UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Faculdade de Engenharia e Ciências de Guaratinguetá

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Analysis of the human resources development scenario and the employability prospects for the next years in the oil and gas area in Brazil and the development of a didactic test bench for the simulation of oil well drilling operations.

Guaratinguetá - SP
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Beatriz Maciel Ferreira Pedro

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Undergraduate Thesis presented to the School of Engineering of Guaratinguetá, São Paulo State University, as part of the requirements for Undergraduate Thesis for Bachelor of Materials Engineering.

Advisor: Prof. Dr. Nazem Nascimento
Coadvisor: Prof. Dr. Marcelo Sampaio Martins

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BEATRIZ MACIEL FERREIRA PEDRO

ESTE TRABALHO DE GRADUAÇÃO FOI JULGADO ADEQUADO COMO PARTE DO REQUISITO PARA A OBTENÇÃO DO DIPLOMA DE "**GRADUADO EM ENGENHARIA DE MATERIAIS**"

APROVADO EM SUA FORMA FINAL PELO CONSELHO DE CURSO DE GRADUAÇÃO ENGENHARIA DE MATERIAIS

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“Sixty years ago, I knew everything; now I know nothing; education is a progressive discovery of our own ignorance.”

Will Durant

ABSTRACT

The fossil fuels still are the world's main energy source and will continue being in the next years. In this way, it is extremely important to assure an qualified and specialized manpower in the sector. The paper consists of an analysis of the human resources development scenario in the area of Oil and Gas in Brazil, through the analysis of people management, the existence of manpower and the need for its qualification. In addition to an analysis of the prospects for employability scenario in the sector by means of a discussion about the historical context of the employability scenario. Data regarding graduation and post-graduation courses related to Oil and Gas were analyzed, in relation to the profile of vacancies and the institutions that offer them. Additionally, were discussed historical events that have influenced the oil price per barrel and related to the population interest in taking courses related to the area in question. Finally, were also analyzed ways for companies and research centers to invest in the qualification of manpower in the sector by means of partnership with universities through human resources development programs with the aim of encouraging students to specialize in the area.

KEYWORDS: Fossil Fuel; Manpower; Drilling Simulation.

RESUMO

Os combustíveis fósseis ainda são a principal fonte de energia mundial e continuarão sendo nos próximos anos. Dessa forma, se faz de vital importância a preocupação em garantir uma mão de obra qualificada e especializada no setor. O trabalho consiste em uma análise do cenário de formação de recursos humanos na área de petróleo e gás no Brasil, por meio da análise da gestão de pessoas, da existência de mão de obra e da necessidade de sua qualificação. Além de uma análise das perspectivas de empregabilidade no setor por meio da discussão do contexto histórico do cenário de empregabilidade no mesmo. Foram analisados dados relativos à cursos de graduação e pós graduação relacionados à petróleo e gás, em relação ao perfil das vagas e instituições que os oferecem. Também foi discutido acontecimentos históricos que exerceram influência nos valores dos preços do barril do petróleo e relacionado com o interesse por parte da população em cursar os cursos relacionados à área. Por fim, também foram analisadas formas de investimento na qualificação da mão de obra no setor por parte de empresas e de centros de pesquisa em parceria com universidades por meio de programas de formação de recursos humanos com o objetivo de incentivar os alunos a se especializarem na área.

PALAVRAS-CHAVES: Combustíveis Fósseis; Mão de Obra; Simulação de Perfuração.

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LIST OF ABBREVIATIONS

ANP	National Agency of Petroleum, Natural Gas and Biofuel
GDP	Brazilian Gross Domestic Product
GFC	Global Financial Crisis
IBGE	Geography and Statistics Brazilian Institute
LNG	Liquified Natural Gas
OPEC	Organization of the Petroleum Exporting Countries
O&G	Oil and Gas

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1 INTRODUCTION

Since the beginning of the Oil and Gas (O&G) Industry in the second half of the 20th century, is observed a cyclic behavior related to prices and productivity, which is strongly related to the economical and geopolitical global scenarios, from the supply and demand relationships. After years of success and high profitability, from the second semester of 2014 it was started a discontinuity of prices in the international market, generating a new context and new challenges for companies to remain competitive. Such changes in the market intensely affect the entire production chain, since the operating companies, structure suppliers, and even the institutions that are responsible for training the qualified labor force for the sector (FERNANDES, 2017).

Especially in a sector with such a dynamic market as O&G, the qualification of the professional of the area brings competitive advantage for the company, so the training of these professionals is of vital importance. Besides the technical qualification of employees, the people management sector is a fundamental part of the company, since it is responsible for its strategic alignment (DOMINGOS; MACHADO Jr., 2013).

The human capital is the main success enabling of a company, one way to obtain an improve on the manpower quality is by partnerships between companies, research centers and universities that generates an environment of information and knowledge sharing. In this connection, these partnerships generate an opportunity of consolidation and expansion of scientific and technologic capacities in the oil engineering sector (TURCHI *et al*, 2013). One consequence of a country with unqualified labor force is the entrance of international manpower by the coming of foreigner engineering companies or recruitment and expatriation of people from other countries. Despite of the positive impacts as experience and new knowledge from the national industry, the foreign manpower causes consequences as loss of vacancies for local people (DOMINGOS; MACHADO Jr., 2013).

In this context, it is important to create resources inside the universities (since this is the main workforce trainer) to stimulate the students to have a better understanding of oil well drilling and improve their abilities as a future petroleum engineer. The test bench for the simulation of oil well drilling operations is a tool to students improve their knowledge in the theme and promote research comparing different drilling conditions and parameters, allowing the comparation between simulation and real conditions.

The main objectives of this paper are to develop a detailing scenario of human resources formation in O&G sector, in national scope, and project a didactic test bench for the simulation of oil well drilling operations. It can be achieved by means of the following specific objectives:

I- Historical approach of the Brazilian Oil Industry;

II- Survey of vacancies in under graduation and graduation courses related to O&G;

III- Search for the main human resources formation programs in the sector;

IV- Economic analysis of the sector in the last 5 years.

V- Develop a project of a test bench, covering dimensions, machinery, materials, costs, etc., that allows the simulation, in real conditions, of oil well drilling under different technical conditions.

2 METHODS

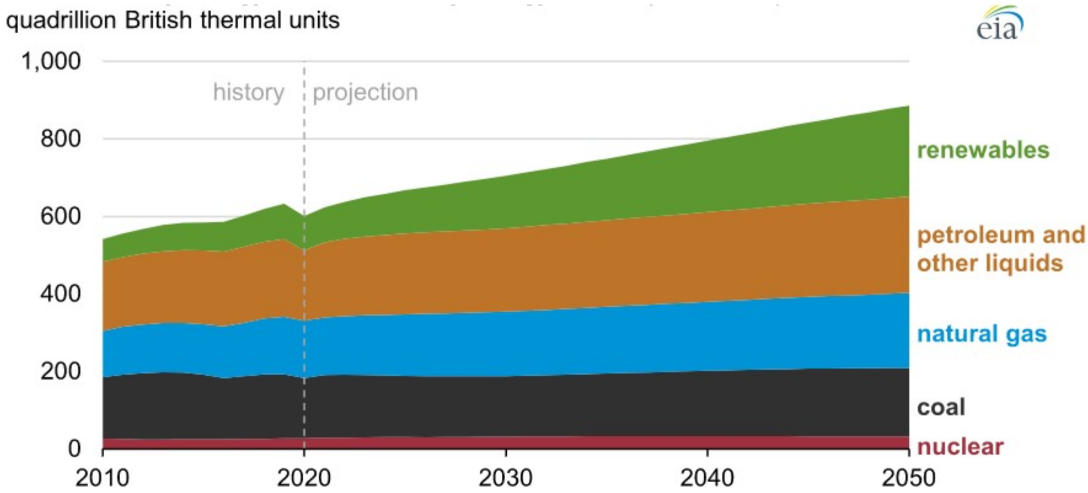
Predominantly bibliographic research of qualitative nature will be conducted from the literature review referring to the human resources formation scenario and employability prospects in the Brazilian O&G sector. In addition, a technical-scientific agreement with the Federal University of Espírito Santo (São Mateus Campus) and Metalúrgica Guará will be made for obtain the necessary information to develop the design of the simulation bench.

