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Development of riveting technology through an analysis of Belgian patents (1830-1940)

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ABSTRACT

The development of riveting technology in iron and steel structures in the 19th and 20th centuries were highly promoted by patents. Although riveting was widely used in buildings and civil engineering structures, little information about the development of this technology – how rivets were manufactured, various installation techniques – is available in literature. This paper discusses a database of patents related to riveting technology that was created to better understand the innovations in riveted connections and their technological evolution. The database includes patents relating to rivets registered in Belgium between 1830 and 1940.

Belgian patents are a good proxy for inventiveness in riveting technology in this period, in industrialized countries generally, not only Belgium. As one of the most industrialized countries, Belgium attracted inventors from many countries seeking to register their inventions: foreign inventions represented approximately 75% of all patents. Breakthroughs by important Belgian, French, British, and American inventors/companies are represented in this source.

A methodology based on both quantitative and qualitative analyses was implemented. The quantitative analysis dealt with the entire database and explored several key parameters, for example, the subject of the patent and the patenting organization/person. The database also permitted qualitative analyses; specifically, it helped enlarge our understanding of pioneering inventors and their inventions, in the important categories of rivet manufacturing (1855-1870) and installation techniques (1895-1910). As background for the conservation and renovation of historic iron and steel structures, it is vital to have an understanding of the know-how that was available over time. This kind of information is revealed in the patent record.

Keywords: *Riveting technology, Patents, Iron and steel constructions, Technological innovations, Manufacturing and installation techniques, Belgian patent data*

1. INTRODUCTION

When engineers and architects have to assess riveted connections in historic iron and steel structures, they are often confronted with issues – both theoretical and practical – for which the available literature may not provide satisfactory answers. In-depth appraisal, including an understanding of the technological history of the materials and assemblies, is a necessary first-stage task before undertaking any renovation project. Riveted connections are a key factor to investigate, given their predominant

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influence on the overall structural behavior [1, 2, 3, 4]. Yet much remains unknown about this complex, and now largely obsolete, technology. The subject of riveting connections has been intensively studied by authors such as Jacomy [5, 6], Frémont [7] and Simmons [8], who focused mainly on sources as contemporary journal articles and books, manufacturers' handbooks, building codes, etc.

The research presented in this paper uses a new source to add to our knowledge of rivet manufacture and installation: *historical patents*. It aims to analyze the development of riveting technology, and more specifically the manufacturing and installation techniques, based on patents related to riveting technology that were registered in Belgium between 1830 and 1940. Within the framework of research on construction history, the patent record can be used to investigate when inventions were introduced, what problems were considered important, and how technologies changed over time. In addition, a quantitative study of patents broadens the research horizon. Studying the patent type, the patented topic, the inventor/applicant's name, the profession and nationality information provides an understanding of the peak-periods, important players (inventor/company), technological challenges, improvement and evolution of techniques, international technology transfers, etc [9]. Increasing the general knowledge on the riveting theory and practice should improve insight into historic construction and thus the renovation project.

2. BACKGROUND INFORMATION AND METHODOLOGY

2.1. The Belgian patent data, reflecting international inventions

Belgium and its extensive patent data were chosen as a case study to analyse the inventiveness of the riveting technology. In spite of its young age (independence in 1830) and small size, Belgium had been competing against the United Kingdom, France, and later against the United States and Germany, to become the most industrialized country in the world. The 'Patent System,' established during the 1810s, was one of the legislative tools used by successive governments to stimulate the economic and industrial growth of the country [10]. Belgium had a dynamic patent system, according to Saiz Gonzales [11], outpacing the USA, UK, etc. in terms of granted patents per 1,000 inhabitants between 1830 and 1880. Financial, cultural and legal incentives, along with an open policy on foreign techniques and technology transfer, were the major distinctive features of the Belgian patent system [10, 12, 13, 14]. Therefore, almost 75% of patents in Belgium were granted to persons and corporate entities from outside Belgium, an amount that also is higher, on average, than in neighbouring countries [10]. As a consequence, the Belgian patent data sheds light on international technological development.

