Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

https://doi.org/10.23913/ride.v12i24.1184

Artículos científicos

Software educativo TREM: evaluación y selección de tuberías de revestimiento y su estado mecánico

Educational Software TREM: Evaluation and Selection of Casing Pipelines and Their Mechanical State

Software Educacional TREM: Avaliação e Seleção de Revestimento e Condição Mecânica

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Resumen

El objetivo del presente trabajo fue elaborar un *software* para la evaluación de diseño de tuberías de revestimiento y su estado mecánico confiable, sencillo y de fácil adaptación entre el programa y el usuario. Para ello, se combinó la teoría técnica y científica con la experiencia en el manejo de *software* especializado en el diseño de pozos petroleros. La estrategia para su desarrollo consistió en la descomposición del problema original en tres secciones: *1)* identificación y manejo de las diferentes propiedades mecánicas de las tuberías de revestimiento, *2)* identificación y evaluación de los diferentes tipos de esfuerzos que se presentan en las tuberías de revestimiento según el diseño del pozo y *3)* esquematización del arreglo de tuberías acorde a la profundidad y diseño del pozo. Entre los resultados se logró combinar la programación con el material especializado técnico y científico: seleccionar, evaluar y esquematizar las diversas tuberías de revestimiento según los datos operativos del diseño del pozo, así como determinar un costo aproximado de las tuberías y de las operaciones en su selección y asentamiento para, finalmente, seleccionar el porcentaje y costo total de la perforación. En conclusión, el trabajo desarrollado resuelve la problemática presentada, pero solo aplica a pozos verticales, dada la limitación de gráficos 3D para la perforación direccional y con una profundidad máxima de 5200 m (17 060 ft).

Palabras clave: colapso, esfuerzos, estallamiento, grados, tensión.

Abstract

The objective of this work was to develop a software for the evaluation of casing pipes design and its mechanical state combining technical and scientific theory with the experience in the handling of specialized software in the design of oil wells. The strategy for its development consisted in the decomposition of the original problem in three sections: *1)* identification and management of the different mechanical properties of the casing pipes, *2)* identification and evaluation of the different types of stresses that occur in the casing pipes according to the well design, and *3)* schematization of the pipe arrangement according to the depth and design of the well. Among the results, it was possible to combine the programming with the specialized technical and scientific material, as well as to determine an approximate cost of the pipes and the operations in their selection and setting, to finally select the percentage and total cost of drilling. In conclusion, the developed work solves the presented problem, but only applies to vertical wells, given the limitation of 3D graphics for directional drilling and with a maximum depth of 5200 m (17 060 ft).

Keywords: collapse, stresses, bursting, degrees, tension.

Resumo

O objetivo do presente trabalho foi elaborar um software para avaliação do projeto de tubos de revestimento e seu estado mecânico confiável, simples e de fácil adaptação entre o programa e o usuário. Para isso, aliou-se a teoria técnico-científica à experiência no manuseio de software especializado no projeto de poços de petróleo. A estratégia para o seu desenvolvimento consistiu na decomposição do problema original em três secções: 1) identificação e gestão das diferentes propriedades mecânicas dos tubos de revestimento, 2) identificação e avaliação dos diferentes tipos de esforços que ocorrem nos tubos de revestimento. revestimento de acordo com o projeto do poço e 3) esquematização da disposição das tubulações de acordo com a profundidade e projeto do poço. Entre os resultados, foi possível combinar a programação com o material técnico e científico especializado: selecionar, avaliar e traçar os diversos tubos de revestimento de acordo com os dados operacionais do projeto do poço, bem como determinar um custo aproximado dos tubos e do operações em sua seleção e liquidação para finalmente selecionar o percentual e o custo total da perfuração. Em conclusão, o trabalho desenvolvido resolve o problema apresentado, mas aplica-se apenas a poços verticais, dada a limitação de gráficos 3D para perfuração direcional e com profundidade máxima de 5.200 m (17.060 pés).

