PROSPECTING PAPERS AND PATENTS OF GAS LIFT VALVES TECHNOLOGY

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Abstract

Between the phases of oil exploration and production, there is this oil transfer through natural or artificial elevation method. When this method is natural, the pressure in the reservoir is sufficiently high and the fluids in it can emerge to the surface, but when this pressure is insufficient, the fluids do not reach the surface without the use of artificial lifting methods. Among the struggles to be solved by engineering, there is the optimization of the geometry of the lift gas valves (VGL) and the sealing material. In this context, this article presents the prospecting of papers and patents related to the technological advances of VGL published in the last five years (2016 to 2020) and as a research contribution, there is the identification of solutions regarding the aforementioned optimization. The ScienceDirect, Scopus, CAPES Periodical Portal, and Web of Science databases were used, and the patent search in the database of the European Patent Office (EPO), Espacenet. The results showed that the number of papers published in this area is low, showing that there have been more publications on the subject in the last three years. In addition, China and the United States of America are the countries with the highest number of patents granted in the years surveyed, and the two North American inventors have the greatest number of inventions.

Keywords: Artificial lifting methods, Gas lift valves (GLV), Oil exploration and production.

1. Introduction

Currently, among the existing energy sources, oil is considered the most important and multiple derivatives are generated from it (gasoline, kerosene, bitumen, etc.) to meet an increasing demand from society (ASSUNÇÃO et al., 2020).

At the beginning of oil production, most wells have sufficient energy capacity for the fluids in the deposits to reach the surface naturally. We associate the ease with which oil reaches the surface with the pressure in the well, with the pressure of the well elevated, production occurs by natural elevation. These wells are called emergent wells and their production has fewer operational problems, due to the simplicity of the installation of their equipment, with higher flow rates and lower costs per unit of volume (THOMAS, 2001).

Over time, as the well produces fluids from the reservoir, the bottom pressure of the good decreases and may reach values below the pressure required for there to be a natural elevation of oil, generating the need to install artificial elevation methods (DEL CARRATORE, 2018).

In this context, we emphasized that the lifting methods are of fundamental importance in the oil and natural gas extraction procedure, with specific technologies that will guarantee the smooth functioning of this process. In addition, of the existing natural resources in the world, hydrocarbon is one of the most exploited,

being a constituent of large reserves of oil and natural gas, with approximately 46% of its fraction being part of the national energy matrix, according to the National Energy Balance of 2020 (the base year 2019) and approximately 53% of the world energy matrix, according to the International Energy Agency, being the most used non-renewable energy source in the world (EPE, 2020; IEA, 2019).

Thus, the study carried out for this article has as a main aim the realization of prospection of articles and patents published in the last five years, on technologies in oil elevation, focusing on the lift gas valves, with the purpose of analyzing the number of patent filing records to check the state-of-the-art and highlight the characteristics of existing technologies.

2. Fundamentals of Technology

2.1 Oil Wells

As exposed by Thomas (2001, p.15), "*oil originates from organic matter deposited along with sediments, whereas marine organic matter is basically originated from microorganisms and algae that form a type of plankton, which it does not undergo the oxygenation process*". Oil formation needs to occur concerning organic matter, sediments, and thermochemical conditions. When oil is formed, migration occurs until it accumulates because of the characteristics of geological structures.

It is noteworthy that the drilling can be both on land (on-shore) and at sea (off-shore) and after this phase and completion; the well is qualified for the production of hydrocarbons (oil or gas). The next step is the most important within a well's life cycle, the lifting phase when the well goes into production. During this period, we produce oil and gas. If the pressure in the reservoir remains high (rising wells), the fluids will reach the surface by natural elevation. However, at the end of the productive life, when the pressure reduction occurs, artificial lifting methods should be used, if considered economically viable, aiming at increasing or resuming the production of a well that is no longer emerging (ALMEIDA, 2006).

For Da Gaia et al. (2016), except for emergent wells that have natural elevation due to the difference in internal pressure, the artificial elevation must be performed to recover the fluid in the well. Therefore, it is necessary to have a detailed study of the characteristics of the well, so that we can identify an elevation method. Of the most used artificial lifting methods, we highlighted the Gas lift; Mechanical Pumping with Rods (MP); Submerged Centrifugal Pumping (SCP), and Progressive Cavity Pumping (PCP).