3 DEVELOPMENT

3.1 PROFESSIONAL QUALIFICATION

Despite moments of crisis in the sector, fossil fuels are still the world's main source of energy and will not be replaced any time soon, as can be seen in the Graphic 1 (EIA, 2021).

Graphic 1 – Global primary energy consumption by energy source (2010-2050)



Source: EIA (2021)

It is necessary to understand the changes and evolutions of the market in order to develop action plans that allow companies to remain competitive and able to serve their customers even in times of crisis (QUALHARINI *et al*., 2016). Therefore, it is important that universities aim the best qualification possible of their students. The design and implementation of a didactic test bench for oil well drilling simulation on the campus of the Engineering School of Guaratinguetá is a tool for students to have a better understanding of the subject and stimulate their interest in the area, thus contributing to the improvement of the national work force. In addition to the use for teaching activities, the bench can also be used in research projects, collaborating decisively to improve the possibilities of interaction of the campus with partner universities in Brazil and abroad.

One of the National Agency of Petroleum, Natural Gas and Biofuel (ANP) attributions, legislated by the Brazilian Law number 9.478/1997, is to stimulate the research and the adoption of new technologies for the O&G sector. By the Research Development and Innovation Clause, present in the exploration, development and O&G production contracts, it is an obligation to the dealers that 1% of the gross income of field production that pay Especial Participation be designated to expenses qualified as research and development. The value invested can be executed by the oil company, by Brazilian companies or by credentialed institutions of the country (Ministério de Minas e Energia, 2020).

By means of these financial resources invested, the qualified manpower formation can be powered, what generates the qualification of manpower in the sector. Besides that, there is partnership programs between universities with the objective of contribution even more with the human resources for the area.

The Human Resources Program of ANP is a way of incentive the specialized manpower formation, by the concession of financial resources in form of scholarships and tax bench for under graduation, *latu sensu* graduation, master's and PhD's programs. Through this program, are created and consolidated skills and is produced strategical knowledge for the oil sector development (PRH-ANP – Finep Gestora, 2018).

Turchi *et al* (2013) affirms that the interaction between PETROBRAS and universities and research institutions with the purpose to develop products and technologies it is a way of contribution on the generation of new knowledges and experience between the researchers that participate of the processes and forms a network in the sector from the stimulus of new contracts by the universities and research institutions with different companies.

According to Fernandes (2017), there is a relation between the interests of coursing courses in the O&G area and the moments of the industry. In periods when the sector showed high profits, the search of technical courses and under graduation courses in the area were bigger, but in moments of crisis, the submissions for taking courses in the area were lesser. Fernandes (2017) also questioned students registered in these courses and find out that the majority choose the course because of the professional opportunities and the perspective of, after concluding, be approved in a civil exam. When the students were questioned if they were considering to dropout the course, almost 60% answered affirmatively and the main motives were bad employability perspectives and the PETROBRAS situation in that moment. This way, it is possible to conclude how the market situation influences the manpower generation in the sector.

3.2 HISTORICAL ANALYSIS OF EMPLOYABILITY

As well as other sectors, the valorization level of the O&G sector affects directly the need of work force. That way, it is natural that, in moments of bigger valorization, it is shown a bigger employability. As a market strongly affect by the global scenario, the global economic and politic situation can be used as a parameter of employability prospect.

In Graphic 2, are showed the crude oil prices history chart after World War II, which is a measure for the sector success.

Graphic 2 – Crude Oil prices history chart.

Source: Macrotrends (2022)

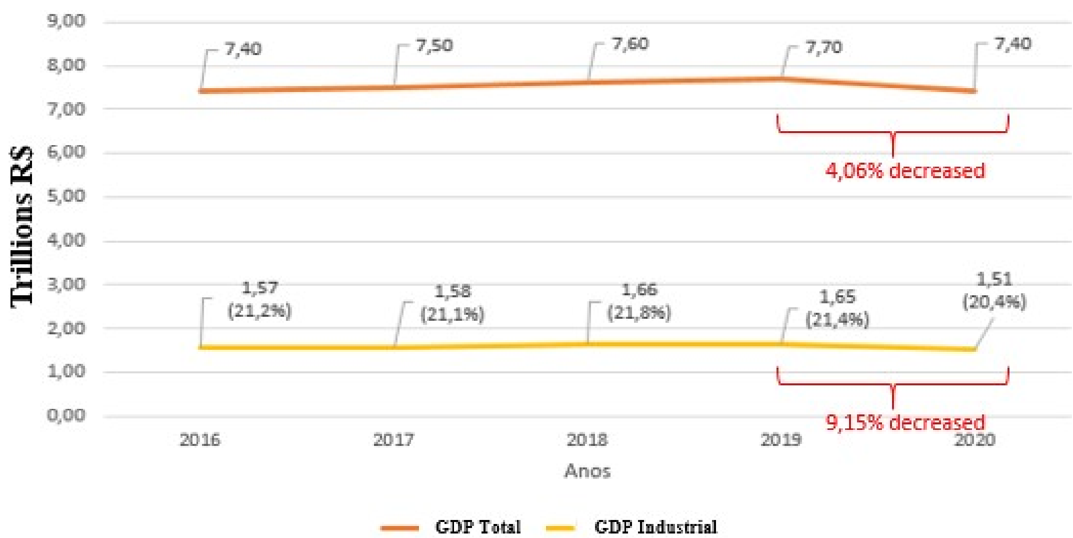
Some key points in the chart can be highlighted in order to reassure the relation between the crude oil prices and geopolitical events. For example, in 1973 there was an abrupt increase in the price, because of the Yom Kippur War when happened a strong polarization between Arabs and Israelis, two strong influents in the oil market. In this context, Saudi Arabia, most influent member of OPEC (Organization of the Petroleum Exporting Countries), led a prohibition in the oil supply to Unites States of America, generating a delivery crisis and consequently a high in the prices.

Events as the Gulf War, the Asian financial crisis, the Global Financial Crisis (GFC) and the COVID-19 pandemic also are examples of moments when crude oil prices achieved peaks positives and negatives. This way, it is notable that the oil market is strongly affected by the global market, mainly of the more influents countries in the sector, so there is a tendency of do not having a big stability.

3.3 ECONOMICAL ANALYSIS

As were previously discussed, the O&G Industry is strongly relationed to the economical scenario. For this reason, it were done an analysis refered to the Brazilian Gross Domestic Product (GDP) in the last 5 years, in order to generate a preview of the following years scenario. The Graphic 3 shows the GDP total and the participation of the industrial sector between 2016 and 2020. It can be seen that an increase on the GDP until 2019 and a decrease of 4,06% in 2020. For the industrial sector, the decrease between 2019 and 2020 were 9,15%.