Palavras-chave: colapso, esforços, estouro, graus, estresse.

Fecha Recepción: Octubre 2021 **Fecha Aceptación:** Abril 2022

Introduction

Currently, the technology applied in the oil industry is of vital importance. Indeed, a petroleum engineer will have greater professional opportunities if he has the necessary knowledge and skills that allow him to apply computer and technological tools in solving the problems that arise in each of the projects in which he develops daily.

Educational software, in the opinion of García and García (2008), are didactic instruments that facilitate the teaching-learning process, whether traditional, face-to-face or at a distance. For his part, Gros (2000) considers them part of a formal learning process. It is a specific design through which knowledge and skills are acquired that, ultimately, manage to develop specialized skills in the student. The didactic materials arise as a result of the fact that, for example, the tools that are available at that moment are incapable of solving a problem and their creation stage is multidisciplinary. For this last reason, professionals with different profiles, levels of experience and points of view on how they should be and how they should be created participate (Padrón, 2009).

This software has, among its fundamental objectives, to facilitate the teaching and learning of the handling and application of technical and operational data of the casing pipes, densities of the different types of fluids, fracture gradients, identification of the efforts to which they submit the pipes, generation and schematization of the mechanical state, as well as handling the concepts and definitions of the different variables involved in the design of oil wells. Software development generally consists of a series of steps that start from the understanding of the phenomenon to be simulated, through the identification and handling of the variables and unknowns that are to be determined by applying the different mathematical models, to the development of the algorithms and finally the generation of the computational code.

The construction of oil wells is a multidisciplinary process, since it requires diverse knowledge: physics, chemistry, geology, hydraulics, materials science and, without a doubt, experience in the field. In fact, it is important to accept that the use of new technologies has provided a greater understanding in the execution of designs and operations, which can be seen reflected in increased productivity, decreased operational risks and care. of the environment, to mention a few (Martínez, Suárez and González, 2017). One way to boost the economic growth of a nation is through the education of its citizens; developing your capabilities will allow you to add value to your daily activities in the industrial sector (United Nations Educational, Scientific and Cultural Organization [Unesco], 2011).

Klementich and Jellison (1986) described the importance of optimizing and automating the design process through the implementation of computational tools. To achieve a more accurate estimation of life conditions and stress analysis, they were freed from repetitive manual calculations. Petroleum engineering can and should make use of computer programs that facilitate daily tasks. And in that line, having a programming language like Visual Basic, together with the potential of spreadsheets like Excel, is essential (García, 2017). However, several of the public and private higher education institutions that offer petroleum engineering careers nationwide in Mexico lack simulation centers, drilling software or simulators, well control, geology, geophysics, and drilling fluids laboratories. , cementation, etc., so that, in most cases, a completely theoretical education is given.

Among the researchers who have developed some applications such as those mentioned above, we can mention Castillo and Chiriví (2008), Sepúlveda, Vargas and Rivas (2014), Chinedu and Onensi (2016) and Mondavi (2014).

For Torres and Anders (1995), Microsoft Visual Basic, being a programming tool that is easy to learn and apply, allows engineers to develop various applications. Along these lines, Bell, Davies and Simonian (2006) point out that the SPOT software of the transnational company Shell arose from Visual Basic/Excel; this duo facilitated its creation, validity and functionality, in other words, the generation of codes, modules and graphical interface was fast, simple and intuitive. Likewise, Utsalo, Olamigoke, and Adekuajo (2014) developed a Visual Basic application in the Microsoft Excel environment for casing selection. Finally, Akpan and Kwelle (2005) developed pipe selection and laying software with a user-friendly, interactive interface with automatable steps and common engineering units.

The main objective of oil well drilling is to make a hole that starts at the surface and ends at the target or producing area, regardless of its depth. The hole must be capable of being the means by which the oil is transported to the surface. In our country, the development of programs or software related to the hydrocarbon sector, such as design, drilling and extraction, has generally been promoted by national and international companies in the oil area and some research centers. However, these programs generally do not reach the universities and technologists that offer the petroleum engineering degree, since their annual rental costs per equipment (PC, laptop) are too high for their acquisition.

