EXPERIENCES OF PRODUCT ENGINEERING CONCEPTUAL DESIGN WITH PATENT DRAFTING

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Abstract

This paper reports an education experience on product engineering conceptual design and its relation to patent drafting conducted in a technical university. Students have been required to draft patents since the 1993/94 academic year. The experience shows that drafting a patent is a good help to improve product designs and also to obtain new alternative solutions. This teaching system is contrasted upon completion of courses with anonymous student opinion polls. This long research work has resulted in a Product Engineering course in product innovation through a structured process in order to obtain a patentable Conceptual Design and to draft a patent. The present paper summarises this process. A case study of an old patent shows several items that serve to improve the design and are frequently repeated in every new patent draft. Several patent applications were made with students. The Conclusions section provides a list of characteristics that improve this general process of conceptual design when including the drafting of a patent.

Keywords: Design education, Conceptual engineering design, Early design phases, Creativity, Patents

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1 INTRODUCTION

Creativity is an essential part of the constant innovation process conducted in leading companies that make engineering design products. Patent applications are a system to protect new products from copying.
The objective of this paper is to present the results of an educational experience on the innovation process of product design refined by students' opinions gathered at the end of courses where the Conceptual Design (CD) phase is regarded as especially important. Some of these courses, e.g. Engineering Projects, Innovation and Patents, Product Engineering and Technical Systems, were offered from the 1992/93 academic year, which were based on the knowledge then given in the university, to which contributions were gradually added from several publications such as: Systematic approach to the design of technical systems and product (VDI 2221, 1993), Total design (Pugh, 1994), or Engineering design: A systematic approach (Pahl and Beitz, 1996). The use of creativity techniques, together with basic patent drafting and the improvements in the design resulting from this task, was the main interest of this research experience, which eventually materialised in as a Product Engineering course.
The motivation behind this experience lies in the belief that the university must encourage in students a spirit of innovation for product engineering and provide them with knowledge of and practice in engineering design, as well as instruction in patent drafting. In this way, university students would meet today's expectations of what a product engineering designer should know. An example of a patent application written with students is presented below.
Students' final product engineering design works are typically evaluated on the basis of the "elegance" of their product solutions, which means simplicity of solution implementation, minimum consumption of resources, full functionality, and social interest. However, in Product Engineering (PE) courses students are also required to present a basic patent draft of their solutions. This is a great challenge for students, and goals are rarely achieved to the full, but students learn and get practice in how to produce new excellent designs.
The process of patent drafting has been repeatedly observed to be generally helpful in:

- Making inventive ideas more specific
- Finding new alternative solutions.

2 PROCESS

A structured process is followed in the PE course by which students present a new engineering design product with its corresponding basic patent draft.
Three main stages of Conceptual Design (Lloveras, 2011) are involved: Directed Conceptual Design, Defined Conceptual Design, and Viable Conceptual Design. The process is wrapped up by the drafting of patents. It is important to note that these stages are interactive in the design work and iteration of needs.

2.1 Directed Conceptual Design

This first phase starts with students producing a list of problems to solve, one of which is selected and analysed. A direction of a Conceptual Design must be obtained to solve their problem. At the end of this phase a preliminary architecture of product is obtained as directed conceptual design.
This phase is divided into the following steps:

2.1.1 List of problems to solve

Tasks leading up the final assignment start at the beginning of the course. First, students gather in groups and are required to draw up a list of problems related to new social or individual needs, needs poorly solved by current products, or new products. At this point students must not provide any technical solutions to these problems because a list of technical solutions implies a specific way of solving a problem that closes the door to other possible solutions.
Next the groups choose a problem to solve from their list of problems, with the tutor's guide and consent. The fact that it is their own choice acts as a motivation for students to do the work.

2.1.2 Applied creativity to search

The creativity of students begins with their search for a new product that solves some part of their problem of choice.
In order to inculcate a spirit of innovation and creativity among students, they are asked to do some practical exercises to find a new product or improvements in existing products. Creativity techniques such as brainstorming, analogies, Mind Maps (Buzan, 2005), Morphological matrix (Zwicky, 1989), Check-list, or TRIZ (Altshuller and Shulyak, 2008) are used.
Each work group applies these techniques to their problem to come up with possible solutions that will lead to the development of a new product or a new part of an existing product.
Making a new product requires thinking and rethinking about the topic to innovate, and giving many ideas of solution and testing them before picking up the best.
The definition of the best CD requires a review the State of the Art, as well as the use of creativity techniques and design tools.

