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Strategic Foresight: Determining Patent Trends in Additive Manufacturing

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ABSTRACT: Additive manufacturing is an emerging technology that brings several opportunities to the manufacturing industry. Therefore, research in this arena on current and future developments is required to make strategic decisions. Under this context, the goal of this research is to develop a patent analysis on additive manufacturing. Keyword-patent analysis is performed to identify the most important organizations, countries, inventors, and technology areas through International Patent Classifications (IPCs) of the additive manufacturing industry. Results show that there is an increase on additive manufacturing research, particularly in 2013 and 2014. The main areas of research are focused on shaping of plastics and after-treatment of shaped products and working metallic powder and manufacture articles from this material. Moreover, the analysis indicates that leading countries on additive manufacturing research are United States, Great Britain and

Switzerland. Additionally, top three companies on this area are: Stratasys Inc. (USA), United Technologies Corp. (USA) and Alstom Technology LTD (Switzerland). Its recent research inventions were identified in this study. The main contribution of this research is to offer a template for analysis in other industries, but it also brings valuable insights to decision makers interested in recent patent efforts developed for the advancement of additive manufacturing.

KEYWORDS: Strategic foresight, foresight, patent analysis, additive manufacturing

1.0 Introduction

Manufacturing is an important sector for the worldwide economy. In 2009, this sector employed 31 million persons in the European Union, generated EUR 5,812 billion of turnover and EUR 1,400 billion of value added (European Factories of the Future Research Association, 2013). With such economic impact, it is mandatory that entities involved in this sector keep abreast of the competitive environment including technological advances to support strategic decisions on Research & Development + Innovation (R&D+I).

Due to current movements in market forces it is expected that not far away from 2020 manufacturers will be confronted by strong challenges for developing more customized products with better performance and less cost. To accomplish this, organizations involved should be more innovative and creative. A proper identification and use of relevant knowledge in decision making acquires a key role to gain new competitive advantages (Youtie et al., 2007).

A promising technology that has emerged recently is Additive Manufacturing (AM). AM produces products layer by layer, contrary to the traditional way of subtracting material from larger pieces. With AM, assembly lines and supply chains may be decreased or removed for many products. Products can be printed on demand and thus, inventories may be reduced. Furthermore, carbon emissions to the environment may be decreased. Finally, more customized products can be developed as production is brought closer to the consumer (Campbell et al., 2011).

AM is a new technology that brings several opportunities to the manufacturing industry so research to identify technical advances, and key players is required. As literature has showed since many years ago patent analysis represents a key tool to determine and analyze industry trends. It provides a way to envisage technology trajectories and to identify on-going developments of organizations (companies, government agencies, centers, universities, etc.) so it is an important tool to support strategic planning in terms of R&D as well as innovation (Hsieh, 2013).

In this research, a patent analysis is developed to determine trends in AM. Main countries, organizations, inventors and technology areas through International Patent Classifications (IPCs) were identified as well as the last inventions of top players. The purpose of this study is to offer valuable knowledge to decision makers interested in knowing patent activity including technological advances and key players of AM. More important, the results of the procedures can be incorporated for a broader strategic foresight analysis.

Strategic foresight comprises the activities and processes that assist decision makers in the task of defining the company's future course of action (Vecchiato, 2012). Strategic foresight provides business executives and government policy makers with interesting methods to envision the future. It also helps them to understand the implications of alternative technological or societal paths (Rohrbeck and Schwarz, 2013).

The paper is organized as follows. Sections 2, 3 and 4 provide a literature review of foresight, AM technology and patent analysis respectively. A description of the methodology followed is detailed in section 5. Section 6 presents the main findings of the research and section 7 presents conclusions.

2.0 Foresight in Organizations

Foresight is a set of systematic attempts to look at the long-term future of science, technology, economy and society, in order to identify emerging issues that are likely to generate the higher social and economic benefit (Balbi, 2001). Moreover, Popper (2008a) defines foresight as a process which involves intense iterative periods of open reflection, networking, consultation and discussion, leading to a joint refining of future visions and a common ownership of strategies.

The first multinational company that formally employed a foresight tool may have been Royal Shell. This oil organization was able to identify and anticipate the scene of the oil crisis that took place in 1973 (Ortega, 2004). Since the 80’s the studies related to foresight have been strongly increased (Da Costa et al., 2003). Roadmapping is one of the most common techniques of foresight (Ortega, 2004). This tool is applied to predict a possible future and results obtained allow delineating or changing strategies (Da Costa et al., 2003). Since long time ago there is a growing interest in developing roadmap analysis particularly in the departments of R&D of high-tech companies (Willyard and McClee, 1987).

Due to a growing intensive competition, organizations have the challenge of adapting them to a fast and changing environment based on a new era of knowledge (Marsh, Mcallum and Dominique, 2002). The authors argue that organizations need to change their traditional planning methods and be able to anticipate competitive environment movements. Nowadays, companies should not plan under a unique vision centered on the present. They should conceive strategies and contingency plans based on possible future scenarios (Ortega, 2004). Under this perspective, foresight emerges as an important methodology.

According to Popper (2008 a,b) foresight analysis typically includes five steps: 1) pre-foresight, 2) recruitment, 3) generation, 4) action, and 5) renewal. During the pre-foresight step, the goal and activities of the foresight analysis are established. A literature review, scanning, bibliometric or patent analysis from academics or research institutes should be performed to identify the project goals. The recruitment step consists on organizing key actors and resources. In the generation step knowledge is obtained through exploration, analysis and anticipation of possible future scenarios and new policies and decisions are produced. Action stage comprises the implementation of results previously determined. Finally, renewal phase includes evaluation and changes.

Popper (2008 b) classifies foresight methods as qualitative (e.g. brainstorming, environmental scanning, expert panels and SWOT analysis), quantitative (e.g. bibliometrics, modeling/simulation, trend exploration/megatrends), semi-quantitative (e.g. cross-impact/structural analysis, Delphi, stakeholder mapping and technology roadmapping) and other methods (e.g. benchmarking and patent analysis).

During this research a patent analysis is developed. The aim is to obtain valuable knowledge that could support organizations' decisions in terms of their R&D+I activities.

Lin et al. (2013), consider that foresight has evolved from being an explorative and tactical tool to become a strategic planning tool. This is not an instrument used to forecast or predict, instead, it is used to define alternative futures and create paths for potential developments.

There is a difference between foresight and strategic foresight concepts. While the first one has been used to describe an inherent human activity, i.e. the act of looking forward daily by individuals throughout society; the second one determines future research activities of organizations (Rohrbeck and Schwarz, 2013). In this paper, the term strategic foresight is applied considering that this research aims to support organizations that are interested on planning for the future.

Strategic foresight analysis provides decision makers new ways to delineate future that could affect competitive position of the organization.

2.1 Strategic Foresight and Competitive Intelligence

Foresight and competitive intelligence (CI) disciplines have similar goals. Both practices systematically monitor the organization environment to provide valuable insights about possible future events (Lin et al., 2013). As Sarpong et al. (2013) establish that CI is one of the practices that organizations have to define the future; other techniques are: scenario planning, counterfactual analysis, peripheral visioning and scenario thinking.

Calof and Smith (2010) deepen this relation. They consider that competitive technical intelligence (CTI) and strategic technological foresight (STF) are fields with similar objectives and techniques. While the authors define CTI as a practice that provides business sensitive information on external scientific or technological treats, opportunities or developments that have the potential to affect a company's competitive position. STF according to them is a collaborative tool that draws upon the talents of many individuals (not only from the technology domain) and is an important source for technical and business intelligence.

CTI and STF have strong similarities and complementarities. Both practices guide R&D+I process, use similar techniques for examining and understanding the environment and both are designed to support key decisions.

