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Journal of Intelligence Studies in Business Vol 4, No 1 (2014) 5-15

Technical Intelligence Approach: Determining Patent Trends in Open Die Forging

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Received January 10, accepted 5 May 2014

ABSTRACT: Open die forging is an important process for alloys and steels present in a variety of industries, such as in the aerospace industry, construction, mining and general machinery. During the forging process several wear mechanisms occur: thermal fatigue, plastic deformation, mechanical fatigue, etc. causing quality damage and economic losses. Academy and industry are devoting significant efforts to confront this situation where research acquires a key role. Under this context the objective of our research is to apply patent analyses as part of a Competitive Technical Intelligence methodology on open die forging. In particular, a keyword-based patent analysis and a patent citation analysis were developed to identify the organisations, countries, inventors, and technological trends more important for this area.

KEYWORDS: Open die forging; Competitive Technical Intelligence; Patent Analysis; Citation Analysis.

1.0 Introduction

Forging is a manufacturing process where metal is pressed, hit or compressed under great pressure to create high-strength parts (Forging Industry Association, 2013). The open die forging process involves the formation of preheated metal pieces placed between an upper and lower die attached to a press (ScotForge 2014). This process can be used for a wide range of alloys and steels in a variety of industries, such as in the aerospace industry, construction, mining, general machinery, etc.

Typically, metal parts are worked on at their recrystallisation temperature, which is between 1900°F and 2400°F for steel. The open die forging process improves the quality of the material via the transformation of the mould structure, which removes any gaps that may be present in the steel (ScotForge 2014).

One of the problems of the open die forging process is the tools that are used are relatively expensive. Therefore, the process is economically attractive only when a large number of parts are produced and/or when the mechanical properties required in the finished product can be obtained only by a forging process, which has been previously described (Shen et al. 2004). Similarly, the wear produced in the tooling during the metal forming process must be accounted for.

During the forging process, dies are subjected to mechanical and thermal stresses induced by thermal cycles and other forging operations, which damage the dies' surfaces and sub-surface layers (Magri et al. 2012). Due to this adverse environment, several wear mechanisms occur: thermal fatigue, plastic deformation, mechanical fatigue, etc. After long-term wear failure has occurred, dies must be removed from service and discarded once the workpiece is either out of dimensional tolerance, exhibits poor surface finish, or sticks to the dies or transfer mechanisms (Choi et al. 2012).

Because there are a significant number of factors involved, it is important to detect the primary technological research trends in the open die forging process. The objective of our research is to apply patent analyses as part of a Competitive Technical Intelligence methodology on open die forging. In particular, a keyword-based patent analysis and a patent citation analysis were developed to identify the organisations, countries, inventors, and technological fields with a more worldwide presence.

This approach is part of a Master's thesis in Quality and Manufacturing Systems at X, where the author is Y (2014). The idea of analysing open die forging came from a project that the Competitive Technical Intelligence unit at X developed for Steel Company X. This project is confidential, and therefore, this paper presents the subsequent research developed during the Master's thesis. Here we removed the names of our Institute as is suggested by JISIB for the evaluation.

This paper is organised in the following sections. First, we present the theoretical background of Competitive Technical Intelligence and Patent Analysis. Then, the analysis is described in the Methodology section. The results and discussion of our research are presented afterwards. Finally, the conclusion and limitations of the research are discussed.

2.0 Competitive Technical Intelligence

Competitive Intelligence (CI) is a necessary, ethical business discipline for decision-making based on understanding the competitive environment (SCIP 2013). At its most basic description, intelligence is analysed information (Fuld 2014). Competitive Intelligence is understood as a discipline in which, through a systematic, ethical process, is responsible for monitoring the competitive environment of a particular industry. This discipline is also seen as a proactive approach for strategic planning, where information regarding the environment is obtained, transmitted, evaluated, analysed and made available to the customer as the end result that supports cognitive decision making (Rodríguez and Lopez 2000).

Competitive Technical Intelligence (CTI) is the analysis of sensitive business information of external scientific research or technological threats, opportunities or developments that can potentially affect the competitive position of a company (Ashton et al. 1994). According to Ashton et al., CTI pursues three main objectives:

1. Provide early warning of external technical developments that represent potential threats or opportunities for the business.
1. Evaluate new products, processes and prospects for cooperation in science and technology to generate appropriate responses.
2. Anticipate and understand trend-related changes in the competitive environment as a preparation for organisational planning and strategic development.

In addition, Competitive Technical Intelligence consists of monitoring the business environment, which involves scientific and technological developments related to processes of research, development and innovation, technology acquisition policies, joint ventures, research and development portfolios, etc. (Rodríguez and Escorsa 1998).