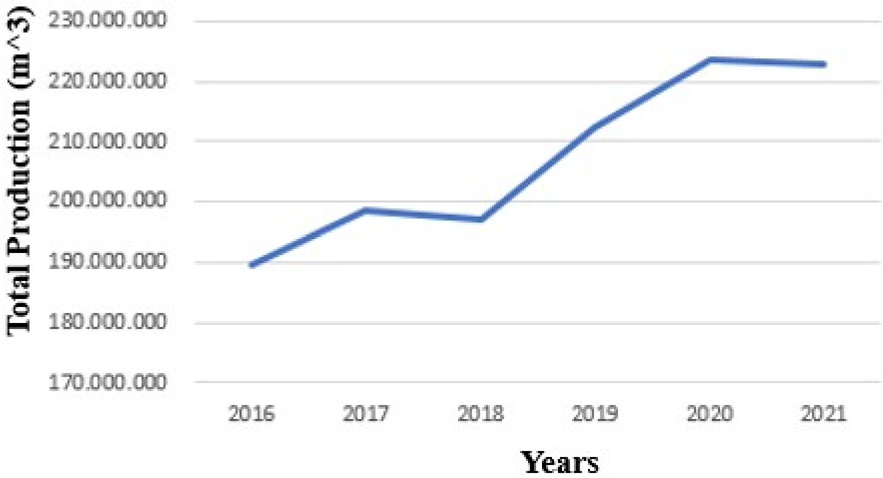
Graphic 3 – Brazilian GDP Total and GPD from Industrial Sector.



Source: Data Sebrae (2022c) compiled by the author.

The Graphic 4, shows the evolution of the production of oil, liquified natural gas (LNG) and natural gas in Brazil, it is observed an increase in the production until the year of 2020 and an decrease of 0.38% in 2021.

Graphic 4 – Total production of Petroleum, LNG and Natural Gas in Brazil.

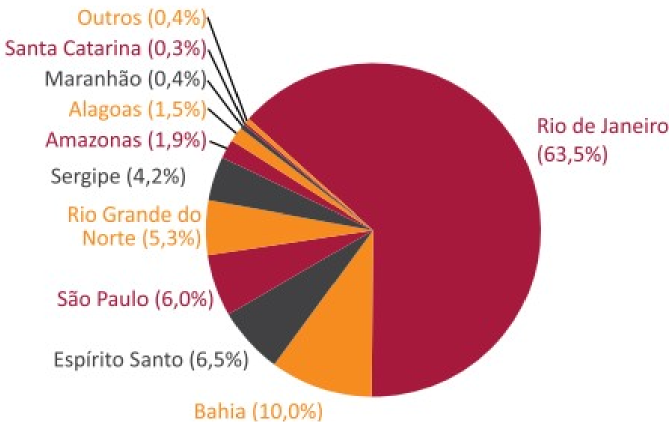


Source: ANP (2022d) compiled by the author.

Comparing Graphics 3 and 4, is noted thar the O&G sector remained productive even when the GDP decreased. For example, between 2019 and 2020 when the GDP suffered an 4,06% decrease and the industrial an even bigger decrease, of 9,15%, is observed that the production of O&G showed an increase of 5,20%. As were previouly discussed, the main responsible for the variations between these years was the COVID-19 pandemic, so, accounts that the oil and fas industry was able to maintain strong and grow even in this scenario, what is favorable to the job generation in the sector.

In Graphic 5, it is shown that the geographical distribuition of the jobs in the Oil Extractive Industry and support activities in 2019. From this data, it can be seen the domain of Rio de Janeiro state in the offer of this kind of job.

Graphic 5– Geographic distribution of jobs in the Oil Extractive Industry and support activities in 2019 in Brazil.



Source: Viana (2020).

3.4 ANALYSIS OF OIL AND GAS RELATED COURSES

3.4.1 Under Graduation Programs

Table 1 shows the available vacancies in Under Graduation Programs in Petroleum Engineering, Petroleum and Gas Engineering, Petroleum and Gas and Petroleum and Gas Production that are actives nowadays, according to the e-MEC (2022a) database. The institutions are divided in private for-profit, private non-profit, public state and public federal. Considering the currently active courses, there is only the face-to-face modality.

Table 1 – Available vacancies in Under Graduation Programs related to Oil and Gas

	STATES															
Administrative Category	**AL**	**AM**	**BA**	**CE**	**ES**	**MA**	**MG**	**PB**	**PE**	**RJ**	**RN**	**RS**	**SC**	**SE**	**SP**	**Total**
Private for-profit		240	2380		1080		360		120	780	180	400		350	2685	8575
Private non-profit		760	50			200			100	1173			100		520	2903
Public state		112								25			80		35	252
Public federal	40	50		40	50			50		90	120	50		50	40	520
Total	**40**	**1162**	**2430**	**40**	**1130**	**200**	**360**	**50**	**220**	**2068**	**300**	**450**	**180**	**400**	**3280**	**12310**

Source: ANP (2022d) compiled by the author.

From the data, it can be seen that the largest number of openings are present in institutions private for-profit, followed by private non-profit. The public institutions have far few vacancies, with the states having the fewest.

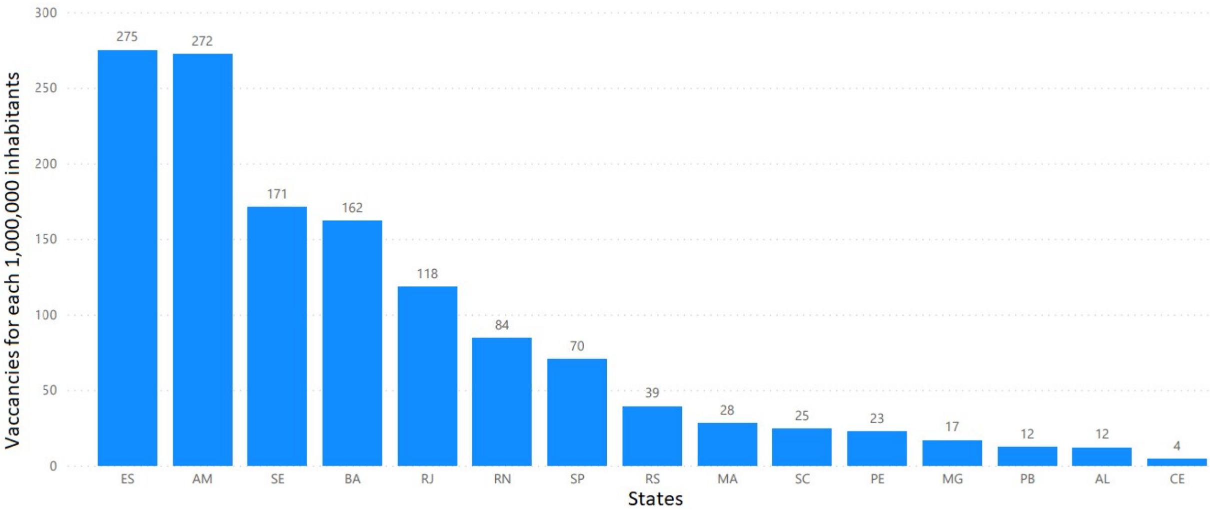
Related to distribution among the states (Figure 1), there is a higher concentration in São Paulo, followed by Bahia and Rio de Janeiro. It can be observed that of the 26 Brazilian states, 11 do not offer vacancies in the mentioned courses.

Figure 1 - Geographic distribution of Under Graduation Programs related to Oil and Gas in Brazil

Source: e-MEC (2022a) Compiled by the author.

Graphic 6 shows the number of vacancies for each 1,000,000 inhabitants in each state, considering the estimated population for the year 2021, according to IBGE (Geography and Statistics Brazilian Institute). In this condition, the states that possess a bigger proportion are Espírito Santo, Amazonas, Sergipe and Bahia and the states that possess a smaller proportion are Ceará, Alagoas, Paraíba and Minas Gerais.