3.0 Additive Manufacturing (AM)

The origins of Additive Manufacturing (AM) can be traced back to the end of the 80's. In 1987 the first commercialization of a stereolithography (3D printing machine) was performed. Since then, the industry has grown in an accelerated pace and as a consequence the number of patents has strongly increased. This industry has a strong interest on developing new technologies (Beer, 2013) to compete more efficiently.

Additive Manufacturing comprises a group of emerging technologies that produce objects through the addition of materials layer by layer (Campbell et al., 2011). These technologies are: binder jetting, directed energy deposition, material extrusion, material jetting, powder bed fusion, sheet lamination and vat photopolymerization (Basiliere and Shandler, 2014). 3D printing is a concept commonly used in the industry when referring to AM (Beer, 2013).

Three main advantages arise when using AM in manufacturing processes. First, the possibility of building complex objects. A diversity of industries are benefited (manufacturing, health, education, etc.). Second, AM does not require assemblage of parts. Both production time and costs decrease. Finally, AM reduces waste and offer the opportunity to use recycled materials (Campbell et al., 2011).

The general process of AM starts with the creation of a 3D model. For this task computer-aided design (CAD) tool or the scan of an existing object is applied, information generated is sent to a specialized equipment that produces the 3D object through the addition layer by layer of material (Campbell et al., 2011).

Nowadays, AM is used to produce a variety of products from automobile and aircraft components, custom orthodontics and hearing aids (Campbell et al., 2011), surgical or medical models, to architectural models and teaching aids (Beer, 2013).

Particularly use of AM has a strong interest from the manufacturing industry. This technique could be used to produce a final or intermediate product. Additionally, it could be used to print tools, dies and molds needed for production. Adoption of this technology accelerate commercialization of products, push production to the customer and give other advantages to compete in a more innovative way (Basiliere and Shandler, 2014). For this reason, manufacturers of several industrialized economies are increasingly using AM technologies. A recent study was developed to reveal how 504 US manufacturers from the Georgia State (USA) with 10 or more employees, deploy information, execute quality management and perform production technologies (Youtie et al., 2014). The results showed that 70% of respondents use at least one advanced technology like additive manufacturing.

3.1 The Future of Additive Manufacturing

The future of AM is promising. During the next decade, it is expected that this technology will have a predominant role in different industries. In particular, two applications are gaining interest among the current and potential users of AM (Campbell et al., 2011). The first one is centered on metal components. Through AM engineers are now able to develop components using titanium and steel alloys. The second one is the desktop-scale 3D printers. The cost of these products is decreasing. In the future, more persons will be able to adopt this technology. Furthermore, advances in metals, development of new design tools, expiration of related patents and other related changes are expected to come, as consequence new business will emerge (Beer, 2013).

Basiliere and Shandler (2014) consider that, within two to five years, it is expected a higher adoption of 3D printing technologies in organizations. The authors also estimate that 3D printing of medical devices such as prosthetics and implants will increase.

Basiliere (2014) estimates that from 2014 to 2018, the total number of 3D printer units shipped per year will grow to 2,319,494 worldwide. This represents a CAGR (Compound Annual Growth) rate of 106.6%. The author considers that by 2018 the sales of these technologies will exceed US$ 13.4 billion. Such forecast is based on the fact that consumers and organizations will rapidly adopt 3D printers for home and corporative use.

The European Factories of the Future Research Association (2013) reports that in 2030, factories will be green and sustainable. To achieve this goal, efforts should focus on reduce energy consumption, close loops for products or production and scarce resources; finally, sustainability in terms of materials and production processes will be required. All the above efforts can be achieved through the use of AM technologies.

4.0 Patent Analysis

Patents are the most accessible and reliable sources of information for assess of a technology (Hsieh, 2013). They are considered one of the most valuable output indicators of the technological innovation process (Hidalgo et al. 2009), (Rodríguez and Tello, 2012).

Moreover, from all the available technological information, 90% can be found in patent publications (Blackman, 1995).

The strategic planning of an organization can be improved if technology is evaluated through patent analysis.

There are several patent classification systems: the International Patent Classification (IPC), the United States Patent Classification System (USPCS) and the Cooperative Patent Classification (CPC). This research focuses its analysis on the IPC. The World Intellectual Property Organization (2015) defines IPC as a “hierarchical system of language independent symbols for the classification of patents and utility models according to the different areas of technology to which they pertain”. IPC divides patents into classes, sub-classes, groups and sub-groups.

4.1 Keyword-based Analysis

Keyword-based patent analysis represents an important tool used to determine technology trends, discover technological opportunities and predict new technological advances. This tool is based on patent keyword frequencies and co-occurrences between them (Choi et al. 2012). It provides decision makers with valuable knowledge to compare the strategic positioning of an industry or organization in different countries.

Analysts can determine who the leaders are in different technological areas or which of these areas are emerging. Similarly, researchers can analyze the profiles of inventors/organizations to identify density of technological domains through their corresponding classifications. Besides, hidden relations between organizations can be determined (Trappey et al. 2011). A patent map uses patent information to create specific graphs and charts that provide simple and intuitive ways to address complex technical information (Zha and Chen, 2010). For this purpose, patent information, such as assignees, inventors, countries and IPCs is considered.

5.0 Methodology

To develop this research, Matheo Patent software was utilized. This is a French software that collects, analyzes and deploys patent information. It offers solutions for decision making, analysis of strategic information and technology scanning. Matheo Patent retrieves information from USPTO and Espacenet databases. While in the first case it is possible to retrieve whether issued patents or applications; in Espacenet there is not such distinction, analysis through the software comprises both types into the same research. Its results provide with an accurate perception of the latest advances in any given research topic. This software allows searching patents through keywords contained on title, abstract, inventor, applicant, patent number and classification codes. (Matheo Patent, 2015).

The results of this research were obtained in three steps. These are explained below.

5.1 Planning

During this phase, the goals and scope of the project were established. The goal of this research was to develop a patent analysis on AM as a first step to conduct a further strategic foresight analysis. Main countries, organizations, inventors and technology areas through International Patent Classifications (IPCs) were identified.

This research is focused on AM patents issued and submitted between 2011 and January 28th, 2015. Matheo software, the tool applied on this research, extracts information from patent families; hence some results may have a period of years longer than the one previously defined. Data was retrieved through Espacenet database. Its search engine offers free access to more than 90 million patent documents worldwide and contains information about inventions and technical developments from 1836 to present (Espacenet, 2015).

5.2 Selection and Gathering of Information

A search was performed using the exact phrase "Additive Manufacturing" in “Title and Abstract”. When using the general terms Additive Manufacturing, relevance of the information gathered could be not adequate. In fact it was tested and more than one hundred thousand patents were obtained where a high rate of patents didn’t correspond to the field of the study.

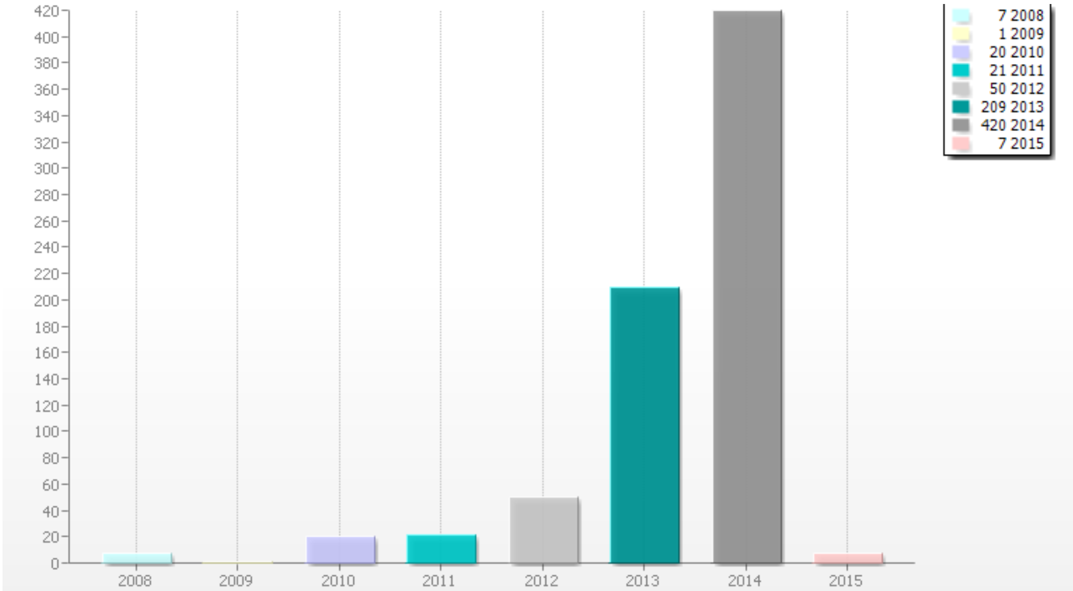

Figure 1. Patents per year. Data from Espacenet using Matheo Patent.