2.1 Patent analysis in CTI

In an organisation, patents are considered the most valuable output indicators in the process of technological innovation (Hidalgo et al. 2009). It is important to state that almost 90% of all technological information can be found in patent publications (Blackman 1995). Patent documents are an important source of competitive intelligence that companies can use to gain strategic advantages; for many years, patents have been considered indicators of technological progress (Rodríguez and Tello 2012).

There are several patent classification systems: the International Patent Classification (IPC), the United States Patent Classification System (USPCS) and the Cooperative Patent Classification (CPC). IPC is a hierarchical classification system of increasing complexity; it is divided into classes, sub-classes, groups and sub-groups. The World Intellectual Property Organisation defines itself 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" (WIPO 2014).

The Cooperative Patent Classification is a bilateral classification system, which has been jointly developed by the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO). The Cooperative Patent Classification improves patent searches, with more detailed classifications and with added and revised sections. IPC has over 70,000 technology entries, whereas CPC has over 250,000. Moreover, CPC has an additional section: "General tagging of new technological developments; general tagging of cross-sectional technologies spanning over several sections of the IPC; technical subjects covered by former USPC cross-reference art collections [XRACs] and digests" (EPO 2014).

2.2 Keyword-based Analysis

The keyword-based patent analysis uses information from patent incidences, which includes defined keyword frequencies and co-occurrences between them. The outcomes of this analysis are used to identify trends in advanced technology, discover new technological opportunities, predict new technological concepts, and develop technology roadmaps (Choi et al. 2012).

The keyword-based patent analysis can also be used to compare the strategic positioning of a certain industry to several countries. By studying patent frequency of assignees from different countries, analysts can determine which countries are taking the lead in different technological areas. Similarly, researchers can analyse the profiles of inventors/organisations to identify the contributions of a specific patent that establishes relations with countries or technological classifications (Trappey et al. 2011).

A patent map uses patent information to create specific graphs and charts that provide simple, intuitive ways to address complex technical information (Zha and Chen 2010). A simple form of representation is through patent incidences, which may be expressed in terms of particular patent information, such as assignees, inventors, countries, IPCs, or based on a defined time period.

2.3 Patent Citation Analysis

A patent citation analysis is useful to identify knowledge flows at distinct levels: national, industrial, business and technological. The patent citation analysis intends to find all patents that have been cited by (i.e., backward citations) and those that cite the analysed patent (i.e., forward citations).

This type of analysis is useful to detect state-of-the-art technology or to determine high similarity inventions (Park 2013). Similarly, a patent can also cite non-patent literature, not only scientific articles but also a mixed set of other publications, such as conference proceedings, books, newsletters, among others (List 2010). Additionally, patent citations made to scientific literature in a particular sector have been used as an indicator of scientific activity within research and development in this area (Bergmann et al. 2008).

3.0 Methodology

For this research, Patent Insight Pro was used, which is a patent research, analysis, mapping and visualisation software. Developed in India in 2004, this software provides decision support solutions, information analysis, and technology monitoring. Patent Insight Pro provides global services to industries that produce energy, electronics, medical devices, etc. (Patent Insight Pro 2014).

Figure 1 illustrates the methodology of this research, which departed from the proposal by Rodriguez and Tello (2012) on its six stages, where the variations in the Patent Analysis were implemented by the aforementioned Author of the Master's thesis.