The selection of each method of artificial elevation to be used in a well will depend on some aspects, such as the diameter of the coating, fluid viscosity, sand production, gas-liquid ratio, flow rate, depth of the reservoir, distance from the wells to stations, reservoir production mechanism, among others. Being one of the most important steps to achieve economically efficient production (CRNOGORAC et al., 2020).

2.2 Lift Gas

The Lift Gas (LG) is a method of lifting oil widely used and applied in wells without emergence conditions and in wells that require increasing their oil production. Its technology comprises the injection of pressurized gas in the lower section of the production pipeline to maintain or increase the potential of the well. The injected gas is mixed with the fluids produced, causing a decrease in the pressure gradient along the pipe and the pressure required at the bottom of the well (MEDEIROS, 2015).

According to Del Carratore (2018), lift gas was introduced as an artificial lifting method around 1864, initially with the use of compressed air and later natural gas for lifting oil. Over the years, this gas has become one of the most widely used artificial elevation methods for wells with high flow rates, influencing elevation, with injections of lift gas being continuous or intermittent.

The continuous injection is like natural elevation, it can be treated as an extension of the natural flow process, according to the displacement of the fluid towards the surface, the pressure of the fluid column reduces, expanding the gas in the fluid from the injection point to the surface. This way, the increase of the gas-liquid ratio will reduce its density, reducing the pressure losses along the column (ELLDAKLI, 2017).

For Elldakli (2017), the intermittent lift gas injection is based on the periodic displacement of liquids, called fluid strokes, from the pipeline by injection of high-pressure gas into the wellbore. In addition, a valve that has a pre-defined time performs the control, following injection and rest cycles. It is noteworthy that this cycle will be determined according to the characteristics of the well.

As highlighted by Maitelli (2010), some disadvantages in using lift gas as an artificial lifting method are related to the need for an external source of compressed gas with limited distances, the need to separate the gas associated with the oil produced, and possible corrosion in the equipment resulting from the gas injection. The system comprises pressurized gas sources (compressors), gas injection controllers on the surface, subsurface gas injection controllers (lift gas valves), separation equipment, and production of the fluids produced.

2.3 Lift Gas Valve

The lift gas valves are fundamental tools for the oil production system, which were developed to regulate the good pressures, controlling the annular flow, allowing the fluid to escape from the well. Its opening occurs due to a pressure difference, when the injection pressure increases in relation to the pressure of the coating and, when opened, the gas is injected to produce fluids (MEDEIROS, 2015).

The valves are installed in piping accessories called chucks, as shown in Figure 1. The lift gas chucks are elements of the production column and have the function of settling the lift gas valves, making it possible to regulate the bottom pressure and allow the flow of gas from the annular space into the production column (ALMEIDA, 2006).

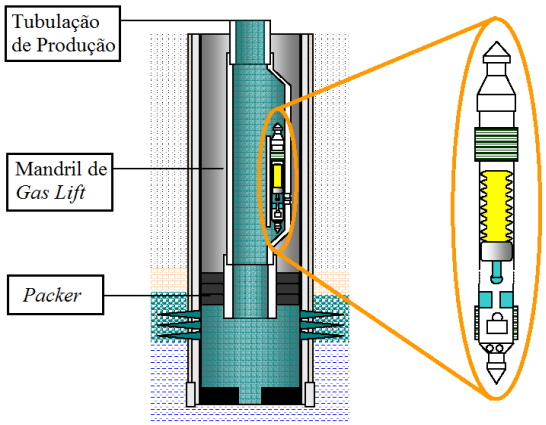

Figure 1. Lift Gas Valve
Source: Medeiros (2015)

According to Santos (2017), lift gas valves are defined in two types. The first valve is of the type that are always open in the direction of the annular towards the column. This valve requires a choke for the restriction of flow and a check valve (check valve), thus avoiding the reverse flow of the column to annul it. The second type of valve has opening and closing mechanisms based on the pressures and / or temperatures in the well.

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It is noteworthy that the basis for a properly designed lift gas system depends on the correct choice of the lift gas valve. Each lift gas valve has different principles and characteristics and is classified in to, but not limited to, orifice type (conventional or venturi) - the through-hole has a venturi shape; pilot type - valve with bellows whose opening of the main section they operate by opening a primary section according to the injection pressure of the coating; blind type - permanently closed valve preventing communication between the production and annular column; the injection pressure of the coating operates type IPO - valve with bellows (LEA JR; NICKENS, 2019).