2.2. Patent procedure

A patent is defined as a form of intellectual property that grants an exclusive monopoly to its holder – the patentee – for using and protecting an invention (material, technique, machine, etc.) during a defined time period, called the patent term. Before being granted and enforced, the applicant – the inventor himself or his assignee – had to file a patent's application that contained an administrative section (patent's title, date, applicant's name, etc.) and a descriptive section (aims, detailed description and claims), with or without illustrations (drawing, plan). Beginning in 1791 during the French annexation of Belgium, and continued by the Dutch law of 27th May 1817, three patent types were established. A patent was called an *invention* when it was first applied for in any country, irrespective of the patentee's nationality. When the invention or improvement had already been granted a patent in another country, the Belgian patent was called *importation*. And *improvement* was used to refer to an improvement of an existing Belgian patent. Unlike the American, British or German patent systems,

no technical patentability requirements – e.g. novelty, relevance, quality, non-obviousness – had to be met in order to be granted a Belgian patent [9, 10]. As a result, many patents were granted which were not effectively commercialized or used in the industry. At any rate, the Belgian procedure stimulated a strong policy on inventive activity.

2.3. Law of 1854: exponential increase in registrations, exponential increase in patent terms?

Before 1854, the applicant could choose one of three patent terms – 5, 10 or 15 years – with the application fee increasing with the term, and the entire fee had to be paid as of the application date. Then in 1854, under new legislation, terms and payment procedures changed: the new law spread out payment of the registration fee, and added an unusual, and long, patent term of 20 years [10, 12]. To maintain the validity of his patent, the patentee had to pay each year a patent annuity that progressively increased over time: a sum of 10, 20, 30 etc. Belgian francs was due for the first, second, third years etc. Thanks to its flexibility, the new legislation contributed to a democratization of invention and generated a considerable increase of patent registration by attracting many foreign inventors (importation patents).

2.4. Research methodology: setting up of a patent database

Unfortunately, historical Belgian patents registered before 1984 cannot be consulted online [15, 16]. Rather, to study them, one must visit the archives of the Belgian Intellectual Property Office in Brussels. From research in this archive, a database [17] of around 300 patents dealing with connection techniques was set up; it includes all patents identified as relating to riveting technology dating from 1830 to 1940. Patents were selected based on their title from inventories (compilation of all the granted patents): *Catalogue des brevets d'invention* (1830-1854) [18] and *Recueil des brevets d'invention* (1854-) [19]. Each patent was then encoded and described by a list of parameters, notably a topic and a subtopic. The use of other filters (time period, inventor, topic, etc.) eased search queries within the database. Finally, a stratified sample was selected and 134 patents were fully digitized [20]. The high correlation percentage (93.2%) between this database and one created by the historian Arnaud Péters, which contains more than 10,000 Belgian patents date from 1830-1873, validates the exhaustiveness and the representativeness of our database, and its potential as a reliable tool.

3. QUANTITATIVE ANALYSIS

The milestones in the evolution of the riveting technology were assessed by plotting a series of charts (line graphs, bar and pie charts) based on the patent database [17]. In the patent inventories, patents dealing with the general topic 'rivets' belonged to the category 'Mining and metallurgy', which was one of the most important in terms of the number of applications. The other important topic was 'Machines and mechanics' [10, 12]. The number of patents in these categories varied over time. Between 1870 and 1914, the 'Mining and metallurgy' sector in Belgium experienced a downward trend in part due to its internal reorganization (merging of companies) increased by the economic depression of 1875-1890. Actually, technological breakthroughs had induced a change in the business strategy: the export of raw materials declined and production of finished and semi-finished products increased [12]. The number of patents regarding riveting technology intensified during that same period, contrary to the global declining trend within the 'Mining and metallurgy' sector [17].

3.1. Use of rivets in structural iron and steel construction

From 1844 onwards, the construction of large-span iron bridges in the U.K. announced the early stirrings of a new joining era – riveted connections – within the field of iron and steel construction [5,

21]. The emblematic Conway (1848) and Britannia (1850) tubular bridges, designed by William Fairbairn under the direction of Robert Stephenson, are fine examples. Though previously introduced by two other industry branches, namely boilermaking and shipbuilding, riveting technique developed and its use became widespread as it was adopted for iron and steel construction [4].
According to Jacomy [5], the heyday of riveting lasted around 90 years, from 1830 to 1920, and use of the technique started to decline around 1930, being progressively supplanted by welding. Structural, financial, and practical considerations made it disadvantageous compared to electric arc welding [4]. These trends are confirmed by the bar chart below (fig. 1): the number of patents for the topic 'rivets' is characterized by a bell curve centered on the peak of 1896-1910. Furthermore, the chart highlights the time-lag with the patenting intensity related to bolts, which were often combined with rivets to connect structural members together (e.g. beam-column joint, portal frames, trusses).