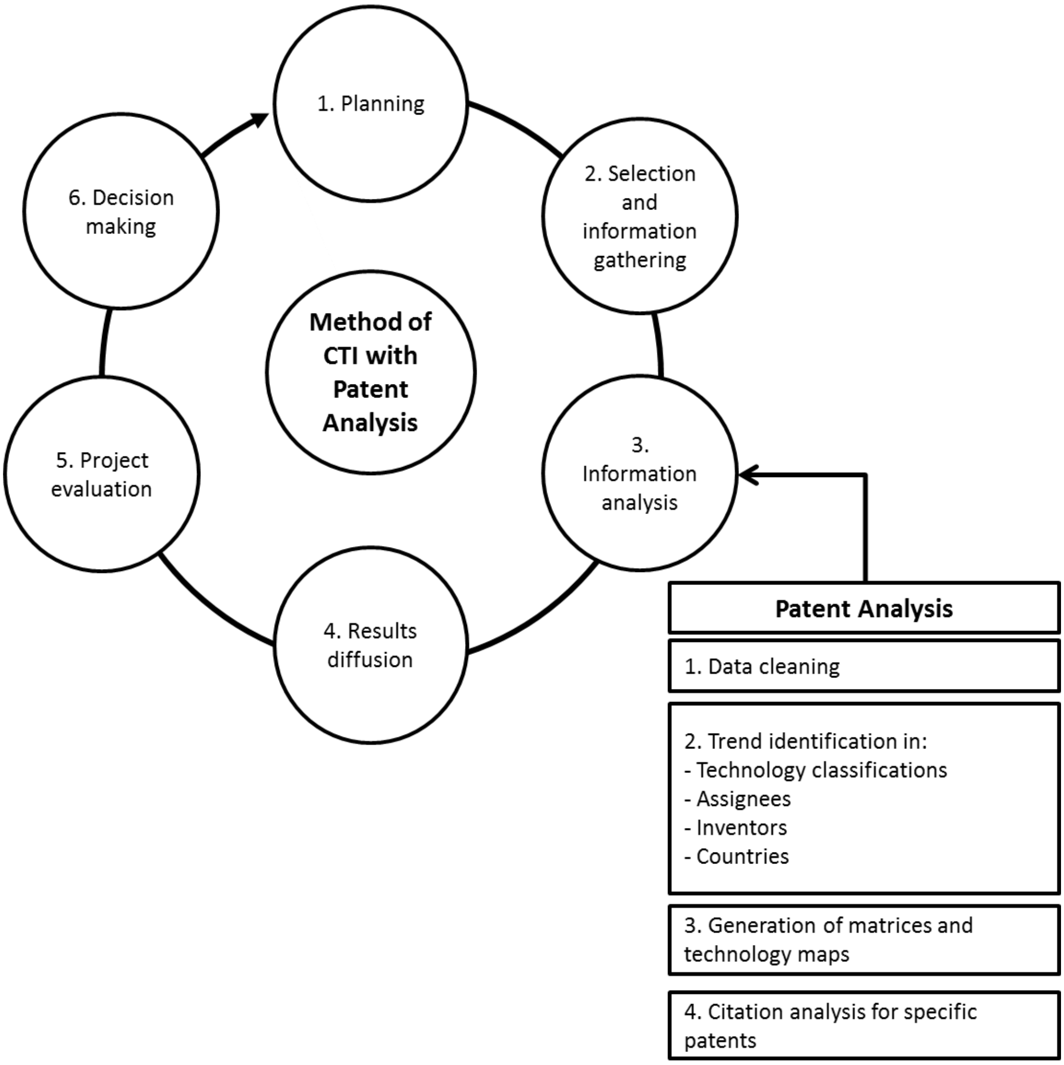

Figure 1. Competitive Technical Intelligence and Patent Analysis. Adaptation from Tello & Rodriguez, 2012.

The following are the descriptions of the six steps shown in Figure 1:

1. Planning: Refers to the objectives statement, scope, and limitations and includes allocation of resources and responsibilities.
2. Selection and information gathering: Primary and/or secondary sources of information. In our case, we focused our attention to the patent source of information.
3. Information Analysis: Different methods can be used. In this case, we developed a patent statistical analysis, which is based on 4 steps:

    - Data cleaning. The patent data obtained from the “Selection and Gathering of Information” step are cleaned; the fields of Assignees, Inventors, Countries, etc., are filled with the latest information.
    - Trend identification. The purpose is to identify the primary applicants, patent codes (IPC, CPC, USCP, etc.), countries and keywords.
    - Generation of matrices and technology maps. In this step, we generate matrices and technology maps that link the identified trends.
    - Citation Analysis. Backward and Forward patent citation analysis is recommended to identify inventions that are highly related to the original patent.
4. Diffusion of Results: Disseminate information to stakeholders.
5. Project Evaluation. The project is evaluated by the stakeholders to receive feedback and to identify areas for improvement.

6. Decision Making. This part of the methodology is performed exclusively by the company or the primary decision-makers involved. This purpose of this step is for the company to use the results presented in the CTI Report to develop action plans based on the analyses performed.

It is important to clarify that, as was mentioned in the introduction, the project developed for the Steel Company X is confidential and therefore, cannot be disclosed in this work. This paper presents a supplementary study, where the author of the Master's thesis developed a search string that is different from the one used in the project. The search strategy was expanded by increasing the range of years and modifying the terms used in the keywords, which resulted in a greater number of patents for analysis.

For the purpose of this research, we will focus on the Patent Analysis stage; similarly, we will cover the first 3 steps of the methodology because the last steps involve the dissemination of information, stakeholders' project evaluation and the decision-making process.

