

A roadmap for innovation on microbiologically influenced corrosion (MIC) in oil and gas pipelines

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ABSTRACT

This exploratory research focused on using patent data analysis to develop a technology roadmap for innovation on microbiologically influenced corrosion (MIC) in the oil and gas pipelines to advance the current understanding of this phenomenon through the LENS patents database.

Evolution in the number of patent documents (applications and grants) from 1990 to 2020 demonstrated that MIC in the oil and gas pipeline had been an area of continuous growth throughout the last 15 years. Since 2007 a remarkable increase in the trends of patent records started, reaching its highest value in 2013. In the retrieved set (1,891 records) the 63.4% corresponded to patent applications, and 36% granted patents. The legal status of patents indicated that 38.9% were related to active patents, 29.1% to pending patents, and 32% to discontinued records. Private corporations dominate as the most productive and influential sector in patent production. The top ten applicants on patent records were private companies, including Ecolab USA Inc (86), Dow Global Technologies (59), Du Pont (59), and from academia only Harvard College (41). The same trend was identified in the top ten owners in the sample, including Ecolab USA Inc (81), Dow Global Technologies LLC (51), Du Pont (41), and from academia just Harvard (24). The USA (1190), WIPO (451), and European patents (235) were the three leading jurisdictions in the data set.

Key words: MIC, oil and gas pipelines, patent analysis, innovation, roadmap.

INTRODUCTION

A recent review provided an overview of current microbiologically influenced corrosion (MIC) research. It established that despite extensive study and numerous publications, fundamental questions relating to MIC remain unanswered and stress the lack of information associated with MIC recognition, prediction, and mitigation (Little et al., 2020). On the other hand, bibliometric analysis on the MIC of engineering systems conducted a knowledge gap analysis to focus research efforts and to develop a roadmap for MIC research (Hashemi et al., 2018). One of the main conclusions of this bibliometric analysis was that despite the nature of MIC research is multidisciplinary, it is siloed between two main subject areas: material/corrosion sciences and microbiology/environmental sciences. Informetric was performed to analyze corrosion of petrochemical equipment (PE), this study used visualization software (CiteSpace and VOS viewer) to explore the related literature on corrosion research from 2000 to 2002. Three primary knowledge bases of corrosion studies of PE were captured. First, hotspots and research frontiers of corrosion studies of PE were visually explored, and the themes of corrosion studies of PE were roughly grouped into three core paths (Lang et al., 2021).

Patent analytics process global technological information to generate competitive intelligence through a combination of data, including inventors, owners, jurisdictions, and emergence of topics in technology evolution. Roadmaps charter the path for an organization to reach innovation milestones. Technology roadmaps have broad applications and have been used in product management, research and development (R&D), and the control of internal processes and systems. Through using an efficient technology roadmap, organizations can identify the whitespaces in their relevant research domain and facilitate research and development for the stakeholders, users, organizations, industry, and the nation (Kelaskar et al., 2016).

The combined use of patent analytics and technology roadmaps has been applied to analyze several topics on emerging technologies such as blockchain, the internet of things (Aristodemou et al., 2017), the eco-friendly building material industry (Shim et al., 2019), and photovoltaic technologies (Kelaskar et al., 2016), identifying and visually exploring the hotspots and frontiers of R&D. We have not identified studies based on patent production data about MIC in oil and gas pipelines or the combination of patent analytics and technology roadmaps on this field. Consequently, the following research question was raised: could a technology roadmap based on patent information on MIC in oil and gas pipelines cover whitespaces uncovered by bibliometric analyses? How is conformed the patent landscape on this topic, and how can this information build strategic planning (roadmap) for innovation?

This exploratory research focused on using patent analytics to develop a technology roadmap for innovation in MIC in the oil and gas pipelines to advance the current understanding of this phenomenon through the LENS patents and its analytics platform (<https://www.lens.org>) and the use of VOS viewer (<https://www.vosviewer.com>)

EXPERIMENTAL PROCEDURE

Patent landscape on MIC in oil and gas pipelines

Database selection

We integrated a database with the information retrieved from patent documents on MIC in oil and gas pipelines through a search strategy in the LENS patents platform version 8.0.13 on December 13th, 2021. This platform has coverage of almost 135 million patent documents in 95 jurisdictions.