2.1.3 Review of the State of the Art

The design process of new products requires confirmation that the developed design is new, i.e. not part of the State of the Art. For this reason, it is important to carry out a search of similar patents in patent databases.
The advent of Wi-Fi connections in the classroom and the use of personal laptops or tablets mean that students can consult patent databases of different countries or international patent organisations like the European Patent Office (EPO, 2016) on the internet. This relatively recent ease of consultation contrasts with the difficulties encountered by students in the 90s of the past century.
These practices of patent search are completed with explanations on patents. The searches made by students are sometimes good enough but are often merely indicative.

2.1.4 General architecture of the product solution and possible alternatives

The first general architecture of the new product is defined with a general description, diagrams, schematic drawings, sketches, or images.
This first task ends with the definition of general and specific objectives based on the direction found to move on to the next phase, i.e. the Defined Conceptual Design.

2.2 Defined Conceptual Design

Actions to define the conceptual design and results of this phase, i.e. defined conceptual design, are listed below.

2.2.1 Actions to define the Conceptual Design

Some well-known design techniques are used:

- Analysis of product functions and interaction with users:
  - Functional Analysis. Functional Analysis System Technique (FAST), (Bytheway, 2007)
  - Analysis of Advantages and Disadvantages of product functionality and improvements
  - User-centred design and ergonomics, (UCD, 2016), (Norman, 2013)
  - Surveys and "House of Quality" of Quality Function Deployment (QFD), (Hauser and Clausing, 1988), (Maritan, 2015)
- Other creativity techniques and alternative solutions:
  - Effects of latency periods. Fist definition of product
  - Inventive problem solving, TRIZ, (Altshuller and Shulyak, 1990)
  - Lateral Thinking (De Bono, 2016)
  - Synectics, (Gordon, 1991)
  - Applied imagination, (Osborn, 2011)
- Product life cycle and Ecodesign strategies, (IHOBE, 2016)
- Safe design:
  - Safe design for people, things and environment
  - Cause and effect diagram (Ishikawa diagram), (Ishikawa, 2007)
  - Failure Mode and Effects Analysis (FMEA, 2016)
- Simplification of design, from Design For Assembly (DFA), (Boothroyd *et al*., 2002)

- Selection of the best alternative solution

Some of these techniques are implemented by students, according to the selected problem.
Other actions are undertaken in this phase, e. g. reviewing the State of the Art for more specific information, especially catalogues and patents, consulting regulations affecting the product, or making a list of functional requirements and product limits.
Additional analysis of technical, economic (market, financial…), social and environmental viability of the defined conceptual design and other alternatives (qualitative justification) is also conducted.
The result of this phase is a defined conceptual design, which is presented as the second assignment task.

2.3 Viable Conceptual Design

The third phase of CD has two parts: actions to analyse the design's viability and summary of results, i.e. viable conceptual design, if applicable.

2.3.1 Actions to analyse the viability of the Conceptual Design

Analysis of the viability of the defined conceptual design and other alternatives (quantitative justification) is carried out. Viability aspects include technical, economic, environmental, and social factors, as well as those related to regulations (which can, in turn, affect various aspects).
Subsequently, the best solution of viable conceptual design is selected.

2.3.2 Features of Viable Conceptual Design

The architecture of the product solution is shown by a description, diagrams, drawings, sketches, or images.
General and specific objectives based on the viable design to obtain the detailed design of the product are specified, followed by conclusions and references.

2.4 Patent drafting

The conceptual development of a new industrial product requires an effort in terms of time and money. In this sense, patents give the right not to be copied for several years, legally preventing third parties from taking advantage of products developed by others.
Drafting the patent of a new product based on the State of the Art related to the new features of the designed product helps defining in detail and improving the invention, as well as spotting new alternative solutions, as discussed in the case study below.
Sometimes a design iteration must be made after drafting the patent.
The final assignment of the PE course consists in the presentation of a basic draft of the patent, namely a short description of the invention, drawings and claims.

3 CASE STUDY

Shortly after the start of the courses of Engineering Projects and Innovation and Patents, several inventions with a possible industrial use and capable of being turned into a patent arose. The patent system was gradually introduced in the courses, first as a general system to protect the engineering designs and then in more detailed. The art of patent writing was taught and practised according to the method of learning by doing. First, the lecturer wrote the patents with the students' drawings and later students progressively participated in the drafting of their patents. Class time devoted to the maturation of ideas and drafting of patent claims also increased gradually over time.
The following case study is an early project arisen from the desire to remove the voltage from unused household power lines in order to increase safety and avoid unnecessary electromagnetic radiation (bio-switch).
The initial idea was to construct a domestic bio-switch, but during the drafting of the patent, new ideas of alternative solutions came up, like adding extra security to have normal current before connecting an appliance.
A new patent was therefore drafted: Automatic device for disconnecting an electrical line below a minimum and connecting with prior checking of short-circuiting and overload (Bargalló *et al*., 1994). Figure 1 shows the scheme of device.