3.1 Planning

In this phase, we established the scope, objectives and participants of the project. The research focused on patents published between 2008-2014. The objective was to identify top companies, inventors and trending technologies developed in the field of open die forging.

3.2 Selection and gathering of information

The collection and analysis of the patent data were performed using the Patent Insight Pro software program. We selected the period of time from 2008 up to March 15th, 2014. This search was conducted on the Espacenet Database to retrieve a large number of patents worldwide, which would provide an accurate perception of the latest progress in this field.

We first searched the abstract and claims sections of the patent documents using (open die forg*) as the primary keywords. However, several of the results were not within the scope of our research because in several cases, the primary keywords were not listed as the patent's central invention or were related to industries different from the forging industry.

Finally, to perform the search, we used the terms, [open die forg* AND (tool* OR die*)], as the primary keywords. The established keywords provided accurate results according to the scope of our analysis.

3.3 Patent Density

To perform the search in Espacenet, we used Boolean terms to transform our keywords into a search string. Through the patent search in Espacenet, we obtained the following results: 86 published patents (80 patent families and 6 individually issued patents), 194 inventors, 78 assignees, 22 IPC main groups, 112 IPC full groups, 9 CPC main groups and 45 CPC full groups.

Figure 2 presents the patent trend by year. The X-axis in the graph indicates years, and the Y-axis indicates the number of published patents. As we can see, there is a steady increase in patent publication since 2010.

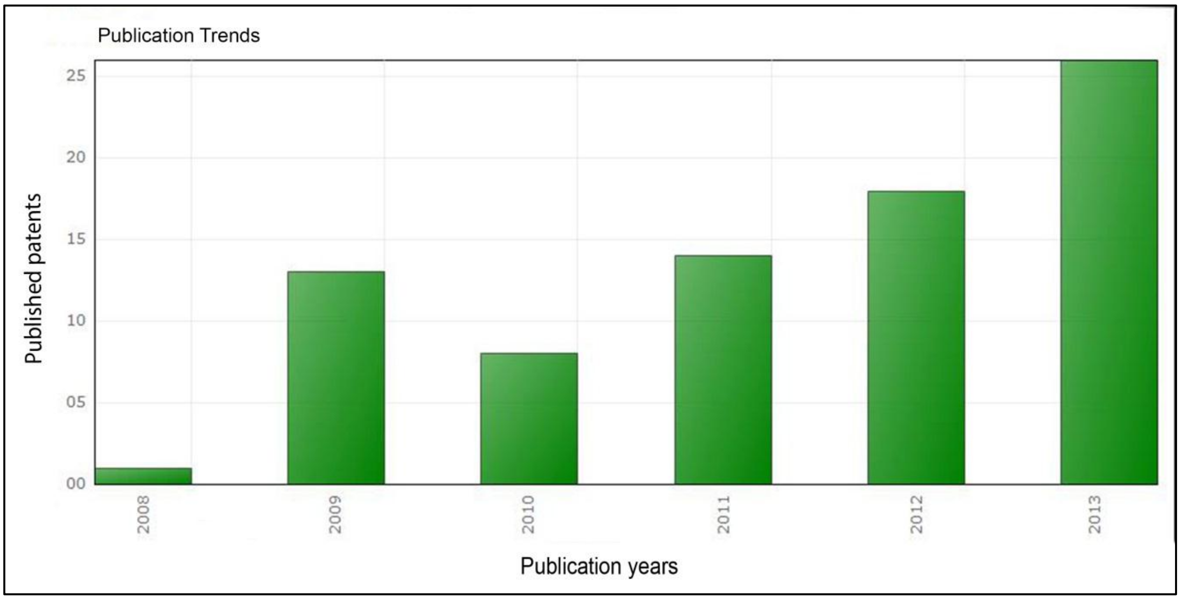

Figure 2. Patent density. Data from Espacenet using Insight Pro.

4.0 Results and discussion

4.1 Data Cleaning

Once we obtained all of the patent documents, we proceeded to filter and clean the data, specifically the ‘Assignees’, ‘Inventors’ and ‘Country’ fields. This task is useful for merging similar terms, updating patent information to the latest assignees, avoiding repeated information, etc. In this stage, internal keywords were identified (453 different keywords in total) among the most repeated words in the Title, Abstract and Claims sections of the 86 patents. The following results are from 2008 to 2014.