The simple hole does not ensure its stability during drilling and productive life time. To do this, it is necessary to line the hole, whose trajectories can be straight and curved, with varying depths, in some cases from 5,500 to 7,000 meters in land and sea areas, respectively; for example, in 2012, the company Exxon Neftegas Limited reported having reached a depth of 12.3 km of trajectory. The different casings and cementing provide, ideally in a safe, reliable and economic way, protection to the walls of the hole (Bassante, 2013). Hence, the coating is one of the most important points in the design and selection of pipes. This is supported by Halal, Warling and Wagner (1996), who describe the importance of the lining program, whose approximate cost, they calculate, ranges between 15% and 35% of the total cost of the well; Jenkins and Crockford (1975) calculate it between 10% and 20%, Pérez (2013) around 20% and Recalde (2018) believes that the approximate cost is 23% of the drilling project. Casing or casing pipes are normally classified as conductive, superficial, intermediate and exploitation pipe (Ángel and Torres, 2018), all of them based on the API

5CT standard; although some short pipes are also used, for example, liner, which are cheaper than production pipes, since they do not necessarily have to reach the surface, but rather they can be parked or placed at a certain depth.

Since each well is different in its design, construction and behavior, the type and number of pipes to be used for its lining are different. Like any engineering process, it is based on technical data, however, its design corresponds to a particular cost, which generates a discussion in decision-making found in the area of safety and costs. The latter can be determined by selecting the steel grade, wall thickness, and coupling types (Wang et al., 2013). Additionally, Morán, Lituma, Vargas and Tapia (2009) and Tao and Xie (2013) consider it important that, in the design stage, the use of new technologies and best operational practices in situ is also included. Generally, the pipes are designed under two points: resistance (manufacturing material) and effort (exposure conditions). The main types of well profiles are: vertical, directional and horizontal. The pipes have different grades, such as those reported by Olanrewaju (2018): J55, K55, N80, L80, C90, T95, P110, Q125, V150. The foregoing is based on the characteristics of soil mechanics (types of formations) and geological behavior of each of the formations to be drilled, since during drilling it is common to find currents of water, salts, gases, plastic, soft and hard formations. that give rise to the existence of normal, abnormal and subnormal pressures, so all pipes must be resistant to corrosion (Lin et al., 2016). In addition to this, Rahman and Chilingarian (1995) also consider points of internal company policies, government regulations, types of artificial lift and equipment that can eventually be placed in the well.

Goins, Collins and O´Brien (1965) and Greenip (1978) confirm that the first procedures in casing design were developed step by step due to the lack of computational capacity to solve the total optimization problem. While Prentice (1970) confirms the importance of carrying out an appropriate and separate evaluation for each type of casing, given the imponderables that may arise when considering the different load cases, when controlling the abnormal pressure zones of formation, loss of circulation and sticking due to differential pressure, in other words, the design of the casing is closely related to the experience and absolute knowledge of the parameters and factors used as a safety measure: any parameter that is not considered can influence negatively in its design.

Wojtanowicz and Maidia (1987) presented the first systematic approach for minimum cost design using the discrete version of the dynamic programming method, where the weight-price problem is detailed along with its impact on the model's efficiency, however, their work is very important for conditions of simple loads. These pipes vary in diameter, from 4 to 20 inches, they are of different weights and grades of steel, which are coupled to each other through the box and pin (threaded joints) in order to reach the desired depth (Aules, 2013). Well casing is a set of pipes joined by a connection. This connection is a mechanical device that allows them to be joined to form a functional continuous pipe, and cover the different sections of the well (Zambrano, 2016).