Search algorithm

The sequence of keywords and Boolean characters that we used for searching documents in the LENS patents platform, the number of records retrieved, families, and citations are shown in Table 1. We recovered the data in CVS format for subsequent analysis using the LENS database and its analytic module.

Table 1. The sequence of keywords and Boolean characters used for searching patent documents in the LENS platform.

Search algorithm	Patent records	Simple families	Extended families	Cites patents ¹	Cited by patents ²	Patent citations ³	Cites NPL ⁴
Microbiological AND corrosion AND pipeline (oil OR gas)	1,891	753	653	1,341	1,109	19,771	973

¹ Number of patent documents that cite other patents.

² The number of patent documents in the result set that are cited by other patent documents.

³ Sum of cited by patent count for all cited documents in the result set.

⁴ The number of patent documents in the result set that cite non-patent literature (NPL).

Mapping the patent networks (inventors and citations)

We used VOS viewer 1.6.17 (Van Eck & Waltman 2007, 2009, 2011) for visualizing the patent networks. The citation networks were integrated with at least three documents, two citations; the node's weight defined by the number of citations; type of plot: overlay.

Mapping emerging trends

We used VOS viewer 1.6.17 to create the co-occurrence map of terms, using the LENS database with 1891 records .RIS format and the following configuration: fields from which terms will be extracted: title and abstracts, complete counting method, minimum occurrences 40, number of words to be selected 78, removing the non-connected items, attraction 5, repulsion -2, type of plot: overlay. Size of the nodes by occurrences score by average records. Finally, a synthetic map of co-occurrence was constructed using just title, the number of terms to be selected 7, attraction 8, repulsion -6, and excluding the non-connected terms, the size of the nodes by average records.

RESULTS

Patent documents over time

We retrieved 1,891 patent documents for the period analyzed and 753 simple families of patents. Evolution in the number of patent documents (applications and grants) from 1972 to 2020 is presented in Figure 1. From 1972 to 1988, the number of patent records produced annually remained under 20. In 1989 a gradual increase in annual applications and grants began presenting an average of 40 documents per year until 2006. Since 2007 a remarkable increase in the trends of patent records started, reaching its highest value in 2013 (148) with 57 grants and 91 patent applications. These trends demonstrated that patenting in MIC in oil and gas pipelines has been an area of continuous growth over the last 15 years.

Patent documents by type

The number of patent applications in the result set matched to 1,199 (63.4%), and the number of patent grants to 681 (36%), the rest 0.6% of retrieved documents included search reports, amended patents, limited patents, and amended applications (Figure 2).