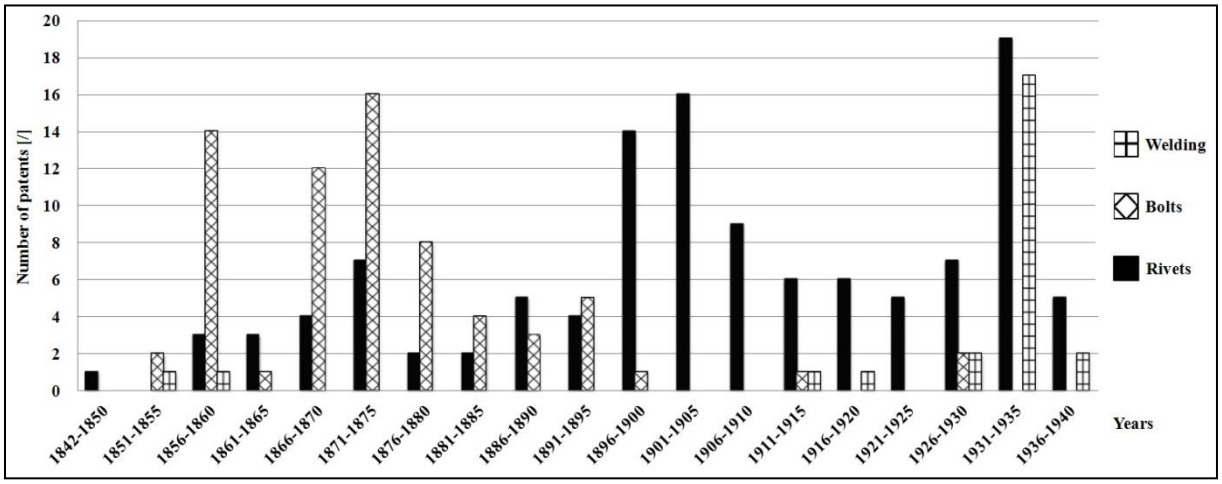

Fig. 1 Change in the number of patents for the main topics 'Welding', 'Bolts' and 'Rivets' registered at the Belgian Patent Office between 1830 and 1940 [/] [17]

3.2. Investigated issues and techniques

The quantitative analysis shows the types of issues and techniques that concerned inventors and their relative importance. Each patent dealing with the main topic 'rivets' was also classified according to one of five subcategories: 'Riveting Machine (all),' 'System and Technique,' 'Manufacturing Rivet (all),' 'Rivet Head,' and 'No subtopics.' With respectively 33% and 32% of patent registrations, the riveting machines and the manufacturing of rivets were the two most important subcategories (fig. 2).
The category 'Manufacturing Rivet (all)' refers to patents that discuss the manufacturing process and machines intended to forge the first rivet head from a cut segment of cylindrical iron rod. These patents reflected the urgent need to mechanize production to meet the rising demand, from 1850 onwards. They deal with the performance of rivet-making machines, e.g. supply of iron bars and ejection of the forged rivets, also intended to increase output. Within the category 'Riveting Machine (all),' around one third of the patents go into more detail about the energy supply for operating riveting machines (fig. 2). The first mechanical processes, aimed to solve the limitations of manual riveting, were replaced step-by-step by riveting machines driven by steam, and then hydraulic, pneumatic, hydro-pneumatic and finally electrical energy [22]. This technological change is exposed in the filing dates of patents: we see in the patent database when specific techniques were first described, for example: 'hydraulic riveting machine' (since 1866, 7%), 'pneumatic riveting machine' (since 1899, 9%) and 'hydropneumatic riveting machine' (since 1925, 3%) (fig. 2) [17].