Graphic 6 – Vacancies for each 1,000,000 inhabitants in each state of Brazil



Source: e-MEC (2022a) compiled by the author.

Also according to e-MEC (2022a) database, there is a considerable high number of extinguish courses or in process of extinction (Table 2).

Table 2 – Vacancies extinguish or in process os extinction in Under Graduation Programs related to Oil and Gas.

	STATES											
Administrative Category	AM	BA	CE	ES	MA	MG	PE	RJ	RN	RS	SP	Total
Private for-profit		790		870		150	255	3890	310	100	1131	7496
Private non-profit	200		100	250	200		200	880	200		535	2565
Public federal								40				40
Total	**200**	**790**	**100**	**1120**	**200**	**150**	**455**	**4810**	**510**	**100**	**1666**	**10101**

Source: e-MEC (2022a) compiled by the author.

According to Table 2, it can be noted that there is a concentration in these kind of vacancies in private institutions. The biggest amount of these kind of vacancies are from private for-profit institutions. Related to the states distribution, the biggest part is located at São Paulo and Bahia.

Accordingly with the data from UFES, UFPel, UDESC, (2023) the candidates per vacancies relation at three Brazilian universities and comparing it with some classical engineering modalities can be seen in Table 3. It is possible to notice that there is not any considerable relation between the data. The candidates per vacancies relation depends more on variables related with the historical of the University than with the courses analyzed.

Table 3 – Candidates per vacancies in different Graduation Programs

Cadidates/vacancies	UFES	UDESC	UFPEL
Petroleum Engineering	4,02	2,47	1,2
Production Engineering	5,03	2,23	2,55
Mechanical Engineering	4	5,47	-
Civil Engineering	3,33	3,35	6,11

Source: CAPES (2022b) Compiled by the author.

Considering the same Universities from Table 3, the Petroleum Engineering courses have the curriculum divided on average 12% of experiential classes and 88% of theorical classes. Also, on average 29% of the classes are part of the basic cycle of engineering and 71% are specific (UFES, UFPel, UDESC, 2023).

3.4.2 *Lato Sensu* Graduation Programs

Table 4 shows the number of available vacancies in *Lato Sensu* Graduation Programs related to O&G, according to the e-MEC (2022a). The courses analyzed were in the following areas: Education; Art and Humanity; Business; Administration and Law; Computer, Information Technology and Communication; Engineering, Production and Construction; Services. The institutions are divided in private for-profit, private non-profit and public federal. Considering the currently active courses, there are the face-to-face modality and the online modality.

Table 4 – Vacancies available in *Lato Sensu* Graduation Programs related to Oil and Gas

	Vacancies available	Registered students
Online	**30795**	**4241**
Private for-profit	27850	4030
Private non-profit	2920	211
Public municipal	25	0
Face-to-face	**10196**	**4047**
Private for-profit	7720	1510
Private non-profit	2290	1100
Public federal	186	1437
Total	**40991**	**8288**

Source: e-MEC (2022a) compiled by the author.

According to the data, it can be seen that there is a lot more vacancies offered in the online modality, whereas considering just the total of registered students, the number is almost the same. Private for-profit institutions have more vacancies and registered students in both modalities.

Figure 2 shows the distribution of vacancies among the Brazilian states, it is notable that there is a concentration in São Paulo, Espírito Santo, Rio de Janeiro and Minas Gerais and of the 26 Brazilian states, 6 do not offer vacancies.

Figure 2 - Geographic distribution of *Lato Sensu* Graduation Programs related to Oil and Gas in Brazil

Source: CAPES (2022b) compiled by the author.

3.4.3 Master's and PhD's Programs

According to Sucupira platform by CAPES (2022b), the institutions that offer the Master's and PhD's Programs related to O&G are only three: Campinas State University (SP) in the area of Science and Petroleum Engineering; Bahia Federal University (BA) in the area of Geochemistry: Petroleum and global environment and Rio Grande do Norte Federal University (RN), in the area of Science and Petroleum Engineering. Figure 3 shows the geographic distribution of these courses that are offered only in the states of São Paulo, Rio Grande do Norte and Bahia.

Figure 3 – Geographic distribution of Master's and PhD's Programs related to Oil and Gas in Brazil

Source: CAPES (2022b) compiled by the author.

3.4.4 Discussion

The analysis of the data concerning undergraduate courses considered in this research shows that there is a high number of extinct vacancies compared to the active ones, 82% of the sum of vacancies correspond to the extinct ones. This data raises the hypothesis that such extinct vacancies may have been created at a time when the market was more favorable, that is the moment when the interest on the part of students in starting an undergraduate course in this area is greater. Similarly, such vacancies may have been extinguished at a time when the sector faced more difficult scenarios, which reduces the demand for new students.

In addition, it is observed that only 57% of Brazilian states offer, in 2022, vacancies in the undergraduate courses, which shows itself as a possible obstacle for students from states where no vacancies are offered.

Another possible explanation is the obsolete educational model still common in these courses. Considering that the new generations are increasingly more immediatist in comparison with previous generations and have lower tolerance to frustration, a behavior strongly related to the rise of social networks, when faced with a course with such a high theoretical workload and concentrated in the basic cycle in the initial years, it is very likely that students get frustrated and may drop the course

In relation to the graduate/specialization courses cited, the actual number of graduates corresponds to 20% of the vacancies, so many vacancies are made available but do not receive students. Besides this, the offer of master's and PhD's vacancies is very small and restricted to a few states.

3.5 DIDATIC TEST BENCH INTRODUCTION

3.5.1 Initial Aspects

The bench projected in this work is an adaptation of the "Mini-Rig Drill-Lab Didactic Bench" from Espírito Santo Federal University, developed by Bissoli and Nascimento (2020), shown in Figure 4. This equipment is located in the Centro Universitário Norte do Espírito Santo (CEUNE/UFES). The didactic test bench is a device projected to assist practical classes and research related to oil well drilling, enabling the realization of tests and analysis of the weight of the drill string and rotation speed applied to a rock formation. In that way, it is allowed the comparison between the values theoretically calculated and those found experimentally with the bench, identifying and understanding the discrepancies of the real system (BISSOLI; NASCIMENTO, 2020 a. BISSOLI; NASCIMENTO, 2020b. BISSOLI; NASCIMENTO, 2020c).

Figure 4– Mini-Rig Drill-Lab Didactic Bench

Source: Bissoli; Nascimento (2020a).

3.5.2 Objectives and Motivation

The objective of having a didactic test bench installed in UNESP Guaratinguetá Campus is the possibility to simulate the drilling of an oil well, for being used in experimental classes and research. In discussions with Prof. Dr. Andreas Nascimento, some improvement points were selected to be realized in this work such as the structural stability and the water circulation. Besides that, some adjustments were made in the mechanical equipment.

Additionally, the bench can be used to compare simulation results with experimental results, combining different parameters such as torque, flow, revolutions per minute, etc, and realize pre-operational tests as the drill-rate test and the drill-off test.

3.6 DIDATIC TEST BENCH GENERAL DETAILS

3.6.1 Operating Principle

The bench project predicts an equipment that simulates the oil well perforation using a range of devices of various areas, such as fluid flow, control and automation and rotation, forming a closed system capable of fluid injection, control of rotation and weight, gravel removal, fluid treatment and fluid re-injection (BISSOLI; NASCIMENTO, 2020a. BISSOLI; NASCIMENTO, 2020b. BISSOLI; NASCIMENTO, 2020c).