5.3 Data Cleaning

This task consisted on combining similar terms and removing repeated information from "Applicants", "Inventors" and "Country" fields on the patents obtained.

6.0 Results and Discussion

6.1 Patent Density

A total of 735 patents, 336 family patents and 629 inventors were obtained on AM between 2011 and January 28th, 2015. In Figure 1, the number of patents per year is presented. As it can be seen, there is a significant increase in patent publications on AM, particularly from 2013 (209 patents) to 2014 when they increased to almost the double (420 patents). Regarding family patents, 129 families were detected in 2013 while in 2014 this amount raised to 247 family patents. Figure 2 shows results according to family patents during the period defined of 2011- Jan 28 2015; it is important to notice that families can be repeated and a patent could have a family before this period, so as it can be seen in the next figure results of patent families comprises 2008 to 2015 counting 434 in total.

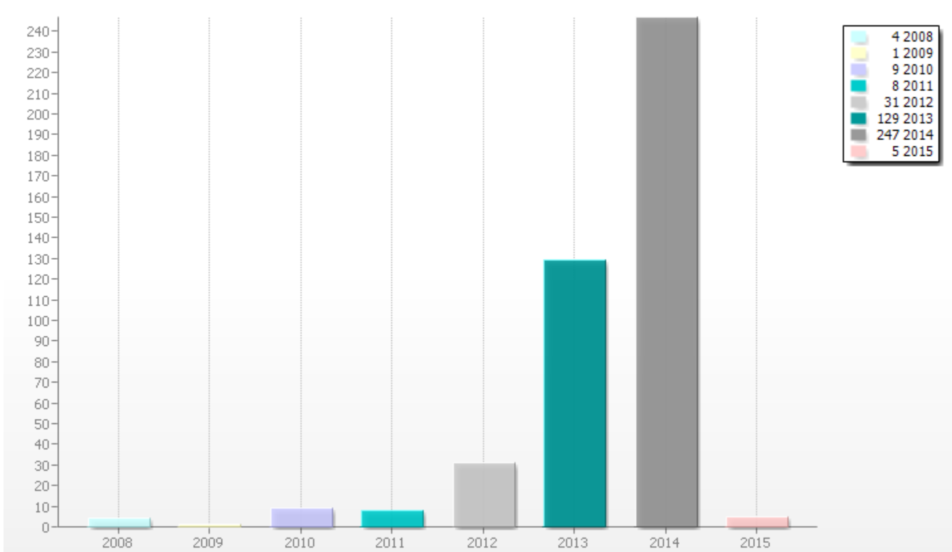

Figure 2. Family patents per year. Data from Espacenet using Matheo Patent.

In the next section a patent density and main focus of research is presented.

6.2 Patent Activity and Main Trends

6.2.1 Top IPC Four Digits Code

Top 3 IPC four digit codes are shown in Figure 3. It can be seen that AM research efforts are focusing on IPCs: B29C, B22F, and B23K. According to WIPO (2015) they corresponds to:

- B29C: Shaping or joining of plastics; shaping of substances in a plastic state, in general; after-treatment of the shaped products, e.g. repairing.
- B22F: Working metallic powder; manufacture of articles from metallic powder; making metallic powder.
- B23K: Soldering without fusion or unsoldering; soldering; coating or plated for soldering; cutting by localized heating, e.g. flame cutting, work by lasers.

6.2.2 Top Applicants and Inventors Countries

From the applicant country point of view a strong patent activity was detected primarily from USA (360 patents), followed by Great Britain (137 patents) and Switzerland (59 patents). These results are shown in Figure 4.

Regarding inventor country, the highest patent activity was from USA (369 patents), followed by Great Britain (139 patents) and Germany (51 patents). Results are shown in Figure 5.

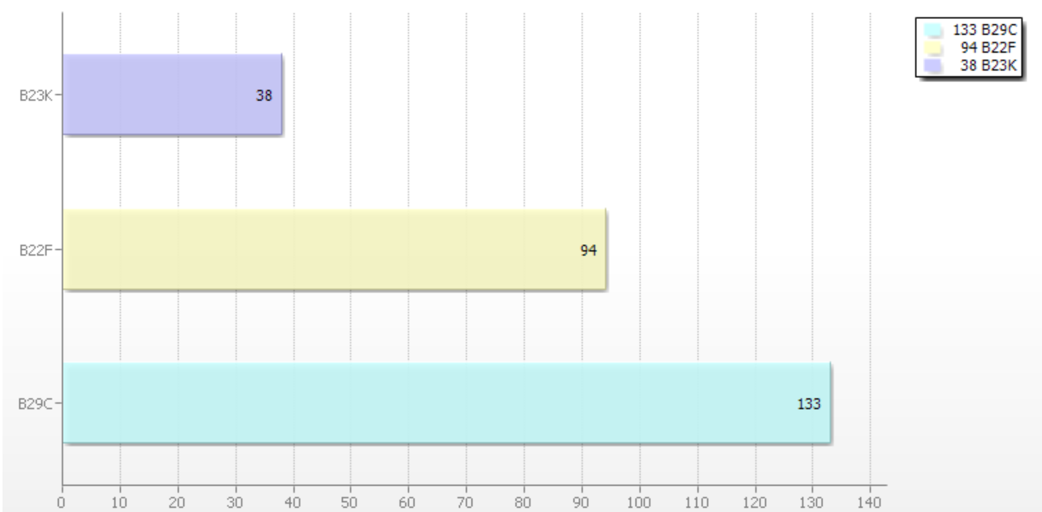

Figure 3. Top 3 IPC four digit codes. Data from Espacenet using Matheo Patent.

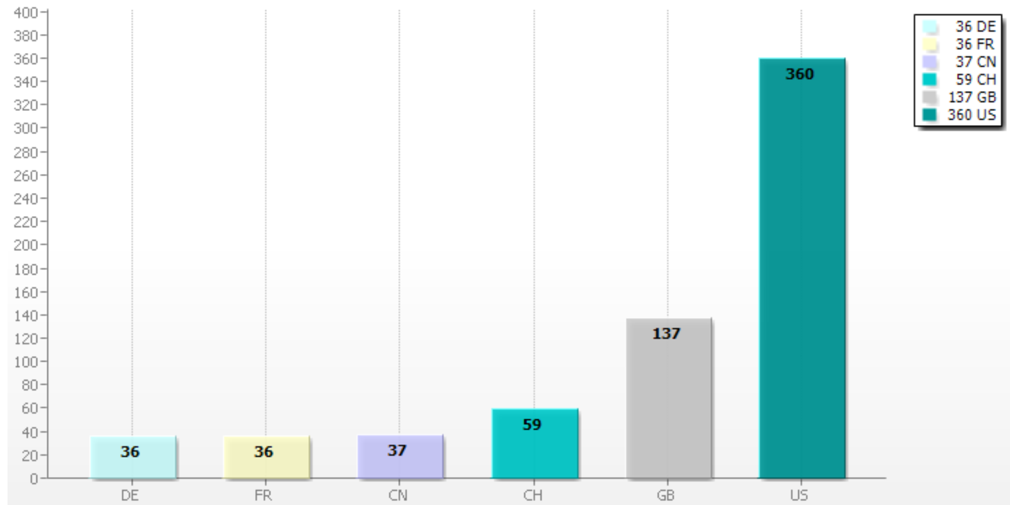

Figure 4. Patents per applicant country. Data from Espacenet using Matheo Patent.