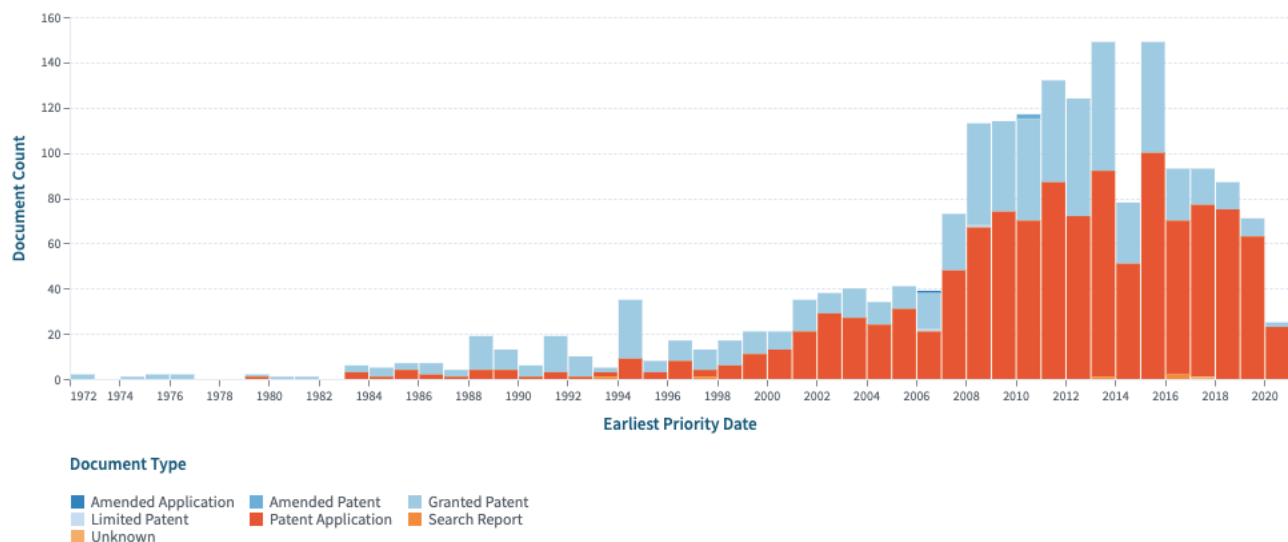


Figure 1: Patent documents over time on “MIC in oil and gas pipelines”

Source: Own elaboration using the LENS database and its analytics platform.

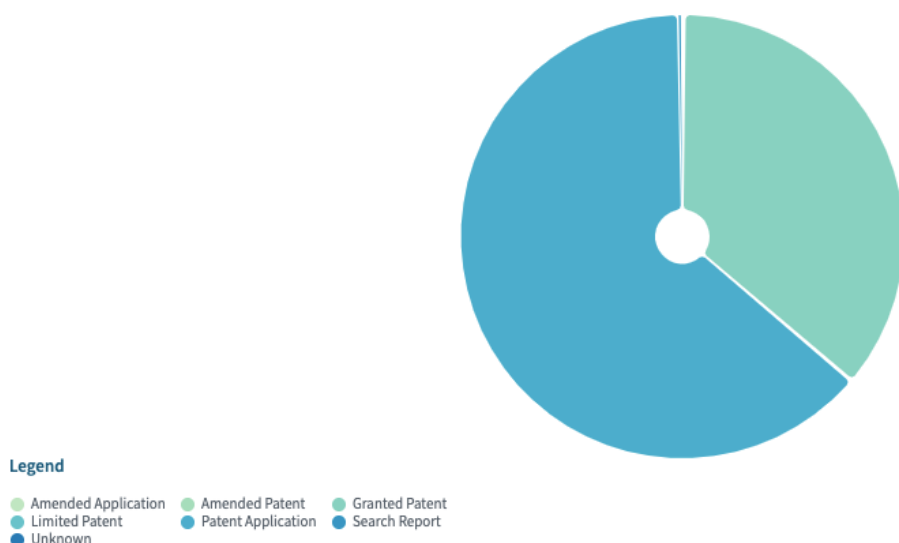


Figure 2: Patent documents by type, applications (63.4%) and grants (36%).

Source: Own elaboration using the LENS database and its analytics platform.

The patent documents by legal status distribution in the set including 38.9% of active patents (735), 29.1% of pending patents (551), and 32% of discontinued (259), expired (189) and inactive (134) documents. The USA (1190), WIPO (451) and European patents (235) are the three main identified jurisdictions in the patent documents sample.

Applicants and owners of patents

The top ten applicants of patents on MIC in the oil and gas pipelines are presented in Figure 3. Private corporations dominate as the most productive and influential sector in patents for MIC in the oil and gas pipelines. Private companies included Ecolab USA Inc (86), Dow Global Technologies (59), Du Pont (53), Novozymes As, Snipr Tech Ltd, Akeso Biomedical Inc, Alsop Albert W, Locus Ip Co and Omya Int Ag. In the leading group we only identified Harvard College (41) from academia. Almost 10.5% patent records are concentrated in the three principal applicants (firms), and Harvard College reached the 2.1% of applications records.

The top ten owners identified in the sample are presented in Figure 4, including Ecolab USA Inc (81), Dow Global Technologies LLC (51), Du Pont (41), Ddp Specialty Electronic Materials, The Dow Chemical Company, Nutrition & Biosciences USA, LLC, Akeso Biomedical Inc, Snipr Tech Ltd, Harvard College (24) and Halliburton Energy Services Inc.