3.6.2 Materials Selection

In this section, a discussion about the most recommended material to be used in the test bench considering the properties requirement will be made. Some specific parts require specific materials and do not fit the general selection made in this section; these cases will be treated individually on the "Mechanical Structure" section.

3.6.2.1 Material and Steel Selection

Materials selection is one of the most complex and important tasks in engineering because it is necessary to understand the performance requirement and apply it on its properties. Also, it is important to control them by proper tests in order to guarantee the quality specification. To the selection process is important to combine performance parameters (that are harder and expensive to measure) and properties easier to control (like hardness and tensile strength) (SILVA; MEI, 2021).

In the last century, steels have been the most widely used materials in industry, specially because its wide spectrum of properties and performance characteristics that can be obtained by low costs (SILVA; MEI, 2021).

The selection of steels must take into account not only the properties of currently available steels but also the development trends in the steel industry itself, since the quality standards and the levels of properties that can be achieved are in constant evolution. Thus, the selection of steels is a dynamic process and must be reviewed periodically (SILVA; MEI, 2021).

3.6.2.2 Engineering Steels

The objective of engineering steels is to attend a specific chemical composition range, since they are usually heat treated in order to obtain the desired final property. The main characteristic targeted when defining the chemical composition is the hardenability. Hardenability is the property of steels and ferroalloys that determines the depth and the hardness distribution produced by tempering and is related to the tempering severity (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

Selecting a steel to a specific application requires a definition of priority on the final properties. Rarely all the properties will be able to be achieved and have the same importance. Calculations are necessary to determine the most required properties in mechanical applications, they involve material resistance, stress analysis, previously experiences with similar components and practical tests of the sets (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

The microstructure that better fits the combination of resistance and toughness in steels is the tempered martensite that is obtained by tempering and annealing processes. In the selection of steels for tempering and annealing, the most important property is the hardenability and combines a metallurgical and heat transmission evaluation. The usual requirement in a project with engineering steels is that a minimal mechanical resistance be assured in a known position in the part. This resistance is related with the steel hardness (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

It is possible to determine which cooling speed a steel need in order to achieve certain hardness in a specific position of the part. Also, the cooling speed can be determined by knowing the part dimensions and the cooling environment. That way, is possible to determine which steel, cooled in which tempering environment will achieve the hardness and resistance desired in the established position (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

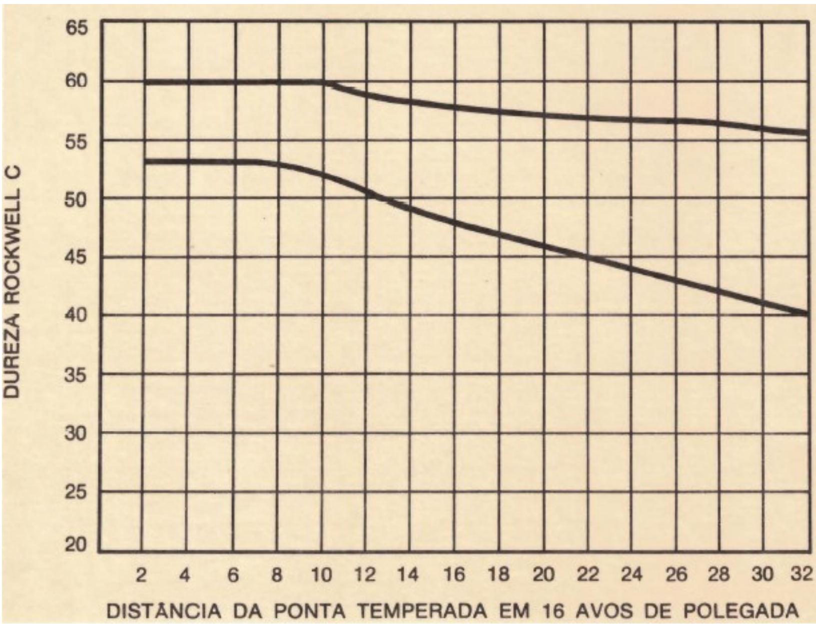
3.6.2.3 Material choice for the didatic bench

Classically, the selection is made using Jominy curves, which allows to obtain information about appropriate cooling speed in tempering in a rapid and simple way. For the test bench application, it will be made a comparation between the steels ASTM 1045, ASTM 4140, AISI 4340 and AISI 8640 (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

When using the Jominy curves, the selection process consists in, first determine the mechanical resistance desired in certain position, then determine the hardness that corresponds to this resistance and choose the martensite content that is necessary in the position considering the kind of solicitation (knowing that the martensite hardness depends on the carbon content, a better hardenability will be achieved when selection a less carbon content). Then choose the hardness after tempering that will result in this hardness after annealing (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

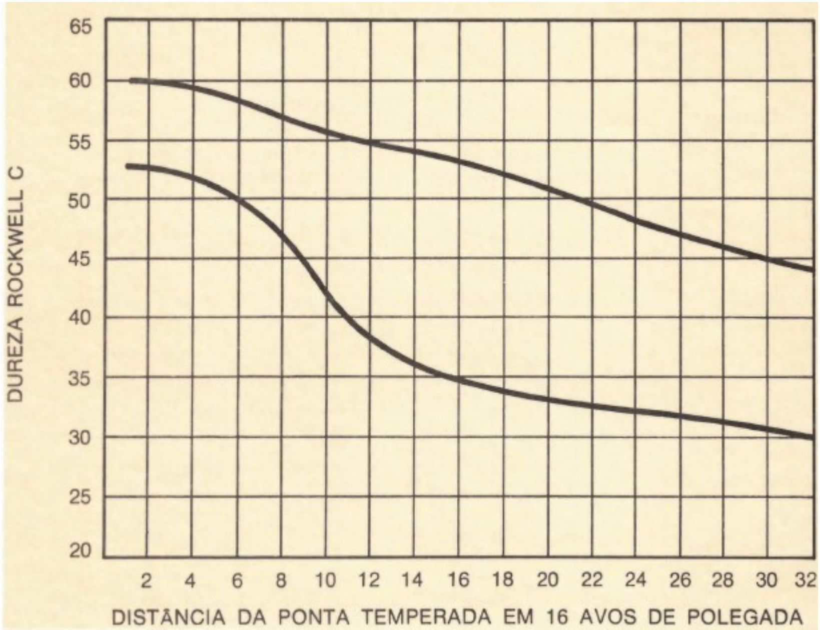
Figures 5, 6 and 7 show the hardenability range of the three steels, it can be noted that ASTM 4140 has a higher range and AISI 4140 is the one that hardness continues more stable as the distance from the surface increases.

Figure 5– Hardenability range of AISI 4340 steel.



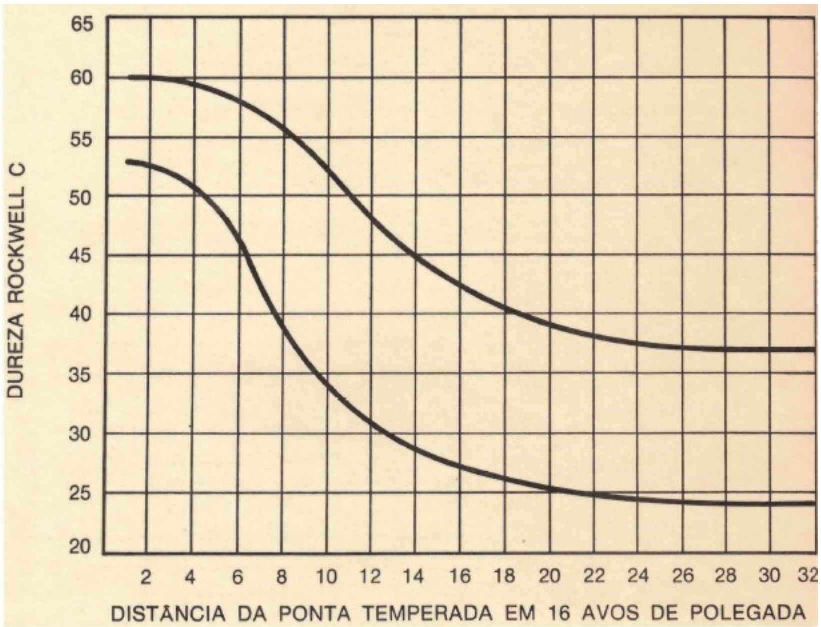
Source: Aços Villares (n.d).