Results show a similar trend for USA and Great Britain. However, the rest of the countries have a different behavior.

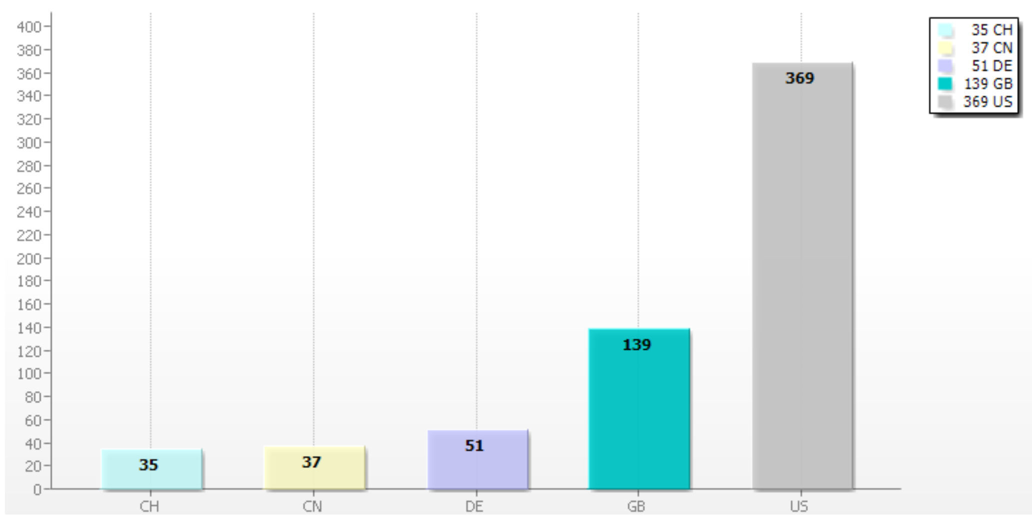

Figure 5. Patent per inventor country. Data from Espacenet using Matheo Patent.

6.2.3 Top Organizations

Organizations with the highest number of patents (issued and submitted) were identified coming from: USA and Switzerland as Figure 6 shows. Top 3 organizations in descending order are the followings:

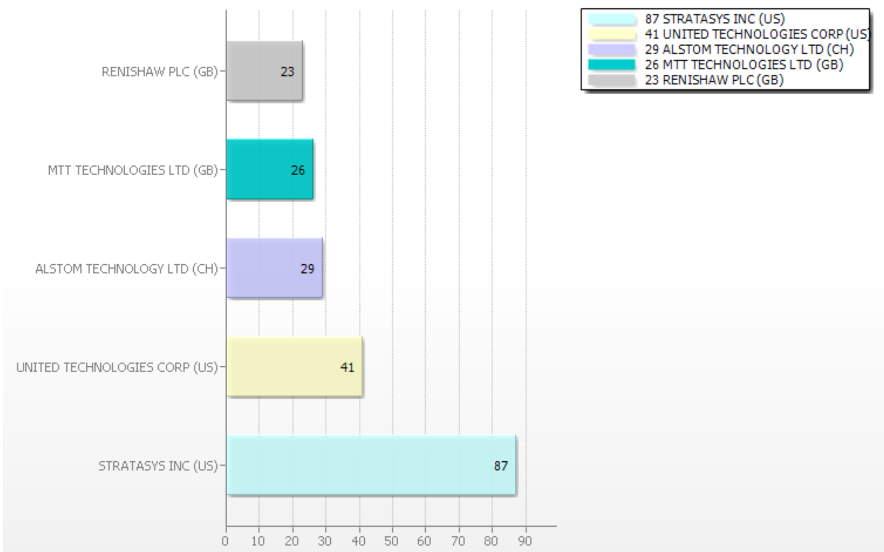

Figure 6. Top Organizations. Data from Espacenet using Matheo Patent.

- Stratasys Inc. (USA): 87 patents
- United Technologies Corp. (USA): 41 patents
- Alstom Technology LTD (Switzerland): 29 patents

Organizations with the highest number of family patents were also identified. Results are shown in Figure 7. The top 3 organizations in descending order are the followings:

- Stratasys Inc. (USA): 36 family patents.
- United Technologies Corp. (USA): 29 family patents.
- Renishaw PLC (Great Britain): 21 family patents.

When both indicators: global patents (issued and submitted) and family patents are considered, there are similarities in only the first two positions. Stratasys Inc from USA leads the patent application activity with 87 patents and 36 family patents, followed by United Technologies Corp from USA with 41 patents and 29 family patents. But the third position is different, Alstom Technology from Switzerland has the third position considering their 29 patents and Renishaw from Great Britain has the third position taking into account their 21 family patents.

In the following sections a more detailed analysis of the top companies will be developed considering number of patents issued and submitted.

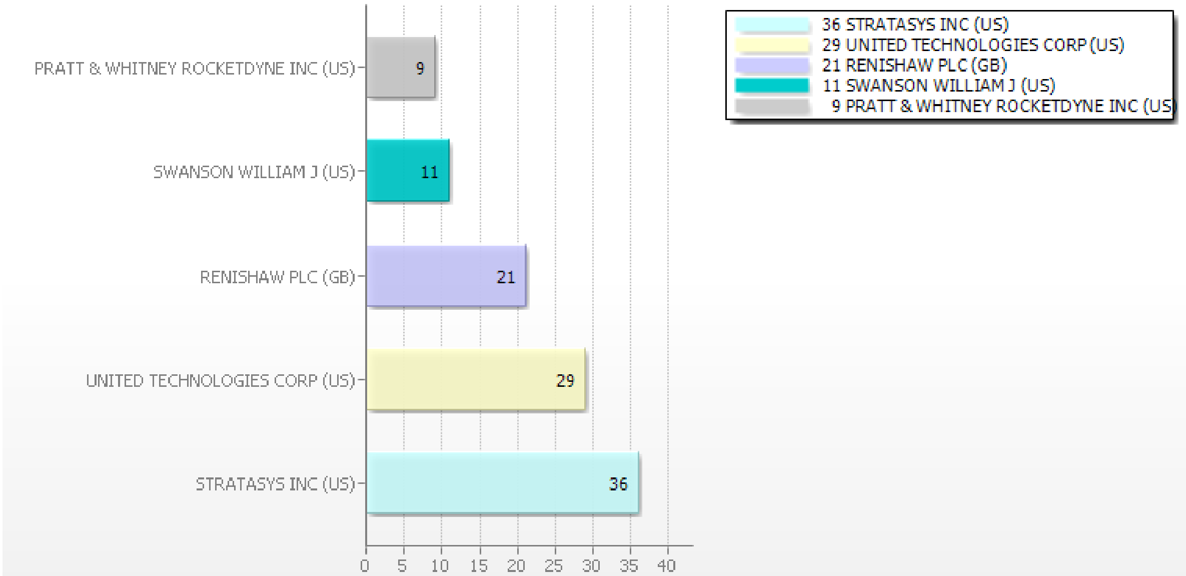

Figure 7. Top Organizations by family patents. Data from Espacenet using Matheo Patent

6.2.3.1 Stratasys Inc. (USA)

Considering that Stratasys Inc. from USA is the patent leader in AM field, this research proceeds to know more about its patent activity during last years. Based on the same period previously established, Figure 8 shows their patent activity from 2011 to 2014 (they did not have results for 2015 when this study was concluded). It is important to remark the growing effort of this company on the advancement of this technology, particularly during 2014 when its patent efforts were of almost 50% more with respect to 2013.