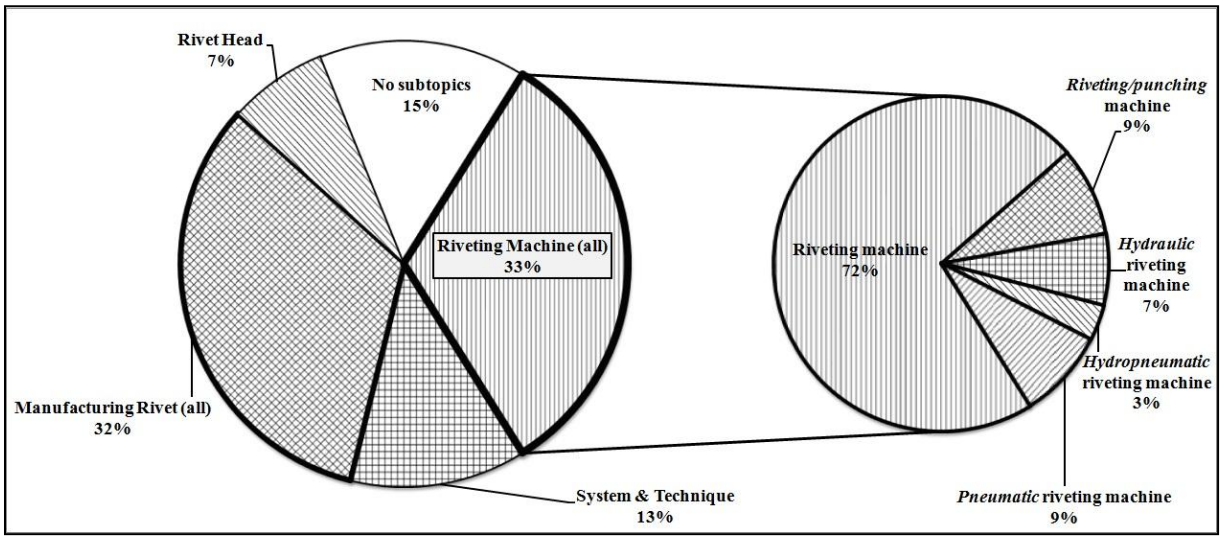

Fig. 2 (Left) Classification by subtopics of patents related to the main topic 'Rivets' (1830-1940) [%]; (Right) Classification of the subcategory 'Riveting machine (all)' according to the technology mentioned in the title of patent (1830-1940) [%] [17]

3.3. Breakthroughs in the riveting technology, two main 'peak-periods'

Although equivalent in terms of relative importance, the two main subcategories were prominent at different times. An interesting observation is the presence of a first peak, from 1855-1870, during which almost all the patents dealt the manufacturing of rivets (86.8% of the registered patents, 1855-1870) (fig. 3). Partly due to the institution of the law of 1854, this peak-period is characterized by a significant number of importation patents (36%) [12].

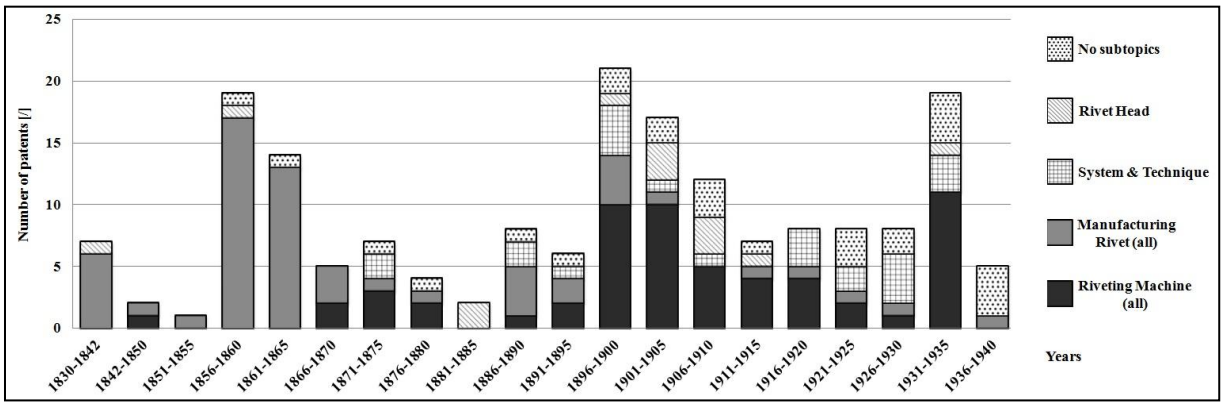

Fig. 3 Number of patents in the main topic 'Rivets' classified by subcategory: 'Riveting machine (all)', 'Manufacturing rivet (all)', 'System and technique', 'Rivet head' and 'No subtopics' (1830-1940) [/] [17]

Many of these machines were multifunctional – manufacturing of bolts and rivets, and nails, etc.; a frequent patent title was *Machine à fabriquer les boulons, (...) et les rivets.* [17]. The literature [5, 7] regarding the introduction of the first rivet manufacturing machine – the invention of a Frenchman boilermaker, Antoine Durenne, in 1836 – fits well with the first patents under this topic appearing in the database (e.g., importation patent of James Vardy, 1838).