Casing pipes during their introduction, parking and fixation inside the hole are additionally also subjected to other types of factors, such as pipe wear (Moreira, Carrasquila, Figueiredo and da Fonseca, 2015; Shen, Beck and Ling, 2014), corrosion, vibrations and effects due to shots, to name a few. For all of the above, a program has been developed that provides a fast and efficient solution for the design of the different stages and pipes that make up the mechanical state and thus conform the geometry of wells. It is a free application that allows to be a bridge between the academic part with the experience in the design of the pipes for vertical oil wells, as well as a sample of application of the theory with one of the computer tools in the solution. of the problems of drilling hydrocarbon wells.

This software was developed with the Visual Basic programming language in a Microsoft Excel macro environment and offers: 1) evaluation of the pipes that will be exposed to pressures at each stage: formation pressure (Pf), hydrostatic (Ph), collapse (Pc), bursting (Pe) and tension (Pt); 2) schematization of the mechanical state, according to the diameters and number of casing and liner pipes, and 3) approximate estimation of the costs of the operations of the pipes and drilling.

Software development methodology

The development of the software was based on the neutral point trial and error method, which is characterized by using the flotation factor, the grade and the nominal weight of the casing pipes in each of the stages individually for their analysis. evaluation.

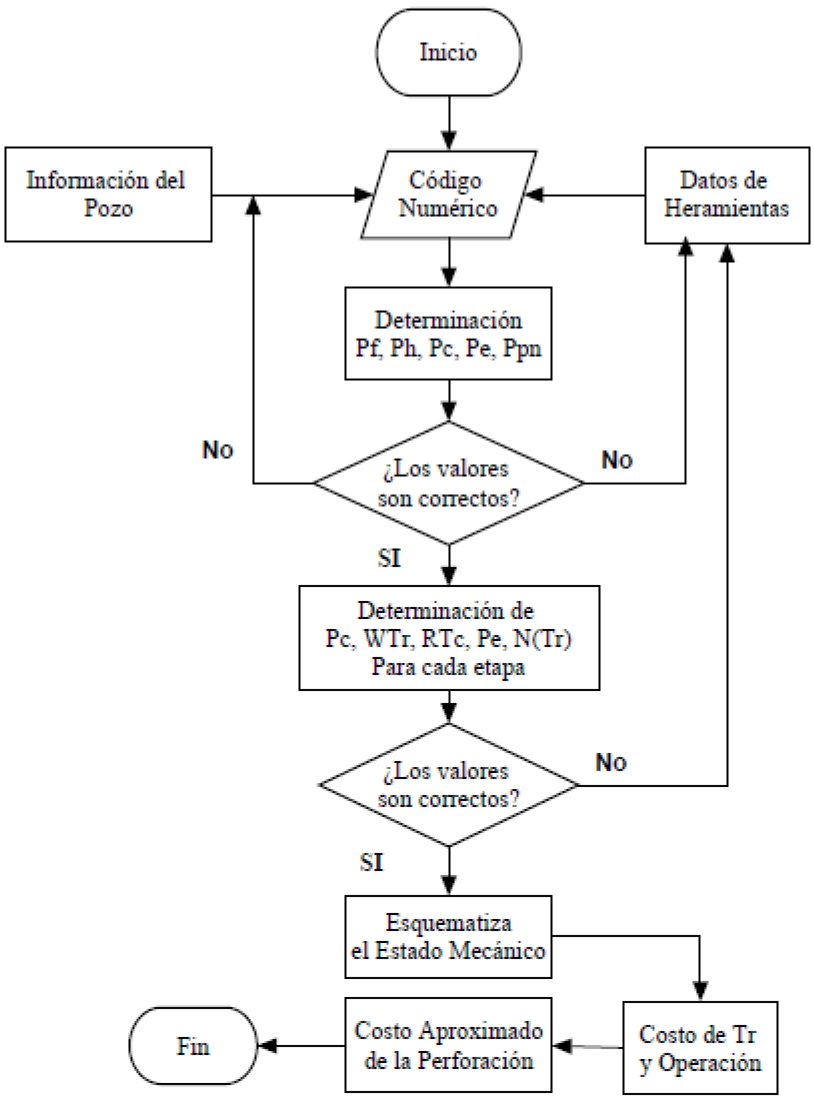
Among the researchers who have applied and validated this methodology operationally are Morán et al. (2009), Peñafiel, Sánchez, Vargas and Tapia (2009), Salas, Rosado, Vargas and Tapia (2009), Fernández and Aguirre (2009), Gandara (1990), Mayorga (1990), Molero (2012) and Recalde (2018).