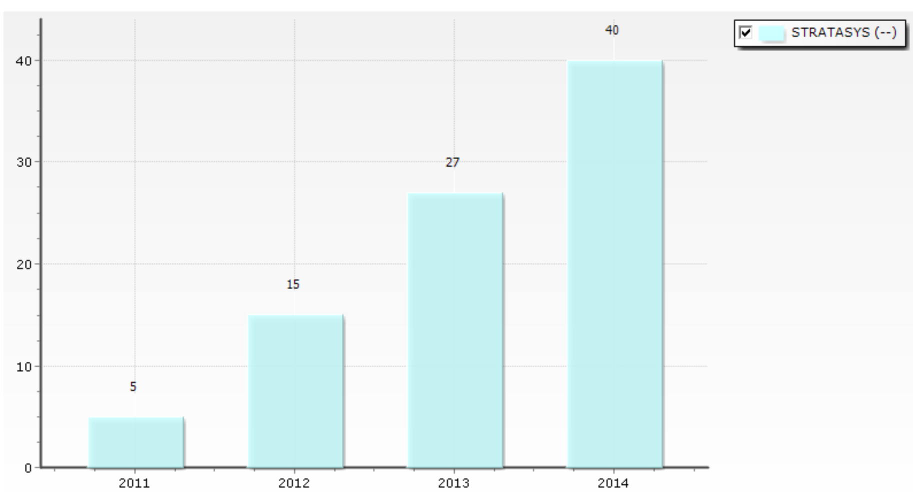

Figure 8. Stratasys Inc. patents per year. Data from Espacenet using Matheo Patent

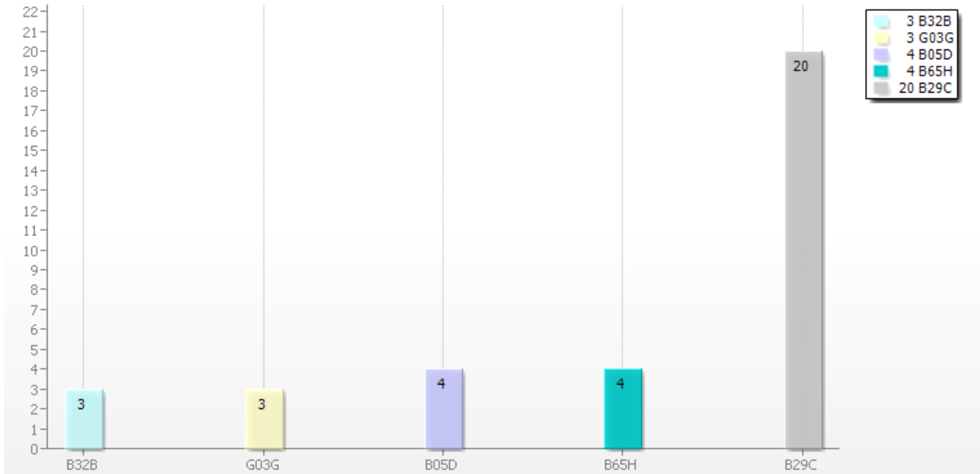

Figure 9. Stratasys Inc. main IPCs four digit codes. Data from Espacenet using Matheo Patent

Top IPCs (four digits) from Stratasys Inc. were also identified. The main results are shown in figure 9. This company focuses its research on IPC code B29C. As mentioned before, this IPC comprises shaping or joining of plastics; shaping of substances in a plastic state and after-treatment of the shaped products. While the rest of the codes corresponds according to WIPO (2015) to:

- B65H: Handling thin or filamentary material, e.g. sheets, webs, cables.
- B05D: Processes for applying liquids or other fluent materials to surfaces, in general
- G03G: Apparatus for electrographic processes using a charge pattern.
- B32B: Layered products, products built-up of strata of flat or non-flat, cellular or honeycomb.

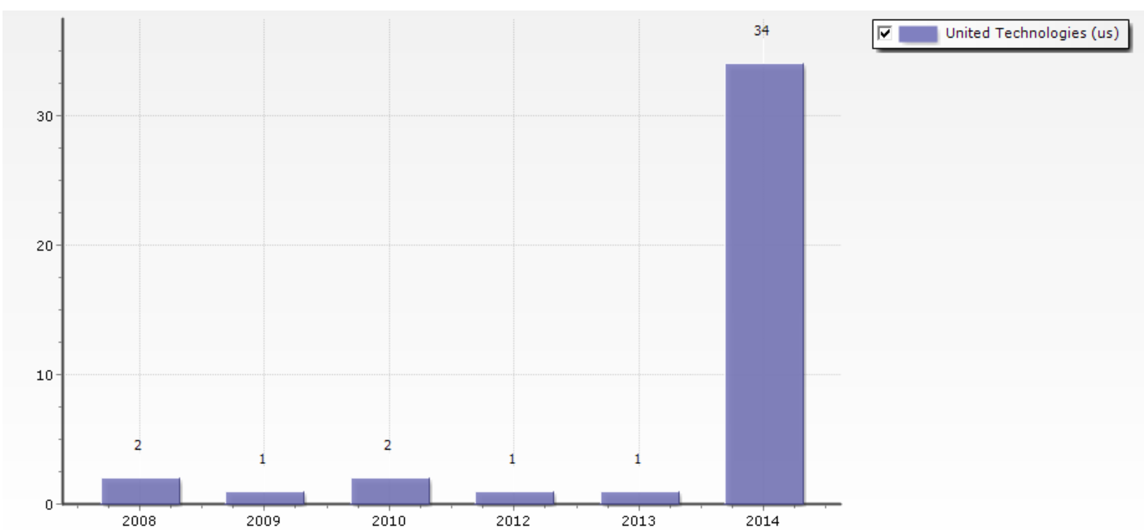

Figure 10.United Technologies Corp. patents per year. Data from Espacenet using Matheo Patent.

6.2.3.2 United Technologies Corp. (USA)

After Stratasys Inc., United Technologies Corp. is the organization with the highest number of patents according to the Figure 10. It is important to notice that, in 2014, the company increased its patent rate in an unexpected rate.

Top IPCs from United Technologies Corp were also identified. Results are shown in Figure 11. The company is focusing mainly in research related to IPC code B22F (working metallic powder, manufacture of articles from metallic powder and making metallic powder) followed by code F01D (non-positive displacement machines or engines, e.g. steam turbines). While the rest of the IPC are as follows:

- F02C: Gas-turbine plants; air intakes for jet-propulsion plants; controlling fuel supply in air-breathing jet-propulsion plants.
- B23K: Soldering or unsoldering; welding; cladding or plating by soldering or welding; cutting by applying heat locally, flame cutting; working by laser beam.
- B29C: Shaping or joining of plastics; shaping of substances in a plastic state, in general; after-treatment of the shaped products, e.g. repairing.