4.2 Patent Activity and Main Trends

4.2.1 Top Organisations

Organisations with the highest numbers of patents were identified; the top 3 organisations in descending order are the following:

- ATI Properties Inc. (USA): 7 patents
- Wuxi Turbine Blade Co. (China): 5 patents
- National Machinery Co. (USA): 3 patents

4.2.2 Top Countries

A strong patent activity was detected primarily from China (52 patents), followed by the USA (13 patents) and Germany (4 patents).

4.2.3 Top IPC Full-Digit Codes

As previously stated, the IPC system offers an international categorisation for different inventions, which allows a trend analysis in different technological areas. The top 10 IPC full-digit code trends are shown in Figure 4.

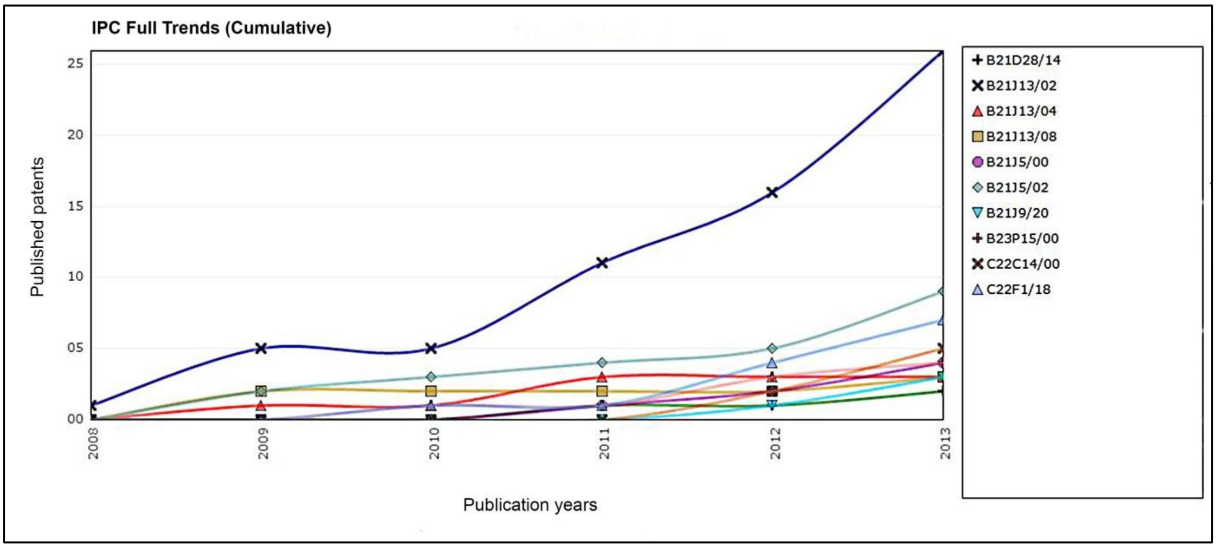

Figure 3. Top 10 IPC full-digit code trends. Data from Espacenet using Insight Pro.

The following are the descriptions of the top 3 IPC full-digit codes shown in Figure 3:

- B21D28/14. Working or processing of sheet metal or metal tubes, rods or profiles without essentially removing material; punching. Shaping by press-cutting; Dies.
- B21J5/02. Methods for forging, hammering, or pressing (for working sheet metal or metal tubes, rods, or profiles B21D; for working wire B21F); Special equipment or accessories. Die forging; Trimming by making use of special dies.
- C22F1/18. Changing the physical structure of non-ferrous metals or alloys by heat treatment or by hot or cold working/high-melting or refractory metals or alloys based thereon.

4.2.4 Top CPC Full-Digit Codes

As seen in Section 2.1, the Cooperative Patent Classification System refers to a technological classification, which contains a revised and more detailed description of each group and sub-group compared with the IPC system. The following figure shows a timeline with the trend of the primary CPC 8-digit codes.