3.1 Short description of the patent

The device is an electrical and electronic piece of equipment that disconnects household power lines while unused and reconnects them (by means of a small current previously injected) upon detection of imminent use of a household appliance, for example. Additionally, prior to connection, the device checks the line for overload, or short circuits, in which case nominal current flow is not allowed.

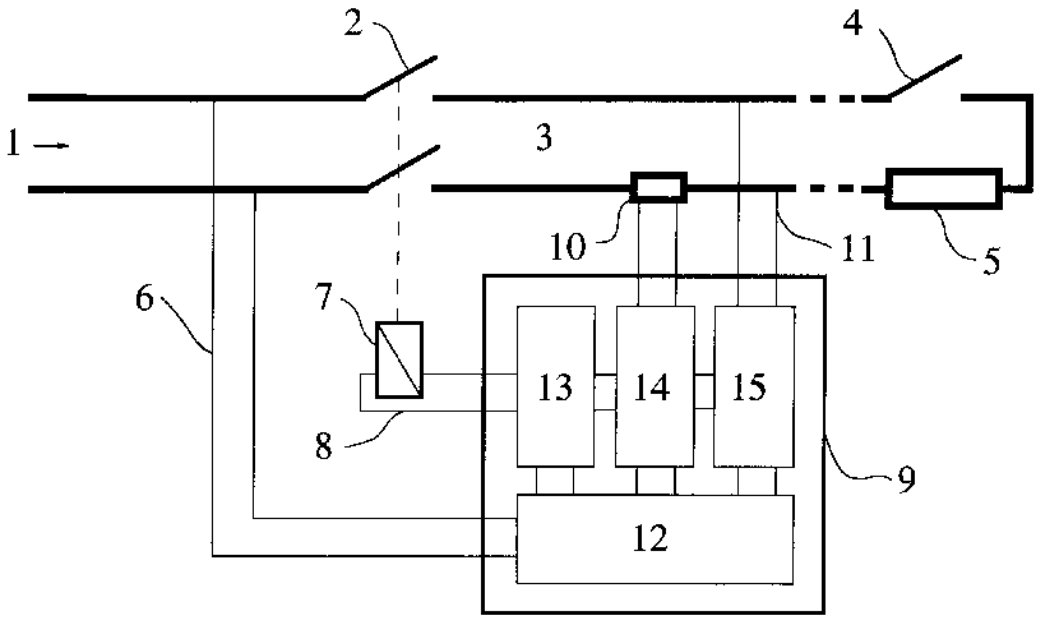

Figure 1. Scheme of blocks of the device with automatic connection and disconnection from a household power line

3.2 Appearance of new ideas during patent drafting

After discussing the essential product architecture and its alternatives during the writing of the first draft of the patent, it was decided to add the line verification for possible overload or short circuits before restoration of the nominal current.

A first patent search showed that it was possible to write two patent applications of this device, with the second being: Electronic device for short-circuit or overcurrent protection in electric lines (Lloveras *et al.*, 1994). This patent application was presented before the first one because it was more general.

This contribution enriched the functionality of the initial device.

3.3 Patent results

The patent application (Bargalló *et al.*, 1994) had 24 claims. The official examination of the State of the Art gave the "A" category for the quality of affectation of these claims with respect other patents. Therefore, the patent is valid and not affected by other patents.

As for the second patent (Lloveras *et al.*, 1994), the official examination of the State of the Art gave several "A" and "Y" categories for the quality affectation of its claims.

These two patents belonged to the university and expired in July 2014, so now they are of free by everyone. The products were not marketed, but when the patents were published, a company showed interest in them and a university/company agreement was done to search related themes.

This early experience to find new alternative solutions by drafting a patent that may end up in two patents has been repeated on eight occasions. Hence, it is considered a good exercise to increase the number of alternatives of solution.

4 EXPERIENCES ON PATENT APPLICATIONS

Now follow some results of patents applications submitted between 1993 and now. Only a few patent drafts of final works done with students become actual patent applications. An average of 2.5 patent applications is made per year, with some years without applications and others with a maximum of five.