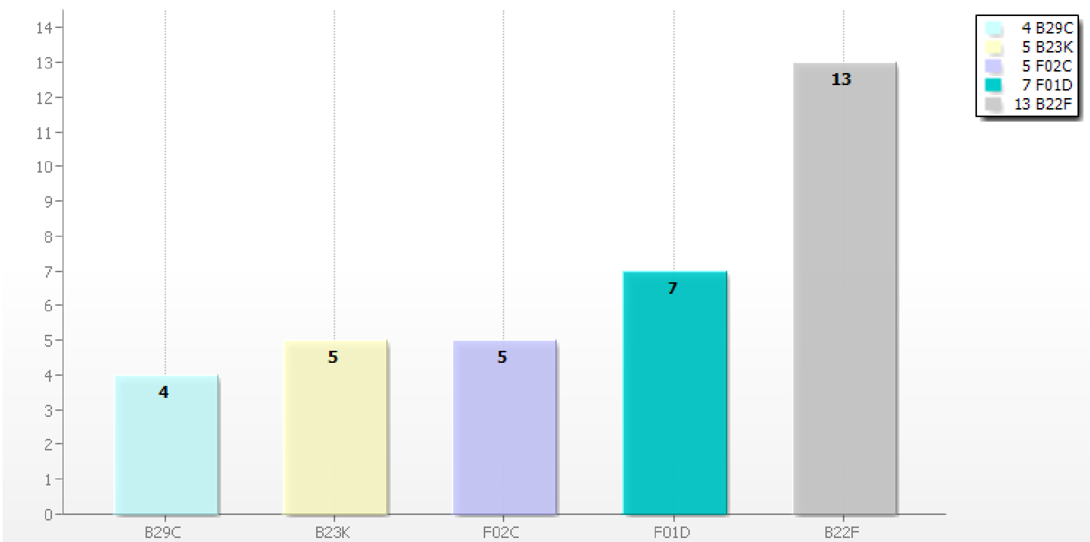

Figure 11. United Technologies Corp main IPCs four digits. Data from Espacenet using Matheo Patent.

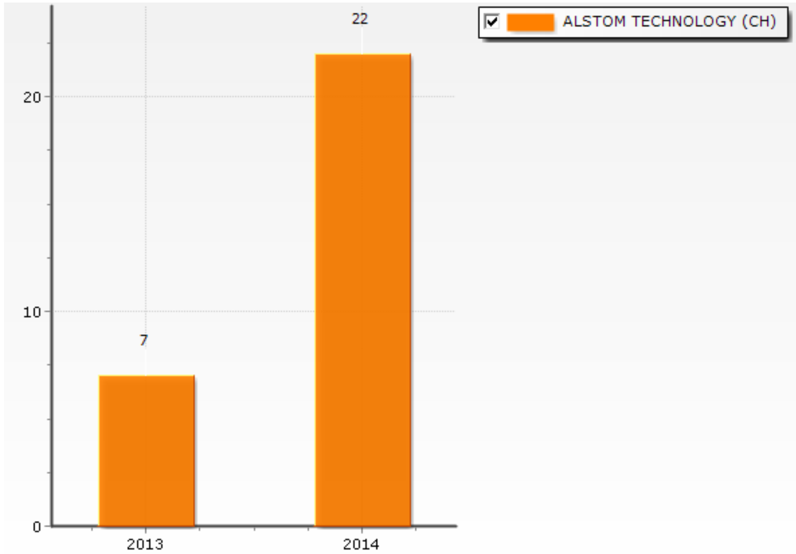

Figure 12. Alstom Technology LTD patents per year. Data from Espacenet using Matheo Patent.

6.2.3.3 Alstom Technology LTD (Switzerland)

Alstom Technology LTD is the third organization with the highest number of patents. As the previous cases, this company presents a big jump from 2013 to 2014 according to Figure 12, in the rest of the years analyzed they do not have patents.

Top IPCs of this company were also identified. Results are shown in Figure 13. As can be seen, the focus of the company´s research is related to IPC code B22F, similarly to United Technologies Corp, this code is associated to working metallic powder, manufacture of articles from metallic powder and making metallic powder.

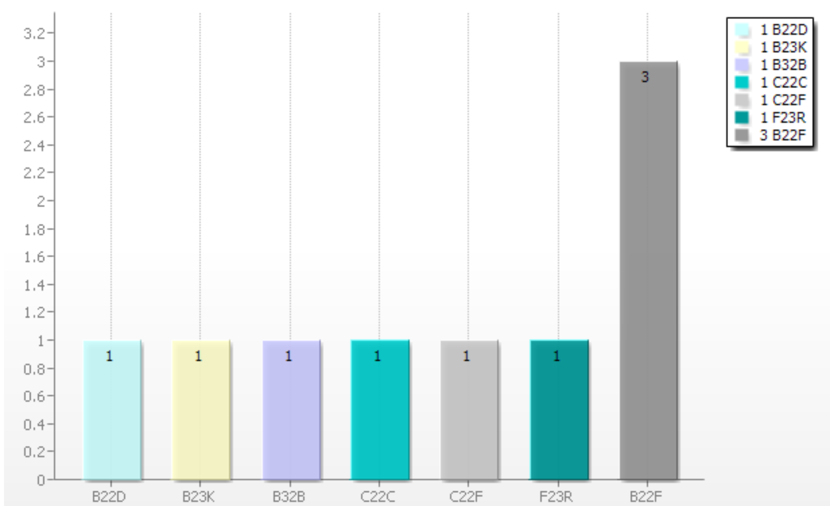

Figure 13. Alstom Technology LTD main IPCs four digits. Data from Espacenet using Matheo Patent

6.2.4. Recent Patents of Top Organizations

In this section, top three companies and their most recent patents are presented.

6.2.4.1 Stratasys Inc.

The three most recent patents of Stratasys Inc. are shown in Table 1.

Patent number US2014358273A1 consists on a method for printing a three-dimensional part with an additive manufacturing system. It comprises the generation and printing a planarizing part having a substantially-planar top surface relative to a build plane, and a bottom surface that substantially mirrors a topography of a platen surface, and printing the three-dimensional part over the substantially-planar top surface of the printed planarizing part.

Patent number US2014265040A1 consist on an additive manufacturing system that retains a print head for printing a three-dimensional part in a layer-by-layer manner using an additive manufacturing technique, where the retained print head is configured to receive a consumable material, melt the consumable material, and extrude the molten material. The system also includes a velocimetry assembly configured to determine flow rates of the molten material, and a controller assembly configured to manage the extrusion of the molten material from the print head, and to receive signals from the velocimetry assembly relating to the determined flow rates.

Patent number US2014252684A1 consist on a method for printing a three-dimensional part with an additive manufacturing system, the method including printing layers of the three-dimensional part and of a support structure for the three-dimensional part from multiple print heads or deposition lines, and switching the print heads or deposition line between stand-by modes and operating modes in-between the printing of the layers of the three-dimensional part and the support structure. The method also includes performing a purge operation for each print head or deposition line switched to the operating mode, where the purge operation includes printing a layer of at least one purge tower from the print head or deposition line switched to the operating mode.

Patent number	Tittle	Publication date
US2014358273A1	Platen planarizing process for additive manufacturing system	12/04/2014
US2014265040A1	Additive manufacturing system and method for printing three-dimensional parts using velocimetry	09/18/2014
US2014252684A1	Additive manufacturing method for printing three-dimensional parts with purge towers	09/11/2014

Table 1. Stratasys Inc. recent patents.

6.2.4.2 United Technologies Corp.

The three most recent patents of United Technologies Corp. are shown in Table 2.

Patent number WO2014210338A1 consists on an additive manufacturing method which segments a Computer Aided Design (CAD) file of a component along a build interface to define at least a first component segment and a second component segment each of the first component segment and the second component segment sized to fit within an additive manufacturing build chamber; manufacturing additively the first component segment and the second component segment within the build chamber; and bonding the first component segment and the second component segment to form the component.

In patent number WO2014193505A1 a machine for fabricating a fiber-reinforced component by additive manufacturing is disclosed. The machine may have a surface, a matrix feed configured to deposit a plurality of matrix layers on the surface, and a fiber feed configured to deposit a fiber layer on at least one of the plurality of matrix layers. The deposition of the plurality of matrix layers and the fiber layer may be controlled by a computer.