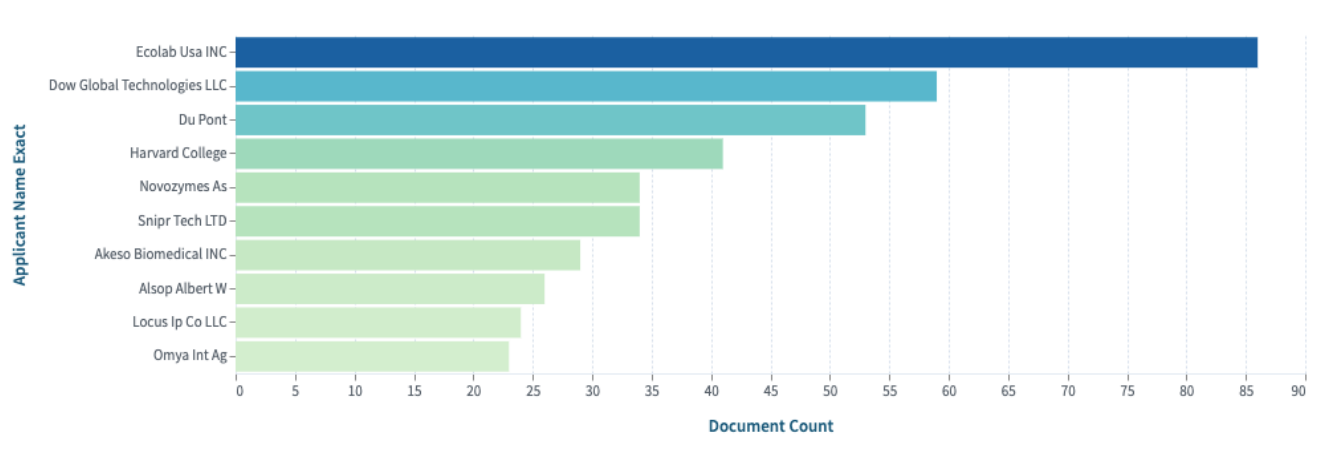


Figure 3: Top applicants of patents on “MIC in oil and gas pipelines”

Source: Own elaboration using the LENS database and its analytics platform.

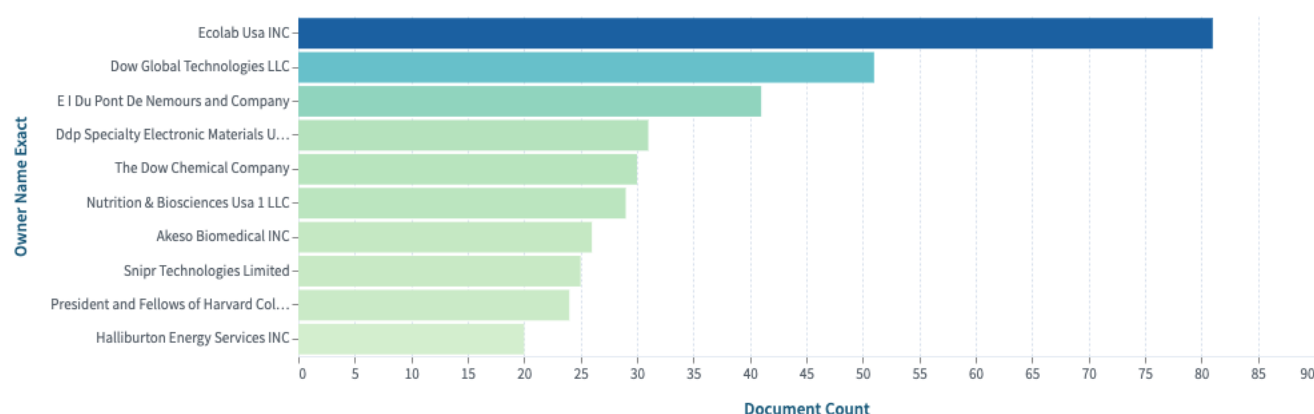


Figure 4: Top owners of patents on “MIC in oil and gas pipelines”

Source: Own elaboration using the LENS database and its analytics platform.