In a second peak period, 1895 and 1910, patent registrations increased for a variety of subtopics, but still the subcategory 'Riveting Machine (all)' dominated, represent 51% of the patents (fig. 3). Although the first riveting machine was invented in 1838 by William Fairbairn in Manchester (UK),

the patents in the period 1895-1910 mainly concerned new machines, improvements, and additions of new components to existing machines, being represented by the patent type 'invention' in most cases (84%) [17, 22].

4. QUALITATIVE ANALYSIS

4.1. Patent term as proxy for valuable invention

Based on the results of the quantitative research, a selection of patents was qualitatively analyzed. These were selected with care, taking into account various parameters. The length of time a patent was maintained is not a perfect indicator of its importance. Indeed, the registration of a patent in Belgium was independent of the quality and novelty of the described invention and its claims [9]. According to de Favereau [12], Belgian patents were characterized by a low profitability, and this fact is highlighted by their usually short terms. Between 1830 and 1914, the average life of patents, irrespective of category, was 2.58 years. This means that 40-45% and another 20-25% of the patent's annuities (fees payable on a yearly basis) were not paid from the second and the third year, respectively, after the filing date! Moreover, the average patent term decreased during the following decades (until 1910). This situation probably reflects the patentee's wish for short-term return on investment and/or his awareness that the chances for successful commercialization of his invention were small. [12, 14]

4.1.1. Invention versus Innovation

Invention does not necessarily mean innovation. Only when a patent was commercialized and effectively used in practice could it be defined as an innovation: its quality, relevance and diffusion within the industry having been proved [9]. Though not a perfect indicator, a patent's term nevertheless represents the value of an invention. Therefore, patent annuities (renewal fees) constitute as a relevant parameter to assess patents' innovativeness. Furthermore, the commercialization of a technique typically required financial backing, which would be forthcoming only for high quality inventions. All in all, the extremely short average term of 2.58 years is a strong indication of insufficient quality of most patents (on average), as well as their unsuitability for what the market (industry) wanted. It should be noted that other parameters justified the ephemeral character of these patents: the presence of 'fashion objects' (short-term life planned from the beginning) and the use of patents as barrier to entry (strategic asset) towards the competitors. Moreover, de Favereau [12] underlines the limited positive influence of the law of 1854 on the average patent term, thus no correlation can be established between the influence of staggered payments and the average term. [12]

4.1.2. From self-employed mechanics to companies

Between 1830 and 1854, most of the patentees were self-employed mechanics, mechanical engineers, or technicians (e.g. André A.-R., Fondu J.-B., Watkins F.). From the middle of the 19th century onwards, 'worker-inventor' patentees declined in number, supplanted by researchers and scientists employed by companies (e.g. Vereinigte Stahlwerke A.G., Société Ve Lambert et Ce). This change was likely due to the increasing complexity and sophistication of the inventions. Though companies were less likely than worker-inventors to abandon their patents after the first year, still the average patent term remained below three years. [10, 12, 17]

4.1.3. Foreign applicant implies longer patent term ?

Considering the heavy administrative procedures, one might expect that inventions patented by foreign inventors in Belgium (invention or importation patent) would be of high quality with commercialization potential. However, data on the geographic origin of patentees in the patent

records, systematically mentioned since 1895, indicate that the average term of foreign patents was not much higher than the Belgian ones. This suggests a patentee's nationality is not a relevant factor in evaluating the importance of a patent.

4.2. Pioneering inventors

4.2.1. Auguste Boin's rivet manufacturing machine

The specific manufacturing machines developed from the second half of the 19th century onwards clearly are aimed at solving the main technical issues of the time. The mechanization of the manufacturing process allowed the many different shapes and dimensions of rivets characteristic of the period before 1850, to be standardized and the variety reduced. Although patented 19 years after boilermaker A. Durenne's breakthrough rivet manufacturing machine (France, 1836), the manufacturing machine registered by Belgian inventor Auguste Boin on 8 August 1855 in Charleroi (Belgium) attracts attention (fig. 4).