Patent number WO2014179679A1 presents a method for operating an additive manufacturing apparatus; the method comprises directing a first energy beam along a surface contour vector in a build plane. A second energy beam is directed along a plurality of substantially parallel hatch vectors disposed in the build plane inward of the surface contour vector. A sum of the surface contour vector and the plurality of hatch vectors define a processed powder region in the build plane. A third energy beam is directed along an offset contour vector in the build plane. The offset contour vector includes a plurality of unprocessed powder regions in the build plane between the surface contour vector and the plurality of hatch vectors.

Patent number	Tittle	Publication date
WO2014210338A1	Additive manufacturing system and method of manufacture	12/31/2014
WO2014193505A1	Continuous fiber-reinforced component fabrication	12/04/2014
WO2014179679A1	Method of eliminating sub-surface porosity	11/06/2014

Table 2. United Technologies Corp. recent patents

6.2.4.3 Alstom Technology LTD

The three most recent patents of Alstom Technology LTD are shown in Table 3.

Patent number EP2772329A1 refers to a method for manufacturing a hybrid component comprising the steps of a) manufacturing a preform as a first part of the hybrid component, then b) successively building up on that preform a second part of the component from a metallic powder material by means of an additive manufacturing process by scanning with an energy beam, thereby establishing a controlled grain orientation in primary and in secondary direction of at least a part of the second part of the component, d) wherein the controlled secondary grain orientation is realized by applying a specific scanning pattern of the energy beam, which is aligned to the cross section profile of said component or to the local load conditions for said component.

Previous patent is also published as patent number US2014242400A1 (the second patent on the Table 1) as well as US2014242400A1, KR20140109814A, JP2014 169500A, CN104014799A, CA2843450A1.

Patent number US2014154088A1 refers to a method for manufacturing a three-dimensional metallic article/component entirely or partly. The method includes a) successively building up said article/component from a metallic base material by means of an additive manufacturing process by scanning with an energy beam, thereby b) establishing a controlled grain orientation in primary and in secondary direction of the article/component, c) wherein the secondary grain orientation is realized by applying a specific scanning pattern of the energy beam, which is aligned to the cross section profile of said article/component, or with characteristic load conditions of the article/component.

Patent number	Tittle	Publication date
EP2772329A1	Method for producing a hybrid component	09/03/2014
US2014242400A1	Method for manufacturing a hybrid component	08/28/2014
US2014154088A1	Method for manufacturing a metallic component by additive laser manufacturing	06/05/2014

Table 3. Alstom Technology LTD recent patents

As it can be seen from the previous information, Stratasys Inc. (Top 1) is patenting methods for developing three dimensional objects with additive manufacturing systems. Specific components (e.g. heads, velocimetry) for manufacturing processes are invented. These components are incorporated to improve the quality of the resulting objects. Moreover, United Technologies (Top 2) is focusing its research efforts on equipment for printing 3D objects. The company has patented a method for operating a 3D printing device and a machine for fabricating fiber-reinforced objects. Finally, Alstom Technology (Top 3) is patenting methods for developing hybrid components with metallic powder materials.

6.2.5 Top Inventors

Top inventors on AM were also identified. As shown in Figure 14, Swanson Williams J. from USA is the inventor with the highest number of patents (in total 32). Secondly, Etter Thomas from Switzerland (28), and thirdly Scott Simon Peter from Great Britain (26).

Regarding family patents, the top 3 inventors in descending order are: Swanson William J. from USA (17) who presents the highest technology diversification in terms of patent families, Renishaw PLC from Great Britain (15) and Mannella Dominic F. from USA (11). These results are shown in Figure 15.

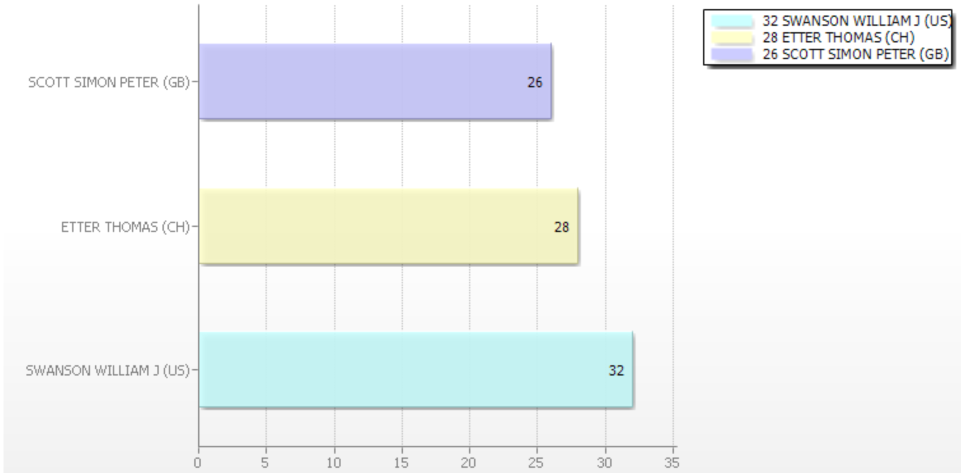

Figure 14. Top 3 inventors per patents. Data from Espacenet using Matheo Patent.

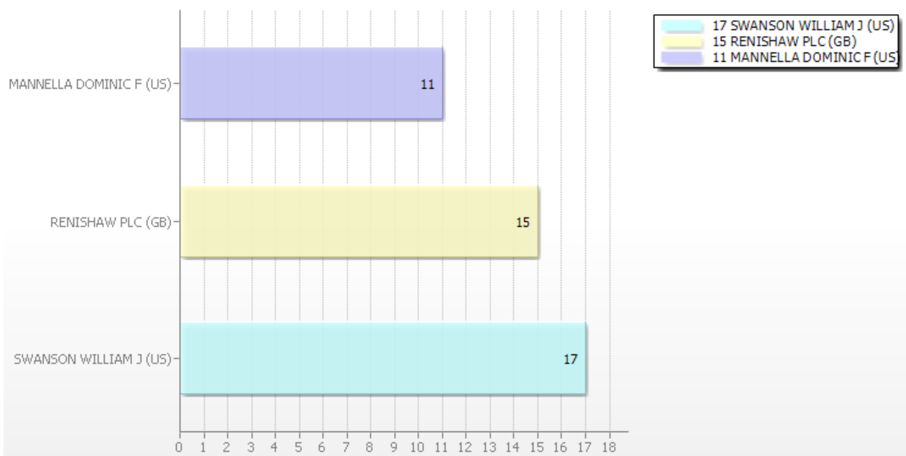

Figure 15. Top 3 inventors per family patents. Data from Espacenet using Matheo Patent.

6.3 Technology mapping

Relationship between Top patent organizations and Top IPC four digits are presented on Figure 16. Top organizations are focusing its research efforts on subjects related to IPC codes B29C and B22F, shaping of plastics and after-treatment of shaped products and working metallic powder and manufacture articles from this material. Stratasys Inc. is the organization that has the highest number of family patents related to IPC code B29C (31 family patents). Moreover, United technologies Corp. is the firm that has the highest number of family patents related to IPC code B22F (16 family patents).