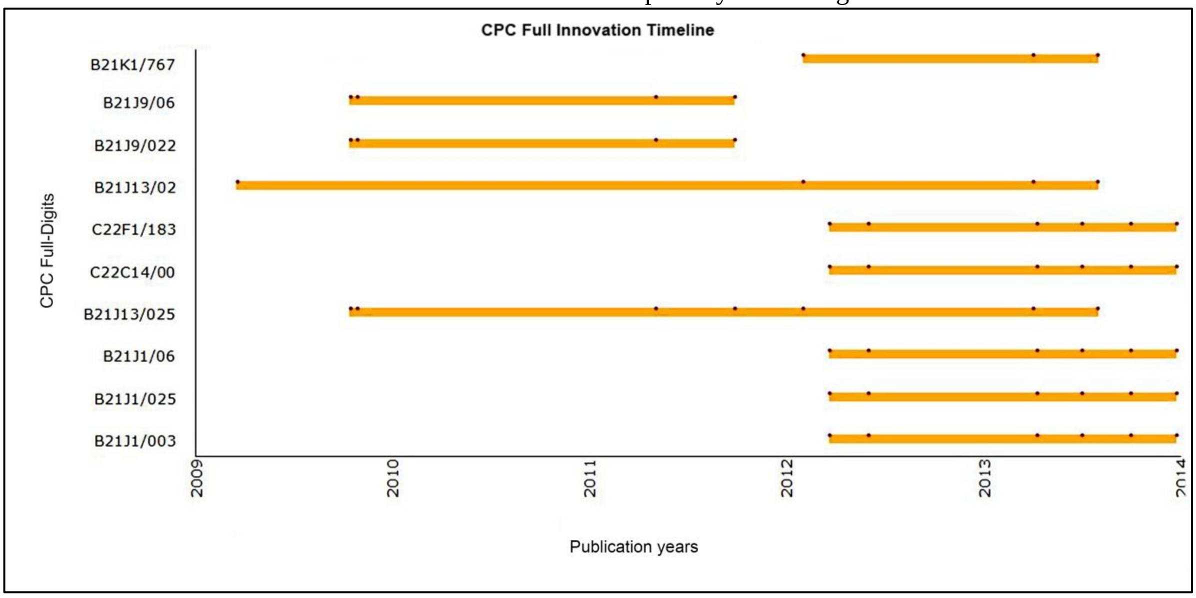

Figure 4. CPC full-digit code timeline. Data from Espacenet using Insight Pro.

There are 5 primary CPCs that jointly present a patent trend:

- C22F1/183
- C22C14/00

- B21J1/06
- B21J1/025
- B21J1/003

The C22F1/183 and C22C14/00 codes are related to metal processing, with a focus on treatment of titanium alloys. Moreover, the B21J1/06, B21J1/025 and B21J1/003 codes relate to the metal treatment by forging, pressing, etc., with sub-classifications, such as heat treatment and material preparation.

4.3 Technology map generation

4.3.1 Technology Map - Organisations VS IPC Full-Digit Codes

To visualise the patent activity of organisations, we generated a technology map that link the top 10 assignees with the top 10 IPC full-digit codes; Figure 5 presents an example of such a map.

