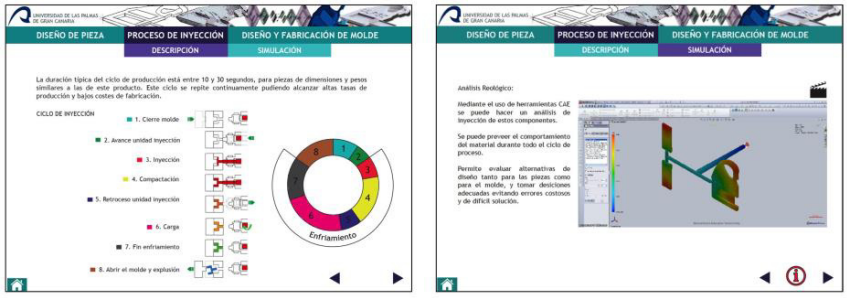
Fig. 6. (a) Publication summary; (b) user instructions.

At this stage of adaptation of this teaching material, several objectives have been raised. The first was that the graphic information predominated over the text, to make a document attractive and motivating. Anyone interested, regardless of their academic level and autonomously, could get a general idea of what means the product development process. Another goal is that the contents were structured, so that it allowed the user to easily scroll through the document, locate the content that wanted to see, and help you take advantage of all resources included in the document by using a few simple instructions, Fig. 6 and Fig. 7.

(a) (b)

Fig. 7. (a) Geometric specifications of COB; (b) interactive graphic window of product.

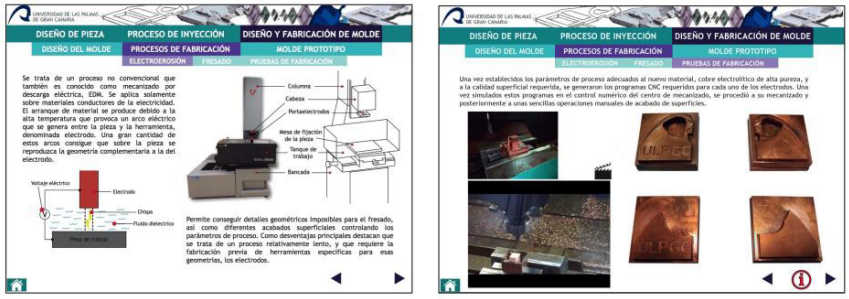
The publication is included in the interactive series of the Journal of Educational Innovation of the ULPGC, and its title is Desarrollo de un Producto en material Plástico por Inyección (I). Is already working on the second part of this publication, including the manufacturing of the final mould, injection testing and production of a first series of this product. The resources that can be found are all homemade and range from simple diagrams, tables and figures, to videos on computer simulations and various manufacturing processes, Fig. 8 and Fig. 9.



(a) (b)

Fig. 8. (a) Diagram of the injection cycle; (b) rheological simulation video.

Design specifications of product and the characteristics of the designed parts are presented: material, dimensions, volume, weight. The need for a prototype is justified and additive manufacturing technology employed is described. An introduction to the manufacturing characteristics of plastic materials, focused on the injection process is done. The solution adopted for the proposed mould, and introduction to basic processes used in their manufacture is described. The required steps, resources used and the results obtained at different stages of the process are displayed.



(a) (b)

Fig. 9. (a) Description of EDM process; (b) video machining of EDM electrodes.

It can also be found two interactive graphic windows, one for the product and one for mould. In the first, the user can display both parts, assembled or isolated, from any point of view. It can also be checked all the constructive solutions by using multiple tools for viewing and measuring, Figure 7 (b). In the second you can interact with the mould as a whole, and can isolate each of its components, see how they are assembled, analyse the functions of each of its systems. A very interesting tool in this case is the visualization of sections, which can be applied on different axes to be able to see all the internal elements of the mould, Fig. 10.

Various applications of this material are planned from the academic point of view. In a first contact may be at the beginning of a course of introduction to manufacturing processes. In this way students get a quick idea of contents to address in the subject you are studying. This material would be available for students in the virtual classroom, so they can view it and analyze it before receiving some of the specific contents that were going to be explained in the class sessions. In the classroom it would be created debates on various aspects, arising doubts would be clarified, justifying the solutions adopted, presenting possible alternatives, and is complemented with a level of detail appropriate to the degree and subject in question. In some of the scheduled lab practices, generated resources and the equipment described in this publication would be used. This would allow to get a greater interest in practise session, and achieve a good integration of the theoretical and practical contents of these subjects.

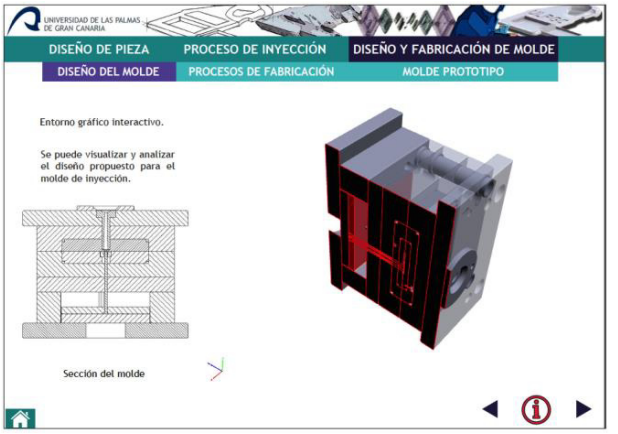


Fig. 10. Interactive graphic window of mould.

It has begun to use this publication as pilot test, in the course of Procesos Industriales of third year of the degree in Industrial Design and Product Development Engineering. Students have shown a participatorier attitude and higher interest to learn more about a work in which has participated a mate of the same degree of previous promotions.

5. Conclusions

This project has achieved an internal collaboration pulse inside of group of educational innovation, involving resources and people to take advantage of the research experience in generating a useful and versatile teaching material. It has opened a new line of work of developing interactive training materials with institutional recognition, which allows you to make profitable the effort that goes into this work in the academic field.

These projects are forced to maintain operating some laboratory equipment that otherwise, because of its sporadic use, may deteriorate easily. The collaboration of students allows the development of works with great interest that the academic activity, research and management of the Faculty could not achieve them in reasonable time periods. It is very gratifying to see how the students develop their abilities with own materials, which consult independently, and then show you a high interest in deepening the content covered in the courses that you teach. It is very satisfying to see how students who are integrated into these works apply the skills acquired in the courses that you teach and others from the same degree, and their experiences in the development of materials that will help partners of the following promotions.

This type of actions allows you to take advantage of the enormous potential of hours of work that students have to be in subjects as external practical or work end of title in the new degrees. At the time that is given out to students who are interested in this type of work, this is used to improve and coordinate academic activities of the institution where you develop your professional work.

Acknowledgements

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