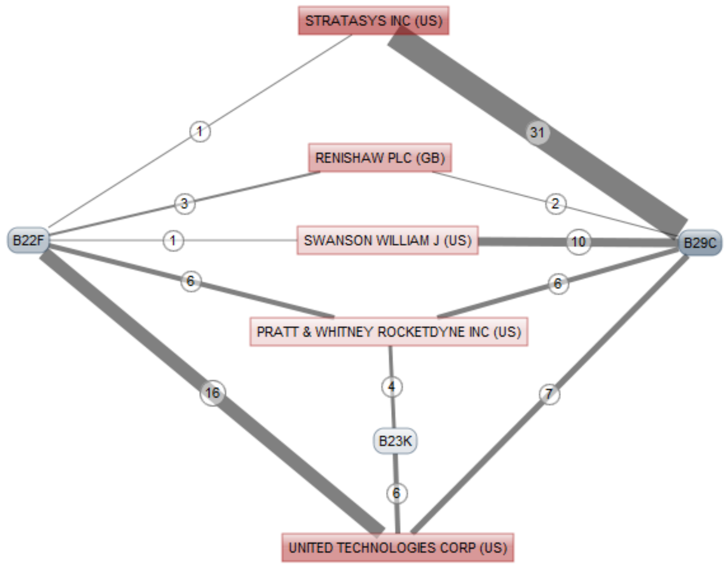

Figure 16. Top organizations vs. top IPC four digit codes. Data from Espacenet using Matheo Patent.

7.0 Conclusions

For the development of this research a patent analysis tool was applied to identify key players and trends in the AM industry. Main countries, organizations, inventors and technology areas through International Patent Classifications (IPCs) were identified as well as the last inventions of firms with the highest patent activity.

A total of 735 patents, 336 family patents and 629 inventors were analyzed in a period of time comprising 2011 to January 28th, 2015. Results indicate that research on AM has had a significant increase in the last years, particularly in 2013 and 2014. The trend is similar when considering family patents, a significant increased could be observed for both years. The main areas of research are focused on shaping of plastics and after-treatment of shaped products and working metallic powder and manufacture articles from this material. Methods for soldering are also considered in research efforts.

From the applicant and inventor country points of view a strong patent activity was detected primarily from USA followed by Great Britain.

An analysis of the top patent companies and their recent research efforts was performed. Top three companies are Stratasys Inc. (USA), United Technologies Corp. (USA) and Alstom Technology LTD (Switzerland). The first company is patenting methods for developing three dimensional objects with AM systems. The second one is focused on the development of equipment for printing 3D objects. The third one is patenting methods for developing hybrid components with metallic powder materials.

A technology map was also developed to identify the most important research lines of the top organizations. Insights obtained show that they are devoting efforts on shaping plastics and on after-treatment of shaped products, as well as working metallic powder and manufacturing articles from this material.

Results obtained aim to offer valuable knowledge to decision makers interested in knowing the technological advances and key players of AM. Moreover the findings serve as model for how to perform similar analysis.

7.1 Limitations and Future Research

This research on Additive Manufacturing represents a first approach for developing a broader analysis on strategic foresight. A patent analysis was developed considering the exact phrase: Additive Manufacturing. A complimentary analysis should be developed adding terms such as 3D printing or rapid prototyping. Additionally, it is important to extend information collection from primary and secondary resources. Expert participation from industry and academy is fundamental. Inclusion of scientific literacy and industry reports is also needed. A future research can also develop technological trends analysis.

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8.0 References

Balbi, E. (2001). Prospectiva, una herramienta de acción. Revista científica de UCES, 5(1), 12-18. Retrived from: http://dspace.uces.edu.ar:8180/dspace/bitstream/handle/123456789/360/Prospectiva_una_herramienta_de_acci%F3n.pdf?sequence=1

Basiliere, P. (2014). Market Guide for 3D Printing. Gartner.

Basiliere, P., & Shandler, M. (2014). Hype Cycle for 3D Printing, 2014. Gartner.

Beer, N. (2013). Additive manufacturing. Turning mind into matter. Sierra College Center for Applied Competitive Technologies (CACT).

Blackman, M. (1995). Provision of patent information: a national patent office perspective. World Pat. Inf, 17(2), pp. 115–123.

Calof, J., & Smith, J. (2010). The integrative domain of foresight and competitive intelligence and its impact on R&D management. R&D Management, 40(1), 31-39. doi:10.1111/j.1467-9310.2009.00579.x

Campbell, T., Williams, C., Ivanova, O. & Garrett, B. (2011). Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing. Atlantic Council.

Choi, S., Park, H., Kang, D., Lee, J. & Kim, K. (2012). A SAO-based text mining approach to building a technology tree for technology planning, Expert Systems with Applications, 39, 11443–11455.

Da Costa, O., Boden, M. & Friedewald, M. (2003). Retrived rom http://forera.jrc.ec.europa.eu/documents/MicrosoftWord-DaCostaSTRMLessonsPraguepaper2.pdf

Espacenet (2015). Retrieved on February 2, 2015 from: http://www.epo.org/searching/free/espacenet.html

European Factories of the Future Researh Association (2013). Factories of the future. Multi-annual roadmap for the contractual PPP under horizon 2020.

Hidalgo-Nuchera, A., Iglesias-Pradas, S., & Hernández-García, A. (2009). Utilización de las bases de datos de patentes como instrumento de vigilancia tecnológica. Profesional De La Informacion, 18(5), 511-520. doi:10.3145/epi.2009.sep.04

Hsieh, C. (2013). Patent value assessment and commercialization strategy. Technological Forecasting And Social Change, 80(2), 307-319. doi:10.1016/j.techfore.2012.09.01

Lin, H., Chan, T., & Ien, C. (2013). Mapping of future technology themes in sustainable energy. Foresight, 15(1), 54-73. doi:10.1108/14636681311310141

Marsh, N., Mcallum, M., & Dominique, P. (2002). Strategic foresight. The power of standing in the future. Australia: Crown Content.

Matheo Patent (2015). Retrieved on January 29, 2015 from: http://www.matheo-software.com/es/)

Ortega, F. (2004). La Prospectiva: Herramienta indispensable del planeamiento en una era de cambios. Retrived from Organización de Estados Iberoamericanos:

http://www.oei.es/salactsi/PROSPECTIVA2.PDF

Popper, R. (2008 a). Foresight methodology. En L. Georghiou, J. Cassingena Harper, M. Keenan, I. Miles & R. Popper (Eds.). The handbook of technology foresight. Concepts and practice (pp. 44-48). Cheltenham Glos GL50 1UA, UK.

Popper, R. (2008 b). How are foresight methods selected? Foresight, 10(6), 62-89

Rodríguez, M. & Tello, M. (2012). Applying patent analysis with Competitive technical intelligence: the case of Plastics. Journal of Intelligence Studies in Business, 2, 51-58.

Rohrbeck, R., Schwarz, J. (2013). The value contribution of strategic foresight: Insights from an empirical study of large European companies. Technological Forecasting & Social Change.

Sarpong, D., Maclean, M., & Davies, C. (2013). A matter of foresight: How practices enable (or impede) organizational foresightfulness. European Management Journal, 31613-625. doi:10.1016/j.emj.2013.03.004

Trappey, C, Wu, H., Taghaboni-Dutta, F. & Trappey, A. (2011). Using patent data for technology forecasting: China RFID patent analysis. Advanced Engineering Informatics, 25, 53–64.

Willyard, C.H. & McClees, C.W. (1987), ‘Motorola’s technology roadmap process’, Research Management, Sept.-Oct., pp. 13-19

WIPO – International Patent Classification (2015). Retrieved on January 30, 2015 from http://www.wipo.int/classifications/ipc/en/preface.html

Youtie, J., Shapira, P., Dodonova, D. & Beckerman, A. (2014). The Georgia manufacturing survey. Making it in the global economy.

Youtie, J., Shapira, P., Urmanbetova, A. & Wang, J. A (2007). A Brief History of the future of manufacturing: US manufacturing technology Forecasts in Retrospective, 1950-Present. International Journal of Foresight and Innovation Policy 3.3: 311-331. Available at: http://works.bepress.com/jan_youtie/54.

Vecchiato, R. (2012). Strategic Foresight and Environmental Uncertainty: A Research Agenda. Foresight, 14(5), 387-400.

Zha, X. & Chen, M. (2010). Study on early warning of competitive technical intelligence based on the patent map. Journal of Computers, 5(2), 274–281.