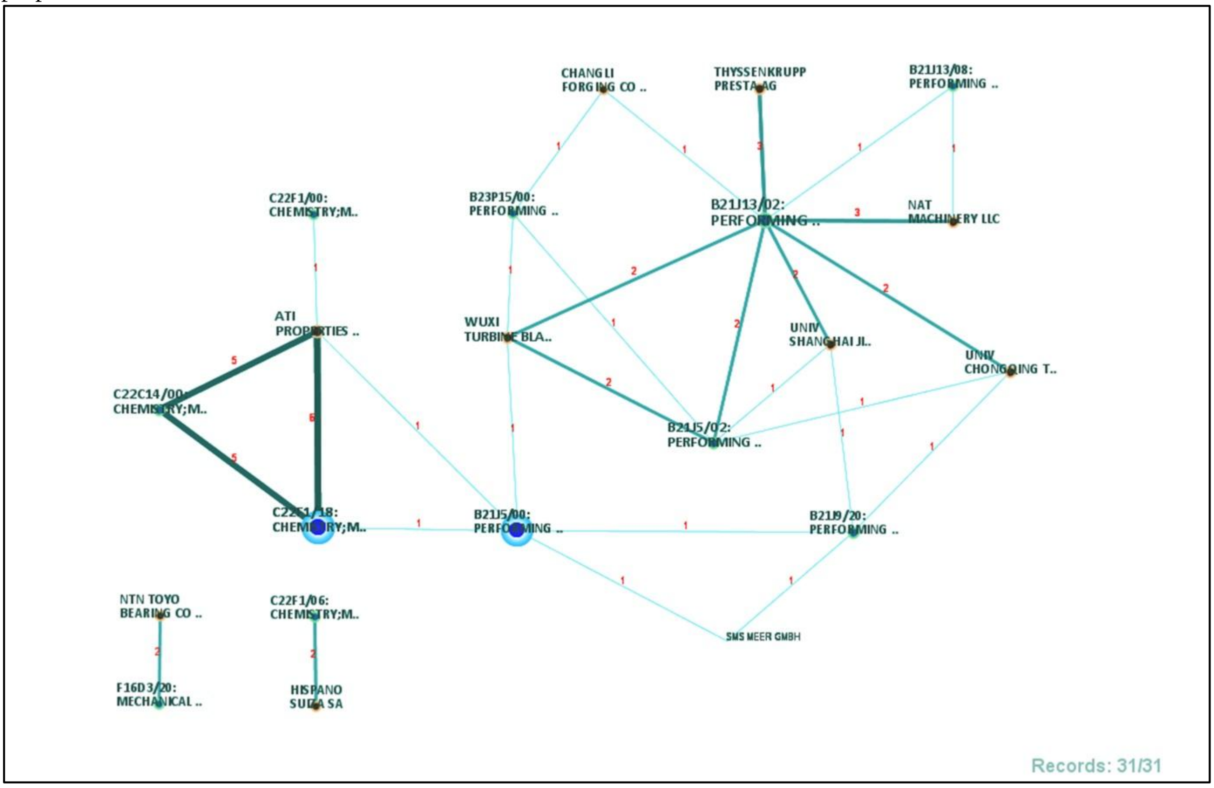

Figure 5. Organisations vs. IPC full-digit codes. Data from Espacenet using Insight Pro.

It should be noted that the company, ATI Properties Inc. (USA), has had a remarkable amount of activity in technological inventions in the following fields:

- C22F1/18 - Changing the physical structure of non-ferrous metals or alloys by heat treatment or by hot or cold working/high-melting refractory metals or alloys or based thereon; and
- C22C14/00 - Metallurgy; ferrous or non-ferrous alloys; treatment of alloys or non-ferrous metals. Alloys/alloys based on titanium.

4.3.2 Chinese Patents

Section 4.2.3 presents China as the country with the greatest patent activity in open die forging. The results show that the top applicants have, on average, 3 patents per organisation. However, there are numerous universities, companies and independent inventors who have a single published patent (31 of 41 Chinese organisations), which altogether, places China as the primary country in open die forging activity.

Additionally, as shown in Figure 6, there is an increasing patent publication trend in this country.

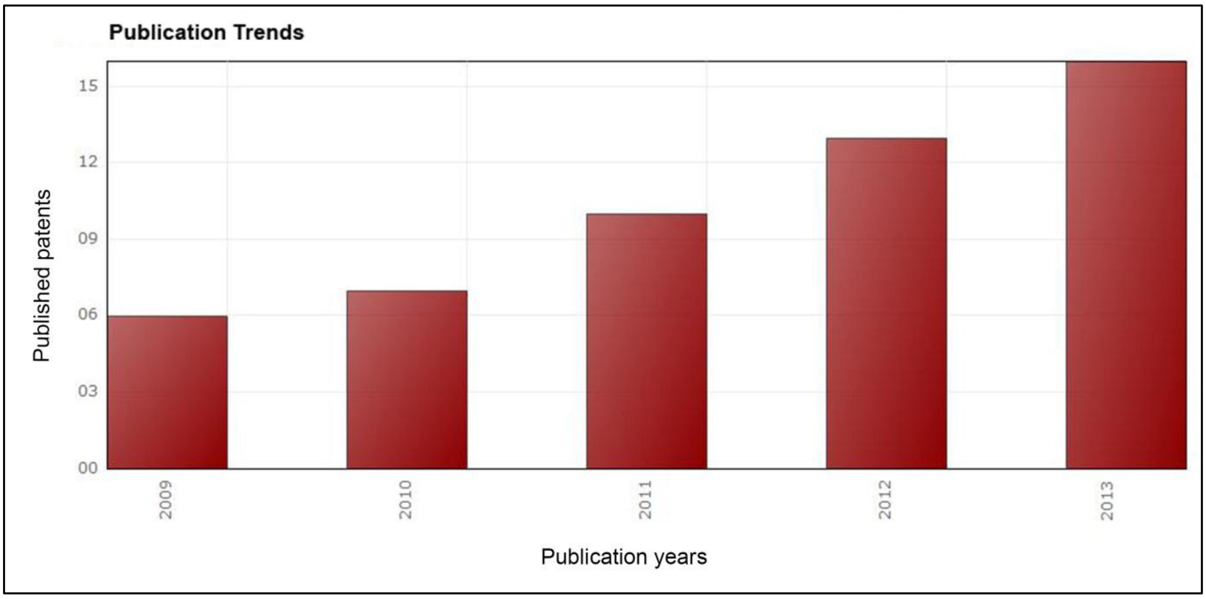

Figure 6. Patent density in China.

From 2009 to 2013, the percentage of patent publication has grown by approximately 160%.