3. Materials and Methods

For the construction of this article, we carried descriptive and exploratory research. For Gil (2017), descriptive research allows investigating phenomena, while they are unveiled, cataloged, and clarified. The author points out that the exploratory approach allows the researcher to have a greater understanding and perception of the studied subject and area, demonstrating the reality of the researched facts.

We searched scientific articles and patent applications on oil lifting technologies, specifically on lift gas valves. Both results were organized, tabulated, and analyzed using Microsoft Office Excel 2013 for Windows®.

For the articles, we carried searches out on ScienceDirect, Scopus, CAPES Periodical Portal, and Web of Science databases, analyzing in the titles and abstracts the keywords “gas lift valve”. Publications between the years 2016 and 2020 were considered. The research returned 79 in ScienceDirect, 78 in Scopus, 24 in CAPES Periodical Portal, and 19 articles in the Web of Science database.

For patent filings, the database of the European Patent Office (EPO), Spacenet, was used, mainly due to the free search and availability of the collection. The searches considered the records that contained the keyword “gas lift valve” in the title and in the abstract. Considering the registrations between the years 2016 and 2020, the survey returned 93 patent deposits, with 49 deposits referring specifically to the lift gas valves, whose identification occurred after analyzing each registration.

4. Results and Discussions

4.1 Bibliographic Survey Between the Years 2016-2020

Research carried out using the term “gas lift valve”, as previously highlighted, in the databases ScienceDirect, Scopus, CAPES Periodical Portal, and Web of Science revealed the existence of 194 articles

in the last 05 years (2016-2020). After analyzing each of the returned works, based on their abstracts, we discarded 155 as it did not relate them to the researched theme, leaving 39 papers with adherence to the theme.

In this scenario, Chart 1 presents a summary of the consultations carried out, showing the total number of articles found, how many are actually related to the lift gas valve, and its years of publication.

Chart 1 - Summary of consultations carried out in the databases considered in this article

Base	Returned items	Adherent articles	Years of publication
ScienceDirect	79	05	2016 (3) 2017 (1) 2020 (1)
Scopus	78	19	2016 (1) 2017 (3) 2018 (7) 2019 (2) 2020 (6)
CAPES Periodical Portal	24	05	2016 (1) 2017 (2) 2018 (1) 2020 (1)
Web of Science	13	10	2016 (1) 2017 (2) 2018 (4) 2019 (2) 2020 (1)

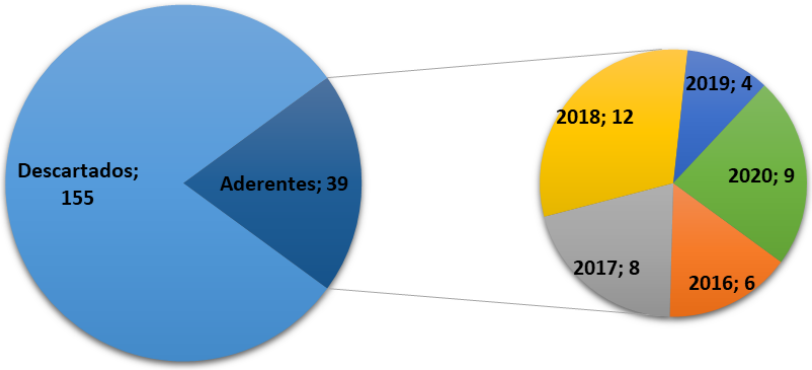
Source: Prepared by the authors (2021)

In the ScienceDirect database, we found 79 articles, of which 06 highlight studies related to the lift gas valve. It was noticed that in 2016 there was a greater number of productions, there are 03 articles that talk about the valves themselves. The projects not considered focused on equipment or processes for extracting oil from wells that did not discuss these valves. In a complementary way, in the Scopus database, we found 78 publications, 19 of which are inherent to the researched context. It was noted the existence of projects in the last 05 years, especially in the years 2018 and 2020, that, even modestly, dissipate more publications in relation to the others.

Based on CAPES Periodical Portal, a survey carried out returned 24 articles that were withdrawn. It was noticed that 05 of them were related to the analysis of the lift gas valves. Regarding the years of publication, considering the time lapse established in this research, there are only no studies available in the year 2019. Also returning a few projects, the search in the Web of Science base resulted in 13 results and, when treated, it was noted 10 of them dealt with lift gas valves. About the year in which these last projects were published, considering the time established in the research, the year 2018 presented more publications.

Figure 2 presents a graph that illustrates the total number of articles returned, emphasizing those that were discarded in this work, those that were considered adherent to the topic studied and the years in which the publications occurred.