Figure 6– Hardenability range of ASTM 4140 steel.



Source: Aços Villares (n.d).

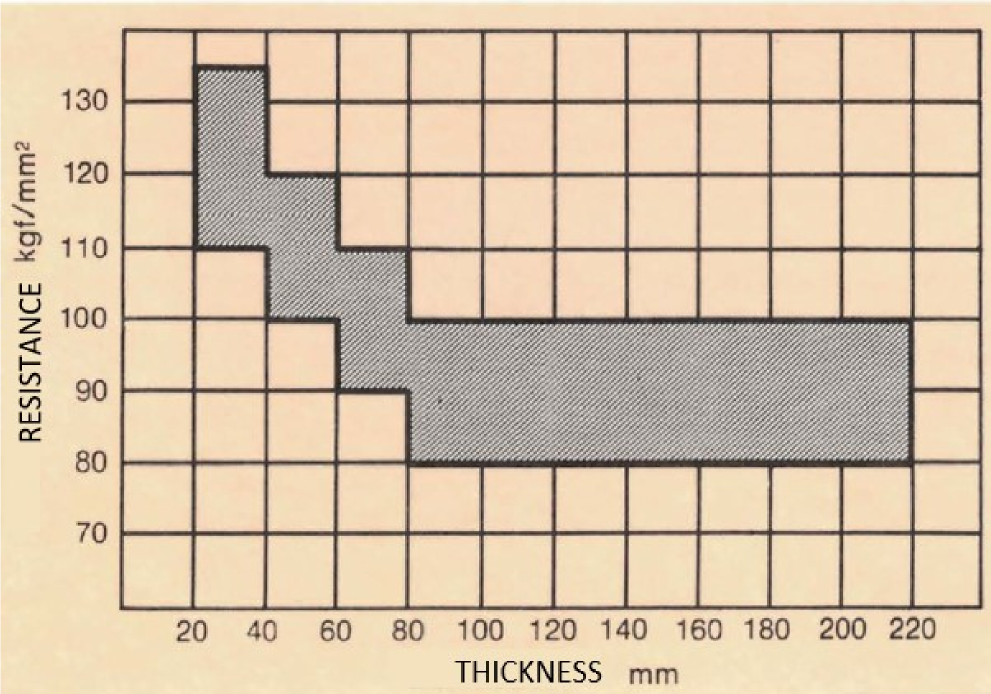
Figure 7– Hardenability range of AISI 8640 steel.



Source: Aços Villares (n.d).

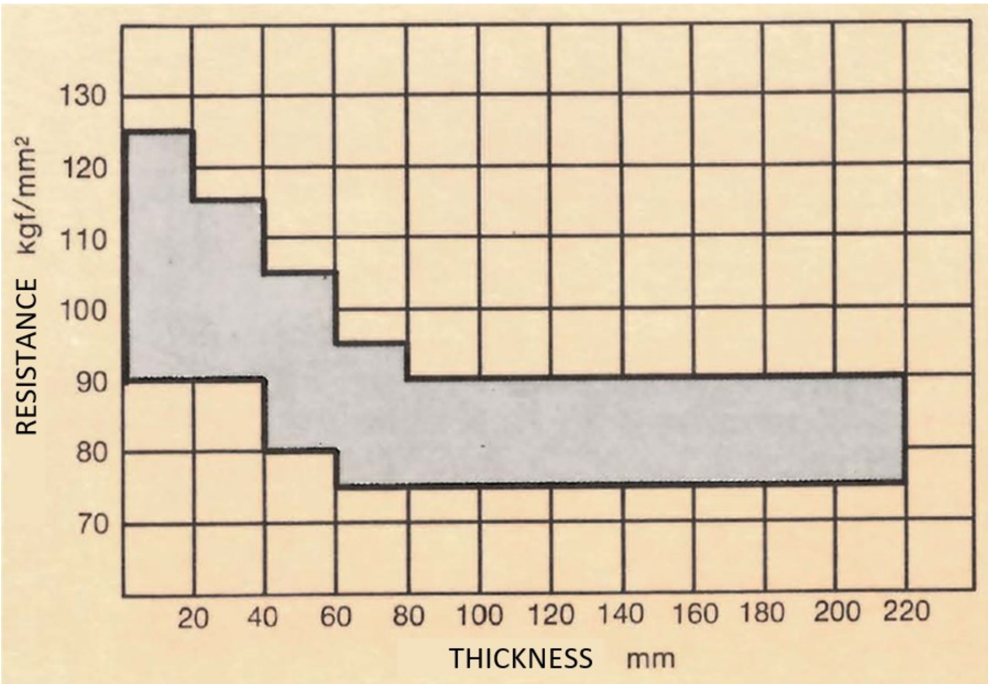
Bellow will be shown some curves comparing the behavior resistance vs thickness of the steels studied in this work (Figures 8, 9 and 10).

Figure 8– Usable resistance as a function of thickness of AISI 4340 steel.



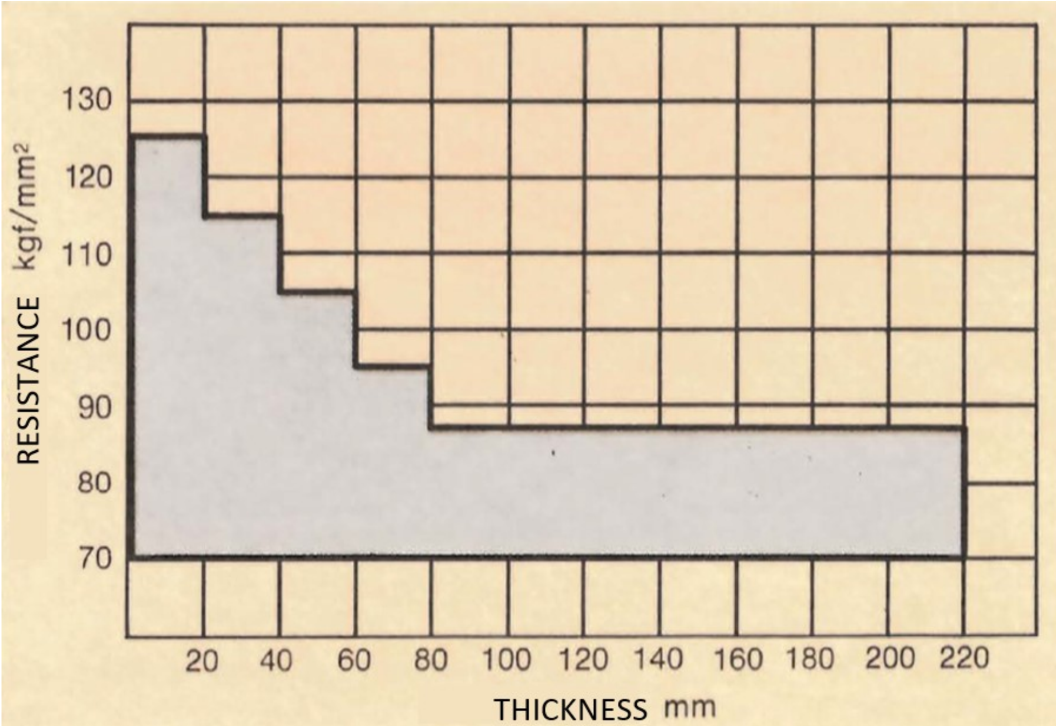
Source: Aços Villares (n.d).