4.3.3 Identification of technological trends

For this part, we focused on several of the primary topics in open die forging (dies for forging, lubricants and hydraulic presses) to identify technological trends. For this task, an analysis of the Title, Abstract and Claims of patents was performed. Here, we present the 2 primary trends supported by 2 examples of the identified patents.

1. Dies for forging. New die forms tend to be a more efficient process, which prevents deformation of parts and increases the life of the die.
    - CN202334187. Zhengzhou Jinyang Electric Co. (China) has proposed a structure with a bottom-top-closed opening, which reduces the deformation in the heat treatment process.
    - CN202752519. Yancheng Liken Forging Co Ltd (China) has designed a die to reduce the forging strength and increase the life of the die.

2. Lubrication systems pursue the uniform application of lubricant in the die system and forging pieces.
    - JP2008207194. Kurimoto Ltd. (Japan) has designed a device for the uniform application of lubricant in a press forge using lubricant spray nozzles.
    - TW201036728. Amada Co. Ltd (Taiwan) has developed a set of punching dies, which includes a lubrication system for the same purpose.

4.4 Citation Analysis

As seen in Section 2.1 - Patent analysis in CTI, a Patent Citation Analysis is useful to find highly related inventions of a certain patent.

The patent US8613818 - Processing Routes for Titanium and Titanium Alloys, was selected due to its importance throughout the investigation. This patent is the one with the most members in their family of patents, with a total of seven (USA, Taiwan, China, Australia, Mexico, Canada and WO-world). Moreover, it belongs to the primary assignee of our research, ATI Properties Inc. (Figure 3), and is also classified into the primary IPC full-digit code (C22C14/00), as shown in Figure 4.

This patent has 11 backward citations but no forward citations. The citation tree for this patent is shown in Figure 7.

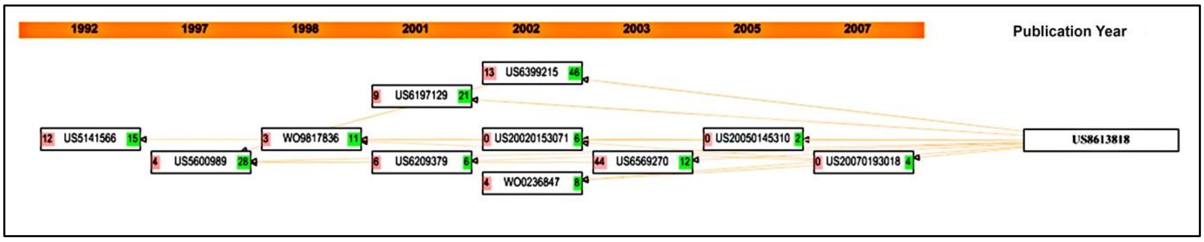

Figure 7. Citation analysis for patent US8613818.

Three of the most recent patent cites are presented on Table 1.
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Patent number	Title	Assignee	Publication date
US20070193018	Methods of beta processing titanium alloys	ATI Properties Inc.	23/Aug/2007
US20050145310	Method for producing homogeneous fine grain titanium materials suitable for ultrasonic inspection	General Electric Company	07/Jul/2005
US6569270	Process for producing a metal article	Honeywell International Inc.	27/May/2003

Table 1. Three backward citations for patent US8613818.

5.0 Conclusions

Through the Patent Analysis methodology incorporated into the discipline of Competitive Technical Intelligence, we identified the key players in open die forging, which include countries, universities, companies and organisations. Similarly, it was possible to establish the primary lines of research through the analysis of patent classification systems, such as IPC and CPC.

By means of technology maps, it was possible to identify the most important research lines of the primary applicants. Additionally, this section presented an analysis of the patent activity of China because it is the primary country that is developing and protecting technology in open die forging.

We also identified technology trends, where major advances are presented in forging dies, lubricants and hydraulic mechanisms for process control. Finally, through the Citation Analysis of patent US8613818- Processing Routes for Titanium and Titanium Alloys, it was possible to find highly related inventions to that patent based on backward citations; this analysis could also provide insights into the evolution of a certain industry.

The methodology of Competitive Technical Intelligence and Patent Analysis makes it possible to gather information regarding leading organisations, research areas, etc. Through this methodology, it was possible to identify trends that could represent a business opportunity or threats to the open die forging industry. This methodology could be combined with other types of analysis (market analysis, Porter five forces, etc.) to enrich and make the process of strategic decision-making more precise.

Acknowledgement

We would like to thank the Steel Company X who provided important advice for the Master's thesis of Alejandro Palacios. We would also like to thank Francisco Paredes (research assistant at the Quality and Manufacturing Center at Tec de Monterrey) for his help in the electronic artwork.

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