Figure 2 - Total proportional distribution of returned articles and years of publication



Source: Prepared by the authors (2021)

In view of the results of the research carried out in the four databases used in this article, the 03 most relevant projects, considering the number of citations and the return in all research, can be seen in Chart 2. A summary of each of these projects will be performed below.

Chart 2 - List with the 3 most cited articles

Title of the article	Reference	Year	Number of citations
Charaacterization of leak rates in thermoplastic barrier valve seals under high static and cyclic pressure loads	Dev et al. (2016)	2016	8
Optimum design for new gas lift valve seat	Elldakli e Soliman (2017)	2017	4
Comparison of Leakage Characteristics of Viton and Polytetrafluoroethylene Seals in Gas-Lift Valve Applications	Dev et al. (2017)	2017	3

Source: Prepared by the authors (2021)

As described in this work, the lift gas is a method of the artificial lifting of oil, used to extract oil from wells that do not inherently flow. The gas is injected through the annular well and to pass from the annular to the pipeline, the gas must flow through the lift gas valve. These valves are unidirectional, allowing gas to pass into the pipeline, but prevent oil from returning through the annular. Therefore, studies are carried out to evaluate some specificities of these valves, such as discharge (evaluation of the tightness of the valve keeping device), performance curve (flow versus pressure), bellows (useful life for valves with bellows), high calibration, among others.

Based on the above, Dev et al. (2016) in his work “Characterization of leak rates in thermoplastic barrier

valve seals under high static and cyclic pressure loads" highlighted the tests carried out to validate the use of PTFE material for sealing lift gas valves, according to the requirements of Statoil Standards. The tests were conclusive, as they met the regulatory requirements.

In the article "Optimum design for new gas lift valve seat", experiments were carried out by Elldakli and Soliman (2017), using CFD techniques, to simulate attempts at the model of a lift gas valve with chamfered seat, from an initial project. Through the study, it was possible to observe a significant improvement compared to the original design, allowing more gas flow with less displacement of the valve stem.
Another work done to validate the performance of the valve sealing material was the "Comparison of Leakage Characteristics of Viton and Polytetrafluoroethylene Seals in Gas-Lift Valve Applications". Based on the comparison between Viton and PTFE materials, Dev et al. (2017) observed that among the sealing capacity tests, gas leak tests, and water leak tests, Viton sealing material showed a better efficiency compared to PTFE at room temperature, the test condition.

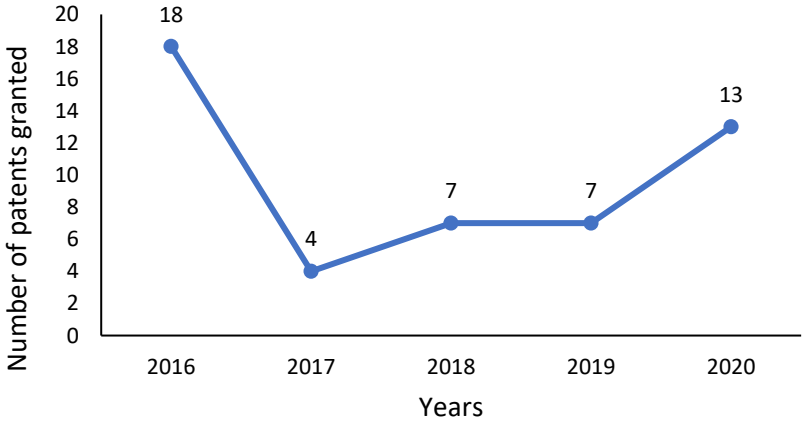
4.2 Technological Prospection Performed in the Patent deposit Bank Between 2016-2020

In research carried out in the database of the European Patent Office (EPO), Spacenet, 93 patent deposits related to lifting gas valves were located and identified. Based on the analysis of each of these records, it was possible to redeem 49 patent documents directly referring to the highlighted valves. Next, we will display the results from the perspective of the years of deposit and concession, countries of origin, inventors, and ownership of patents.

4.2.1 Years of deposit and concession

Figure 3 shows a longitudinal distribution regarding the granting of patents in the Spacenet database. In 2016 there are more publications, possibly encouraged by cyclical fluctuations in the price of oil from the second half of 2014, which led the oil companies to engage and review exploration and production strategies, leading to the prioritization of projects and focusing on cost reduction (PEDROSA JR; CORRÊA, 2016). Another important aspect to be highlighted is that the concession curve is currently growing.