Figure 9– Usable resistance as a function of thickness of ASTM 4140 steel.



Source: Aços Villares (n.d).

Figure 10– Usable resistance as a function of thickness of AISI 8640 steel.



Source: Aços Villares (n.d).

It can be noted that for thickness until 80 mm, AISI 8640 has the widest resistance range, followed by ASTM 4140 but the AISI 4340 has the highest hardness values. After 80mm, AISI 4340 has the highest resistance, followed by AISI 8640. For the bench application, most components are thinner than 80mm so, for parts that require higher resistance the AISI 4340 is more recommended, and for parts that do not require resistance so high, the AISI 8640 is adequate.

The difference between these three steels exists because of the chemical composition. Table 5 shows the percentage of each element for them (SILVA; MEI, 2021, AÇOS VILLARES, n.d).

Table 5 – Chemical Composition of ASTM 4140, AISI 4340 and AISI 8640

	%C	*%P*	*%S*	*%Si*	*%Mn*	*%Cr*	*%Ni*	*%Mo*
AISI 4340	0,38	máx.	máx.	0,15	0,60	0,70	1,65	0,20
	0,43	0,035	0,040	0,35	0,80	0,90	2,00	0,30
ASTM 4140	0,38	máx.	máx.	0,15	0,75	0,80	-	0,15
	0,43	0,035	0,040	0,35	1,00	1,10		0,25
AISI 8640	0,38	máx.	máx.	0,15	0,75	0,40	0,40	0,15
	0,43	0,035	0,040	0,35	1,00	0,60	0,70	0,25

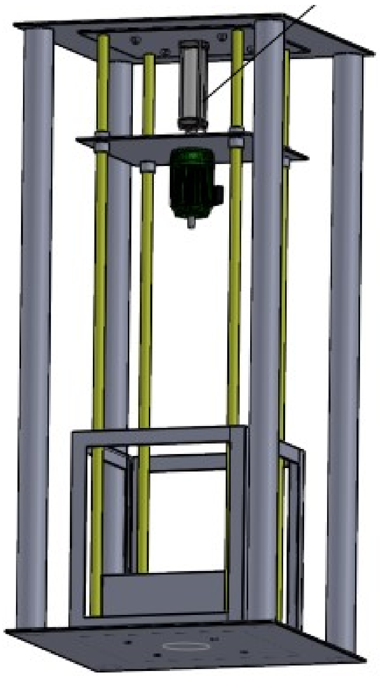
Source: Aços Villares (n.d).

The percentage of Carbon, Phosphorus, Sulfur and Silicon can be considered as identical in the three steels. The amount of Manganese is higher in the ASTM 4140 and AISI 8640 while the percentage of Nickel is considerable higher in AISI 4340, inexistent in ASTM 4140 and low in AISI 8640. Molybdenum is a little bit higher in AISI 4340. These differences explain the properties of each steel.

3.6.3 Mechanical Structure

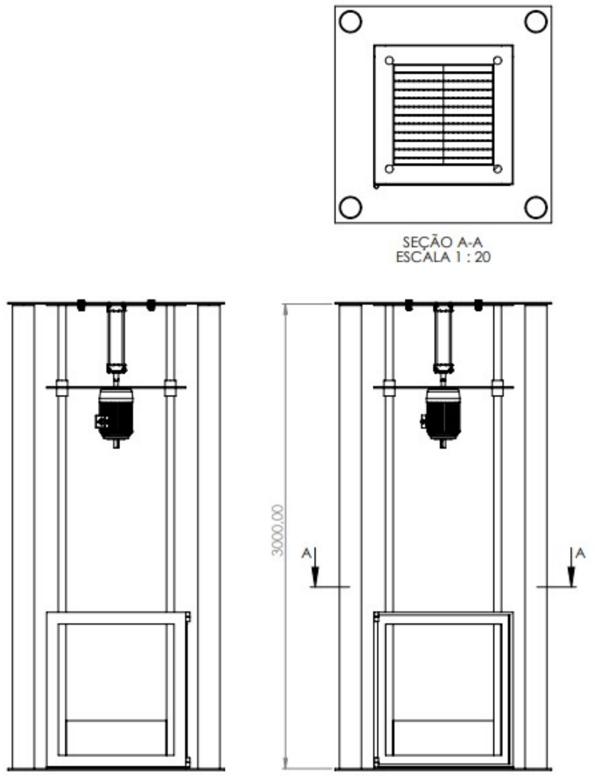
The 3D mechanical project and the technical drawing of the didactic test bench is shown in the Figures 11 and 12.

Figure 11– 3D mechanical Project of the Didactic Test Bench.



Source: Bissoli; Nascimento (2020).

Figure 12– Technical drawing of the Didactic Test Bench.



Source: Bissoli; Nascimento (2020).

3.6.4 Main Components

The main components of the test bench will be described in this section.

3.6.4.1 Moving Guide

Allows the drilling set to move vertically and prevents change in direction.

Figure 13 – Moving Guide.

Source: Linearmotion (2023).

3.6.4.2 Limit Switch

Indicates the end of movement range available to the motor and its structure and works as an electric control switch.

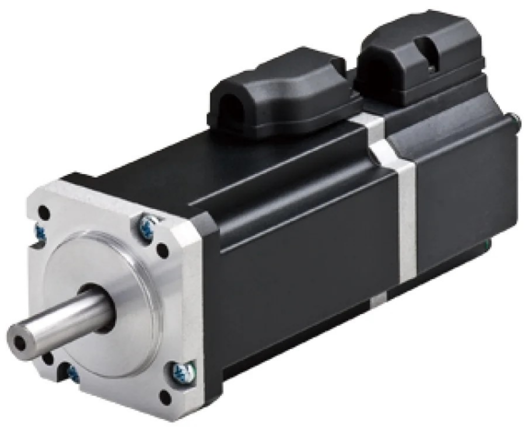
Figure 14 – Limit Switch.

Source: YKRS (2023).

3.6.4.3 Servo Motor

The Servo Motor is an equipment that controls the rotation of a shaft through 360° in two directions. In the bench, its function is to raise and lower the motor/drill pipe/drill assembly, controlling the weight applied to the rock sample.

Figure 15 – Servo Motor.

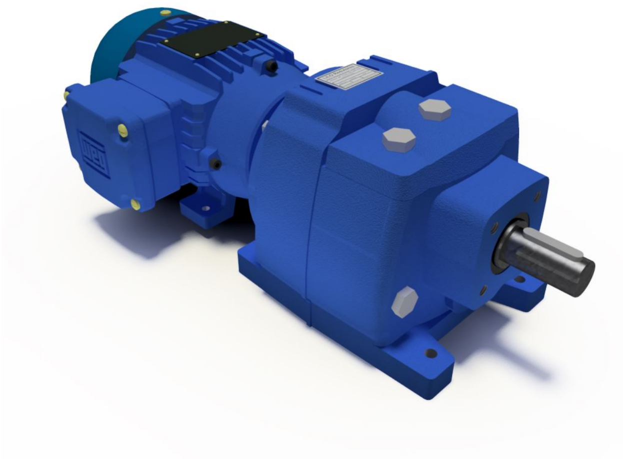


Source: Mectrol (2023).