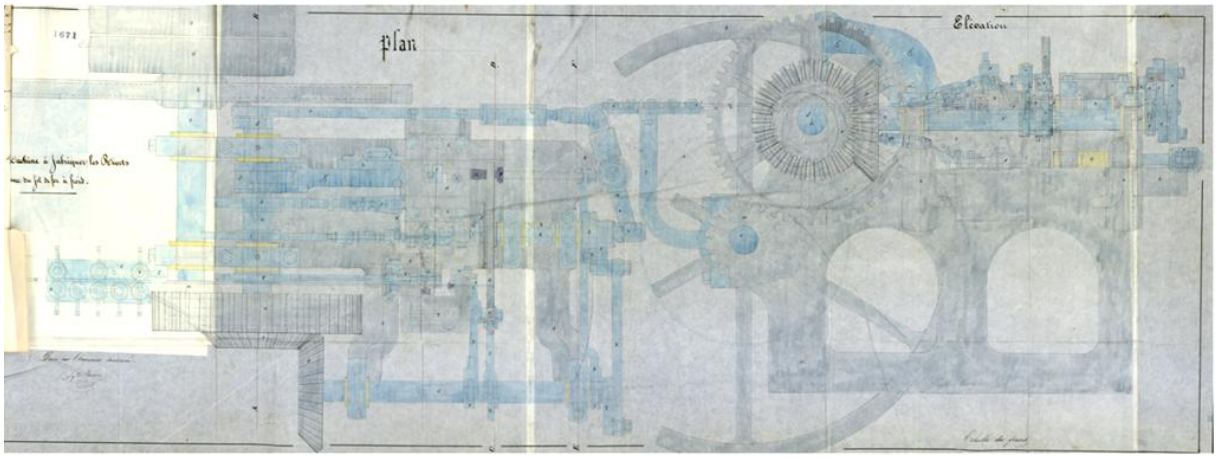

Fig. 4 Invention patent N°1,656-1,671 of A. Boin for a machine to manufacture rivets with round and flat heads, Belgian Patent Office (Intellectual Property Office), 08/08/1855. [20]

This patent was maintained for a longer than average term. To determine how long a patent was maintained, one must consult the *Moniteur Belge* [23] (Belgian government publication) [9, 12]. The 60th publication of the abandoned patents – forfeiture owing to non-payment – provided by the appendix of the *Moniteur Belge* N°300 (27th October 1865) shows that the annuities of his invention patent N°1,656-1,671 had been being paid for 10 years [23]. In fact, Boin's property right had been transferred to the company *Société Ve Lambert et Ce*. This patent's long term, combined with the interest shown in it by a company, are good indications of innovativeness.

The descriptive text written by Boin permits one to understand the working of his machine down to the smallest detail. Unlike Durenne's *machine à fabriquer les rivets*, which simply adapted one of his previous punching machines (driven by a belt), Boin's invention was specially designed for the manufacturing of rivets. Specialized machines became usual from 1855 onwards. Boin's machine avoided overheating – an important issue – by opting for a cold forging technique, which meant that the iron bar was not heated before the forging of the first rivet head. In contrast, the Frenchman J.-V. Gauthier had opted for a water cooling system for his manufacturing machine of 1863.

Aimed to forge the first rivet head without any burr, the basic running consisted of a rotating round plate (called *grand plateau mobile*) that brought each rivet – via four matrixes – in front of other parts of the machine; each of them corresponding to a peculiar step within the manufacturing process (e.g.

cutting the iron bar, forging the rivet head, ejecting the rivet). Boin stated his machine was able to produce 3,000 forged rivets per hour when working at full capacity. [7, 20, 22]

4.2.2. John F. Allen's riveting machine

Symbolizing a kind of 'myth of the automaton,' the breakthroughs linked to riveting machines permitted the diameter of the rivet shank to be increased. Paradoxically, the search for a 'perfect' riveting machine resulted in a tool that could only upset the rivets; all the prior steps in installation were still carried out by hand (i.e., making the rivet hole, heating the rivet). In particular, the major technological innovations of hydraulic riveting machines were developed before 1900. From around 1890 onwards, they were progressively supplanted by pneumatic transmission and air hammers (a substitute for the hand-held hammer). Around 1875, the American manufacturer John F. Allen (New York) was the first to design pneumatic riveting machines by applying the principle of compressed air to portable riveting machines. [6]