It is worth pointing out that universities receive government support to help with patent application costs.
Most patents are drafted with undergraduate students and a few by graduate or doctoral students. The number of students listed as inventors on submitted patents is 195, which is a small percentage of the total number of students.
Submitted patents can be classified into three categories according to their technical complexity: fairly high (25), medium (14), and low (14). These categories are usually correlated with the maturity of students and time available. However, the result has been basically the same: no patent has been acquired by any company, irrespective of its degree of complexity.
The result of examining patents submitted to the Patent Office (SPO, 2016) is reflected in the Report of the State of the Art (RSA) of each patent, which shows the qualities of claims affected by other patents. About 38% of patents had claims affected of "A" category only, which means that no claims were in conflict with other patents, and therefore all claims are valid. 14% of patents had claims affected of "Y" category. Finally, 38% of patents had claims affected of "X" category, indicating that the search of the State of the Art failed to detect similar patents.
The university owns most submitted patent applications. A small percentage of these patents are owned by the companies with which the agreement was signed. In case of sale, half of the profits go to the inventors. However, is not made much effort to promote the sale or use of their patents. Companies of the sector may not have been well informed or have interest in the inventions. Also, neither the tutor nor the students have taken much interest in setting up a spin-off project or a small company from the patents. However, interest has grown in recent years.

5 DISCUSSION

At the beginning of the courses, students are often wary about this patent drafting exercise, but at the end they find advantages about it.
Once a feasible CD that can be patented is defined, it is interesting to do a first draft of the patent, with some drawings and claims. The first independent claim must encompass most State of the Art, trying not to invade other fields already patented, which would invalidate this first claim. This must be born in mind when writing claims. At this point, other solutions not thought of before may come up in the field of solution.
It is also interesting to think like another inventor who sees this draft patent as an inspiration to fill another patent. This exercise can increase the number of solutions and quality of the invention, or even lead to a new patent, as has been the case.
The first patent draft in the final stages of conceptual design allows the invention to be rebuilt and the product design to be improved in an iterative manner. It may also serve as a rough draft in case of presenting a final patent application of a more evolved technical solution.
An interesting agreement with a company was to design a new urban piece of furniture, but the two patents that were drafted do not mention the university inventors. In the context of reference, general university-company communication could have been improved.
The direct impact of the patents on the industrial network has been admittedly low.
The following proposals for the immediate future have arisen from these experiences:

- Increase creativity in student outcomes and the number of students involved in creative designs of product engineering
- Enhance conceptual engineering design with patent drafting exercises at university
- Strengthen the patent office responsible for managing patents in the context of the university of reference, especially regarding professional patent search and drafting, and patent valuation, but also, the monitoring of patents in the time and the prosecution of infringements
- Increase general knowledge of patents in industrial environments
- Improve communication between universities and industrial companies regarding product innovation
- Promote start-ups around some patent inventions
- Further study the degree of improvement of patent drafting throughout the Conceptual Design process

6 CONCLUSIONS

The processes of product invention and product upgrading are aided by creativity techniques used to obtain new ideas. Patent databases are consulted to make sure that the idea is original enough, and if this is the case, a patent with drawings of the inventive parts is drafted and claims are written. As observed repeatedly, this last phase generally helps to make inventive ideas more specific, and thus find new alternative solutions of a product. The result can be one or two patent applications.
Sometimes these new ideas force us to redesign the product and add new approaches to patent claims in an iteration that can be repeated more than once.
As can be seen, drafting the basic patent can be considered not only a technical aid of the CD process which expands the invention, but also a creativity technique because it helps to obtain and specify new ideas of solutions.
The results of these academic projects for product engineering innovation show indirect benefits rather than direct economic benefits, such as selling a patent to a company or creating a spin-off from university-based research.
A direct benefit was the sale of a patent to a company with which the university had an agreement.
Indirect benefits included student familiarisation with the creative process of product innovation, including patents, and, for example, the interest shown by two companies in two patents upon their publication, which resulted in two research agreements for the development of similar topics.
In the context of reference, the government support to universities to develop and manage patents has pushed the former on their way to excellence.
Some advantages of this CD process with patent search and drafting are:

- Increase of student motivation
- In-depth search of State of the Art
- Use of creative mental faculties and creativity techniques
- Refinement of inventions and their technology
- In-depth discussion of alternative solutions leading to more solutions
- Open continuous improvement of products and iteration of design process
- Identification of essential claims of new products and their possible value
- Development of possible new related patents arising from discussion of alternative solutions
- Awareness of the limits of new design with respect to other patented products
- Gain of knowledge of usable technology of expired patents
- Possibility to find related ideas for a new patent
- Possibility to protect the design from copying

These advantages arise from the experience of Conceptual Design process, including patent drafting in academia, but probably this process can also be applied in the early phases of the CD process in the industrial sector.
Perhaps, in the medium term the patent system will be unified into a global, more efficient patent system. In the long term, the industrial production series could be controlled globally by a democratic institution that would allow the production of a particular product if it was excellent and of public interest. In this utopian vision, only an excellent and really innovative product, competitively designed in a centre of design and prototyping, could be produced. In this context, the patent system might be unnecessary because production would already be controlled, but patent drafting would surely be a systematic aid in the design process.

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