3.6.4.4 Geared Motor

The function of the Geared Motor is to match the speed to the rotation required in the device, in the bench, it is responsible to rotate the drill, crushing the rock.

Figure 16 – Geared Motor.



Source: Liloredutores (2023).

3.6.4.5 Coupling

The coupling is responsible to match the inter-axle connection, promoting the joint and keeping the axes aligned during the rotation processes, avoiding angular, radial or axial deviations. In the bench, the coupling is used between the Geared Motor and the Water Injector.

Figure 17 – Coupling.

Source: Desch (2023).

3.6.4.6 Water Injector

The Water Injector is localized between the Geared Motor and the Drill Pipe, being responsible to inject water in circular motion into the Drill Pipe.

Figure 18 – Water Injector.

Source: Mbxmaquinas (2023).

3.6.4.7 Drill Pipe

For the drilling it is necessary a pipe that simulates the drill string, at its end is coupled the drill and the water injector at its beginning, connected by the couplings.

Figure 19 – Drill Pipe.

Source: Directindustry (2023).

3.6.4.8 Drill-bit

The drill-bit is the part responsible for drilling into the rock by the high-speed rotation. In order to have a wide range of test parameters, different types of drills should be used, varying the geometry and material of them.

Figure 20 shows some types of drill-bit that can be used depending on the material to be drilled and the material subsurface expected to be found. They can be constructed from materials such as steel, natural diamonds, synthetic diamonds, and tungsten carbide. Each rig is composed of at least two toothed cones, and rotating discs that are used to roughen the rock among other materials.

Steel-toothed drill bits are the most common type of equipment used in oil extraction. Tungsten carbide can be inserted into steel devices to add strength and allow movement through stronger materials. Synthetic polycrystalline diamonds can also be added to drills with tungsten inserts to make them stronger through rock formations. Where this type of relief is extremely strong, a diamond embedded in the drill bit can be used, making these drills 40 to 50 times stronger than steel drills.

Choosing the right type of oil well drill bit is important in the early stages of operation, through rock and sediments, because it is very difficult to change a drill bit after the whole process has started.

Figure 20 – Drill-bit.

Source: Mecanicaindustrial (2023).

3.6.4.9 Rock Sample Support Table

The Support Table is used to prop the rock sample to perform the drilling, there is a drain to filter the fluid used in the drilling and remove the larger gravels. There is a level sensor that activates the Injection Pump controlling the fluid volume inside de Table. The debris and fluid deposited at its base can be collected for analysis and study. An acrylic container will be installed around the Table to prevent liquid splashing out.

Figure 21 – Rock Sample Support Table.

Source: Bissoli; Nascimento (2020).

3.6.4.10 Self-Priming Pump

The principle of operating of an Self-Priming Pump is the air elimination inside the pump and the suction pipe by filling them with the fluid before the trigger.

Figure 22 – Self-Priming Pump.

Source: Xylem (2023).

3.6.4.11 Injection Pump

The Injection Pump is used to re-inject the fluid in the system through a hydraulic hose and allows the flow control.

Figure 23 – Injection Pump.

Source: Bombashopping (2023).

3.6.4.12 Water Tank

The Water Tank is the recipient where the fluid is drained, pumped and re-injected into the drilling. Additionally, the tank has a series of hydrocyclones responsible for eliminating the coarse particles.

Figure 24 – Water Tank.

Source: Enduraplas (2023).

3.6.4.13 Water Circulation Pipes

It is necessary to use pipes, hydraulic hoses and other adapters to transfer the fluid from the Water Tray to the Self-Priming Pump, from the Self-Priming Pump to the Water Tank and from the Water Tank to the Injection Pump. For these parts can be used the Polyvinyl Chloride (PVC) that combines lightness, low cost and adequate resistance.

Figure 25 – Water Circulation Pipes.

Source: Conquistamaquinas (2023).

3.6.4.14 Valves

In order to control the fluid flow to be injected in the drilling to enable maintenance and stops, it is used a valve.

Figure 26 – Valves.

Source: WSV (2023).

3.6.5 Measuring Instruments

3.6.5.1 Load Cell

A Load Cell is used to convert the load that acts on it into a measurable electrical output.

Figure 27 – Load Cell.

Source: UKRS (2023).

3.6.5.2 Rotary Torque Transducer

The Rotary Torque Transducer is used in the bench to measure the amount of rotational force present during the operation, they are transmitted to the control systems so that the components can function correctly.

Figure 28 – Rotary Torque Transducer.

Source: Omega (2023).

3.6.5.3 Vibration Sensors

The Vibration Sensor is used to inform the velocity variation of the movement according to a certain time limit.

Figure 29 – Vibration Sensors.

Source: Phdsensors (2023).

3.6.6 Control Panel

3.6.6.1 Electric Power Supply

To control the electrical system and the bench operation is necessary to have a control panel where the operations of all the equipment will be controlled by the user. It is important to verify if the room where the bench will be installed has capacity to supply the energy need.

3.6.6.2 Hydraulic Supply

The fluid used in the drilling is water, so it is important to verify if the room where the bench will be installed has capacity to supply the water need.

4 CONCLUSION

Brazil has an elevated number of extinct vacancies in under graduation courses analyzed in this research, strongly because of the instability in the O&G sector, which affects the student's motivation. Another point of attention is the obstacle to students of some states that need to move long distances in order to find some university that offers these courses. The students also need to face an obsolete model of education that makes them loose a lot of time and motivation. In graduation/specialization courses, a lot of vacancies are available, but the search for them is low. In master's and PhD's there is only 3 universities offering vacancies.

Knowing the instability that the O&G sector has and the difficulties in the manpower generation, as were widely cited in this research, it is necessary that partnership programs between companies and research centers with universities receive investment to mitigate the effects of periods of crisis in the training of skilled labor.

The didactic test bench for the simulation of oil well drilling operations whose project were detailed in this work is an opportunity to narrow the contact between the Guaratinguetá UNESP Campus students and the O&G sector. A suggestion for a new PRH 34.1 FEG/UNESP member is to implement the project of the bench and install it on the campus. It can be used in the subject “Introduction to Petroleum Engineering” as part of the course outline and in research for under graduation, specialization, master’s and PhD’s students.

SCIENTIFIC COMUNICATION

Oral presentation:

a) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos e desenvolvimento de uma bancada didática de testes de simulação de operações de perfuração.** III Jobshop Oil & Gas International PRH-ANP-FINEP 34.1 FEG/UNESP, 2020.

b) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos.** XX Encontro Anual de Iniciação Científica UNIPAR, 2021.

c) PEDRO, B. M. F.; NASCIMENTO. N. **Analysis of the human resources development scenario and the employability prospects for the next years in the oil and gas area in Brazil.** IV Jobshop Oil & Gas International PRH-ANP-FINEP 34.1 FEG/UNESP, 2021.

d) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos.** XXI Congresso de Iniciação Científica CONIC SEMESP, 2021.

e) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos.** XXXIII Congresso Nacional de Iniciação Científica UNESP, 2021.

f) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos.** XXIX Congresso de Iniciação Científica UNICAMP, 2021.

g) PEDRO, B. M. F.; NASCIMENTO. N. **Análise do cenário de formação de RH na área de petróleo e gás no Brasil e das perspectivas de empregabilidade para os próximos anos.** XX Rio Oil & Gas, 2022.

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