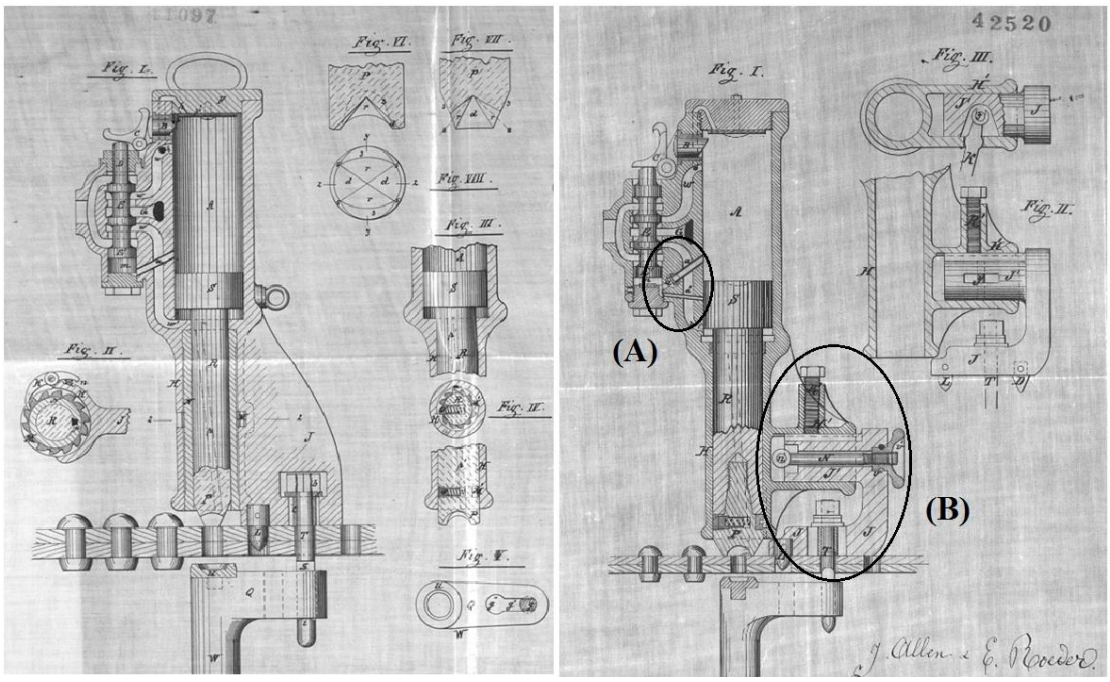

Fig. 5 Patents registered by J.F. Allen and H.E. Roeder for a riveting machine, Belgian Patent Office (Intellectual Property Office): (left) invention patent N°41,097 (15/12/1876) and (right) improvement patent N°42,520 (26/06/1877). [20]

At the same time, John F. Allen registered patents for riveting machines in different countries such as in the USA and in Canada [15, 16]. Together with Henry E. Roeder, he applied for patents in Belgium too (fig. 5). On 15 December, 1876, an invention patent N°41,097 was registered for a pneumatic riveting machine, for which the claim concerned mainly the running of the valves [20]. Six months later (26/06/1877), they introduced two new main improvements to this machine (improvement patent N°42,520), as shown in figure 5: (A) the use of an automatic valve – to avoid any pressure return in the cylinder – combined with an additional valve; and (B) a mechanical process – use of a movable foot *J'* equipped with a friction bolt *R'* – intended to move the whole riveting machine.

An interesting observation can be inferred from the comparison of these two Belgian patents and their American equivalents. Actually, approximately the same patent as the invention patent N°41,097 (15/12/1876) had been granted in the USA to the benefit of Allen & Roeder, but more than one year before, on the 5th of October, 1875 (US patent N°168,314). Similarly, the Belgian improvement patent

N°42,520 (26/06/1877) preceded the American copy N°194,396 – improvement of the US patent N°168,314 – granted two months later (21/08/1877). Comparing an inventor's Belgian patents with those taken out in other countries for similar inventions, often reveals interesting differences. Being able to readily identify the patentees and then comparing patents has been one of the most important added-values of the patent database and patents research. [15, 16, 17]

5. CONCLUSIONS

Patents are a remarkable source for the analysis of the innovations linked to riveting technology. In particular, they provide precise information – valuable text and drawings – about the running of the machines and other techniques; the inventor's nationality; and the international diffusion of his/her patent(s). In the absence of any other information, the patent's term seems to be the best parameter to use as an indication of the importance of an invention. The large number of patents granted in Belgium, and its attractiveness to foreign inventors, made it exceptional. A quantitative analysis of patents highlights the inventive climate (intensity, topics) on an international scale whereas a qualitative study can deal with technical descriptions and the record of modifications to inventions. The categories manufacturing of rivets and riveting machines were the two containing the most patents, which confirms the major issues discussed by the traditional literature. In most cases, inventors who registered a large number of patents (e.g., John F. Allen) simultaneously protected their technique in different countries – Belgium often included – by adding small changes and/or by deliberately fragmenting one given invention into multiple applications.