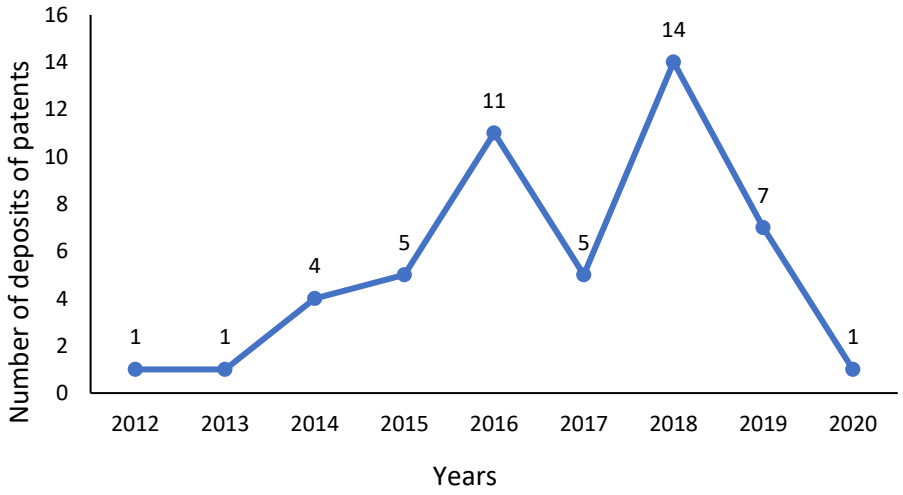
Figure 3 - Longitudinal distribution of patents granted on lift gas valves between 2016 and 2020



Source: Prepared by the authors (2021)

It is important to make a parallel between the granting dates and the patent filing dates. Thus, it will be possible to carry out a more accurate analysis regarding the number of registrations carried out in a certain year and the corresponding number of publications. Figure 4 shows a longitudinal distribution of the years of deposit of patents granted between the years 2016 and 2020, and it is possible to notice a steady increase in deposits between the years 2012 and 2016, a peak in registrations in 2018, and a decline from the year 2019.

Figure 4 - Longitudinal distribution of the years of filing of patents granted between 2016 and 2020

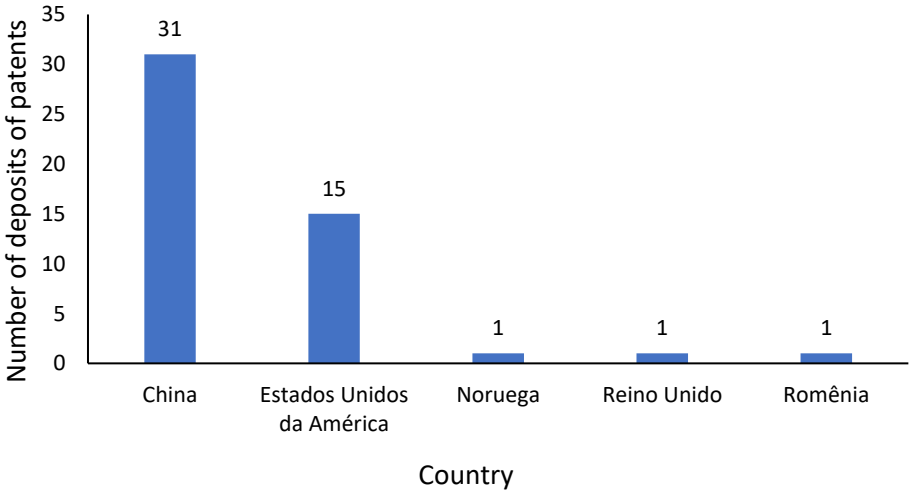


Source: Prepared by the authors (2021)

4.2.2 Origin countries

Figure 5 illustrates the granted patents distributed by countries. The countries that most filed patents on lift gas valves between 2016 and 2020 were China and the United States of America. It is noteworthy that China, representing 63.27% of the total patents, with 31 occurrences in the country with the most concessions, followed by the United States of America with 15 patents, corresponding to 30.61%. The countries of the United Kingdom, Norway, and Romania, together have 3 patents, representing 6.12% of publications.