The strategy consisted of decomposing the original problem into three sections:

1) Identification and management of the different mechanical properties (types and grades) of the casing pipes.
2) Identification and evaluation of the different types of efforts that occur in casing.
3) Schematization and cost of the casing arrangement according to the well design.

The software not only integrates the evaluation of the design of the pipes, but also allows to outline the mechanical state, estimate the cost per stage of each grade of pipes and the cost of operation to finally determine the approximate value of the drilling. . The following functional structure corresponds to the program operation process (figure 1):

Figura 1. Estructura funcional del *software*

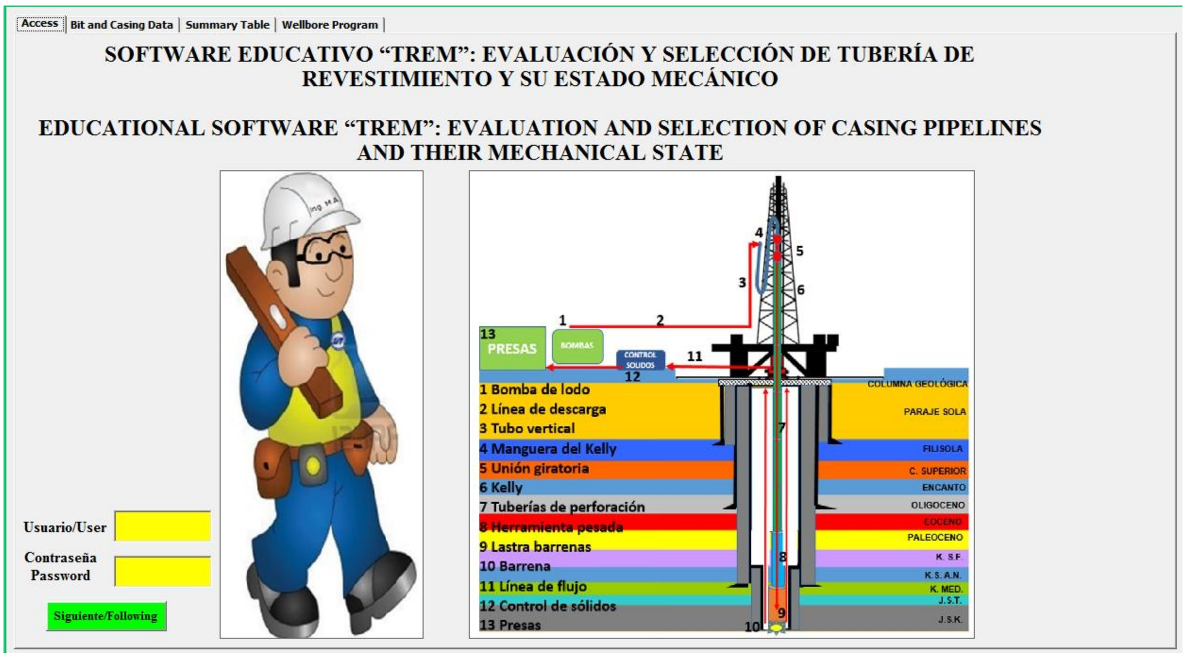


Fuente: Elaboración propia

Cover Page

Figure 2 corresponds to the main cover of the "Educational software for the evaluation of the design of casing pipes and their mechanical condition". There, the user must provide the "User/Password" access information, if that is the case. The program has the capacity to outline the pipes to a maximum depth of 5,500 m (16,404 ft), with a maximum of five stages and only applies to vertical wells. This includes the following three cases: 1) five bottom-to-surface pipes, 2) three bottom-to-surface pipes and two hanging liners, and 3) four bottom-to-surface pipes and one hanging liner. The black lines represent the walls of the well and the yellow lines correspond to the pipes.