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REFERENCES

[1] Gustafson K. (2007) Evaluation of Existing Structures. *Modern Steel Construction* February 2007: 41-43
[2] Kühn B. et al. (2008) *Assessment of Existing Steel Structures: Recommendations for Estimation of Remaining Fatigue Life (JRC Scientific and Technical Reports).* Luxembourg, Office for Official Publications of the European Communities
[3] D'Aniello M., Fiorino L. (2008) Structural performance of riveted connections in historical metal structures. In: *Proc. 6th Int. Conf. on Structural Analysis of Historic Construction* Bath, University of Bath, 431-439
[4] Collette Q., Wouters I., Lauriks L. (2011) Evolution of historical riveted connections: joining typologies, installation techniques and calculation methods. In: *Proc. 12th Int. Conf. on Structural Studies, Repairs and Maintenance of Heritage Architecture* Chianciano Terme (Italy), 295-306
[5] Jacomy B. (1983) *De l'objet à l'homme. Rivets et riveurs à travers la civilisation industrielle.* PhD in social psychology (Université Louis Pasteur - Strasbourg 1), unpublished, Strasbourg
[6] Jacomy B. (1998) The technological evolution of riveting machines. *The journal of the Society for Industrial Archaeology* 24(2): 36-52

[7] Frémont C. (1906) *Etude expérimentale du rivetage.* Paris, Société d'encouragement pour l'industrie nationale
[8] Simmons D.A. (1997) The continuous clatter: practical field riveting. *The journal of the Society for Industrial Archaeology* 23(2): 4-20
[9] Dekeyser L., Collette Q., van der Tempel M. (2012) Historische patenten onthullen inventiviteit en innovatie binnen bouwhistorische studies. *Monumenten en Landschappen (M&L)* (in review)
[10] Péters A. Le système belge des brevets au 19ème siècle. In : *Colloque 'Nouvelles sources, nouvelles approches, nouvelles méthodes dans la recherche historique, 2006* Louvain-la-Neuve, Université catholique de Louvain, (in press)
[11] Saiz Gonzales P. (2003) Patents, International Technology Transfer and Spanish Industrial Dependence (1759-1878). In Hilaire-Pérez L., Garçon A.-F. (ed) *Les chemins de la nouveauté: innover, inventer au regard de l'histoire*. Comité des travaux historiques et scientifiques, Paris
[12] de Favereau de Jeneret C. (2011) *Faire germer le progrès. Déterminants techniques, sociologiques et culturels de l'inventivité brevetée agricole en Belgique (1830-1913).* PhD in history (Université catholique de Louvain), unpublished, Louvain-la-Neuve
[13] Péters A. (2008) Le savoir technique et sa circulation à travers les brevets d'invention. Le cas des métaux non-ferreux (1830-1854). In : *Congrès de Namur. Actes du LVème Congrès de la Fédération des Cercles d'Archéologie et d'Histoire de Belgique* Namur, Association des cercles francophones d'histoire et d'archéologie de Belgique, 519-529
[14] Péters A., de Favereau C. (2011) Vers une histoire du système belge des brevets au 19ème siècle. In Eck J.-F. (ed) *Innovations et transferts de technologie en Europe du Nord-Ouest aux XIXe et XXe siècles.* PIE - Peter Lang, Brussels
[15] Online database DEPATISnet (German Patent and Trade Mark Office), http://www.dpma.de, accessed on 21/09/2011.
[16] Online database Espacenet (European Patent Office), http://worldwide.espacenet.com/, accessed on 21/09/2011.
[17] Collette Q. (2010) *Iron and Steel: Manufacturing and connection techniques (1830-1940).* Patents database 'DB3' (Excel file)
[18] Dujeux J.-B.-C. (1842) *Catalogue des brevets d'inventions délivrés en Belgique* (5 supplements covering the period until 1855). Brussels
[19] *Recueil spécial des brevets d'invention* (1854-1940), Vol. 2 to 88. Brussels
[20] Archive departments of the Intellectual Property Office (FPS Economy) and the National Archives of Belgium. Brussels
[21] de Jonge R.A.E. (1945) *Riveted joints, a Critical Review of the Literature Covering their Development.* New York, ASME Research Publication
[22] Collette Q., Wouters I., Lauriks L., Verswijver K. (2012) Riveted connections in historical iron and steel structures: one turbulent century of technological, structural and geometrical considerations (1840-1940). *Matériaux & Techniques* 100(2): 137-154 (DOI 10.1051/mattech/2012023)
[23] *Moniteur Belge*, 1863-1869. Brussels