Figure 5 - Distribution of patents by country



Source: Prepared by the authors (2021)

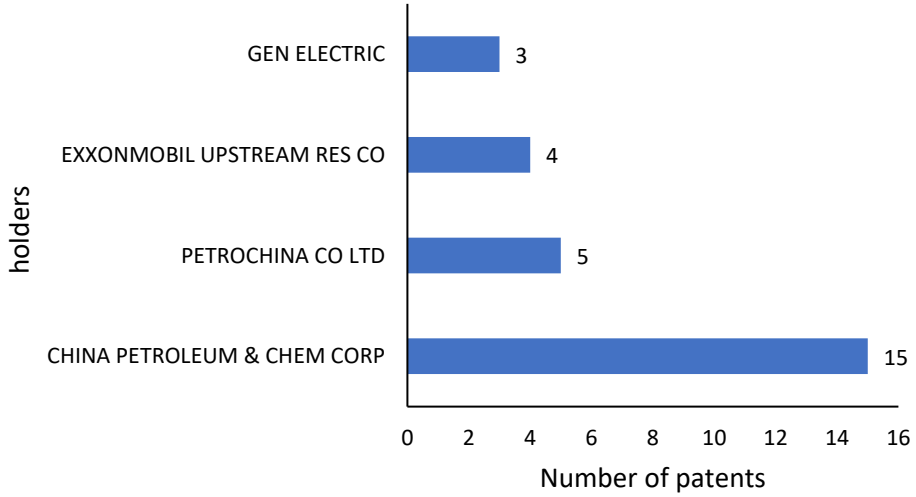
4.2.3 Patents ownership and inventors

According to the legislation pertaining to Intellectual Property, especially in Art. 6, § 2 of the Industrial Property Law (Law No. 9.279 / 96), it is up to the author, as an inventor, or his heirs to request a patent application. However, because of employment contracts, ownership of the invention may be assigned by the inventor to another individual or legal entity.

According to research conducted at Spacenet, the inventors with the highest number of patents granted on lift gas valves between 2016 and 2020 are: Chen Dongbo, Li Lintao, Lusted Roderick Mark, Romer Michael C, Song Hai and Wan Xiaoyong. We observed that these have a concentration of inventions in the petroleum area, above all, in the proposition of technologies to improve the processes of oil extraction in wells.

In this context, of the 49 records analyzed, 81.63% (40) of patent holdings are owned by legal entities and 18.37% (09) have individuals as holders. Figure 6 shows 04 associations that have more ownership of protected inventions. A principal holder, China Petroleum & Chemical Corporation - Sinopec Group - is a Chinese supergroup of petrochemical and petroleum companies, operating in the on-shore and off-shore exploration of crude oil and natural gas, besides processing, refining, distribution, transportation, and marketing your products. Sinopec is the second-largest oil and gas producer in China, the largest refining company, and the third-largest chemical company in the world (SINOPEC, 2020).

Figure 6 - Ranking of patent holders analyzed



Source: Prepared by the authors (2021)

5 Conclusion

This work carried out a bibliographic survey, using initial concepts, doing scientific and technological prospecting on the technology of the lift gas valves. Through the analysis of articles from the board referenced scientific bases and the registration of patent deposits from a base with documents from over 90 countries, it was possible to check the state-of-the art and highlight the characteristics of existing practices. Given the results of the searches, the study of lift gas valves in isolation is not very noticeable. There were few results in the researches done and most of the publications only mentioned the mentioned valves, not

considering them concisely. There was no pattern of growth in the production of articles, but in the last three years, there have been more publications on the topic. Regarding the annual evolution of the granting of patents, there is an increase in deposits in the year 2018, which, making a comparison with the returned articles, is the year that also presents more work.

In addition, the results show that China and the United States of America are the countries with the highest number of patents granted between the years 2016 and 2020, with two North American inventors having the greatest number of inventions on gas valve lift. A Chinese oil company is the main patent holder, including the ownership of inventions is predominant in companies and organizations.

It was evidenced that Brazil does not have any patent deposit in the research carried out, a fact that requires a lot of attention, since the country is one of the primary producers and consumers of oil in the world, having large proven oil reserves. In this way, the study of these technologies could contribute to the maximization of the extraction and utility process of the wells, following the world's tendency to outline strategies for oil exploration and production, emphasizing actions, projects, and technologies that improve production processes and reduce costs.

For future work, it is important to consult a larger number of patent bases and extend the research with the use of new keywords, as well as consider a longer period too, for example, highlight technologies produced in the last decade. Another possibility is to deepen the study of the returned documents, in order to bring similarities and points that, perhaps, are not yet explored.

6. Acknowledgement

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