Figura 2. Portada del *software*

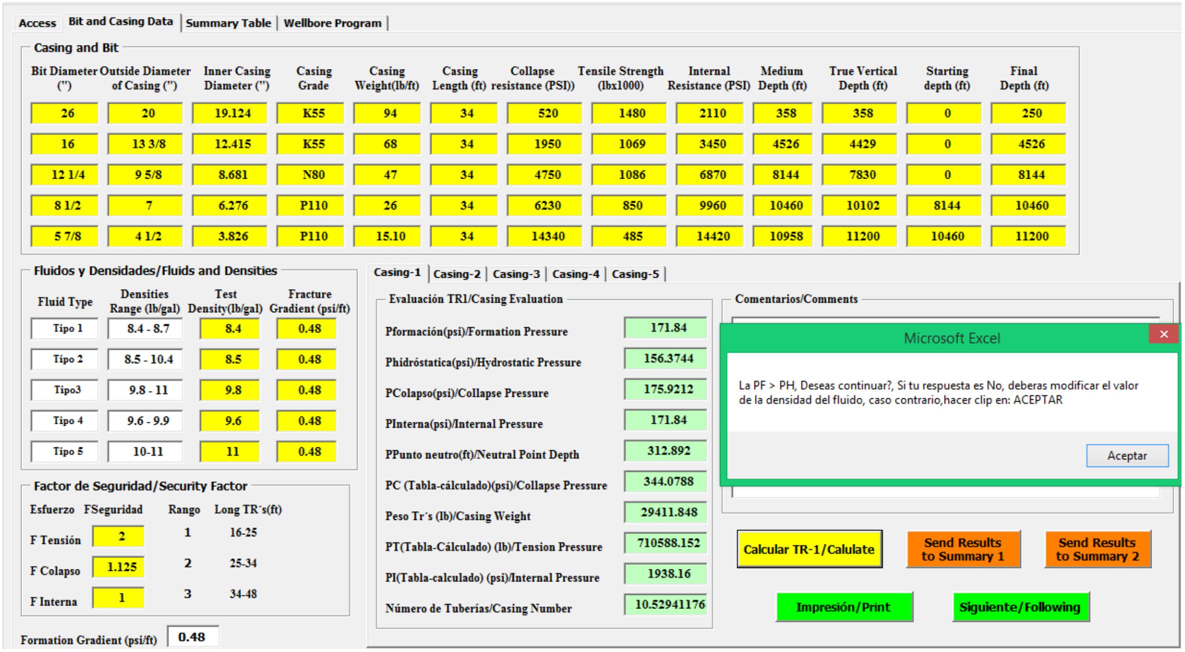


Fuente: *Software* educativo TREM

Program feed

Figure 3, labeled "Casing and Bit", corresponds to the insertion of the input data. In each of the yellow boxes at the top, the name of the variables is specified (bar diameter, outside and inside diameter of the casing and casing pipe, mechanical properties, steel grade, etc.), each with their respective measurement units. These correspond to the design to be evaluated and outlined, that is, the number of stages that the well design engineer considers pertinent according to the field information and the methodology to be applied.

Figura 3. Datos y resultados de la evaluación de tuberías de revestimiento por etapa



Fuente: *Software* educativo TREM

In the box in the center of the left side, "Fluidos y Densidades/Fluids and Densities", the user will establish the names and ranges of densities of the different types of fluids, real density and fracture gradients for the test in each of the stages . The “Factor de Seguridad/Security Factor” box corresponds to the assignment of the numerical value that the user considers appropriate for the evaluation of the efforts presented in each of the stages.

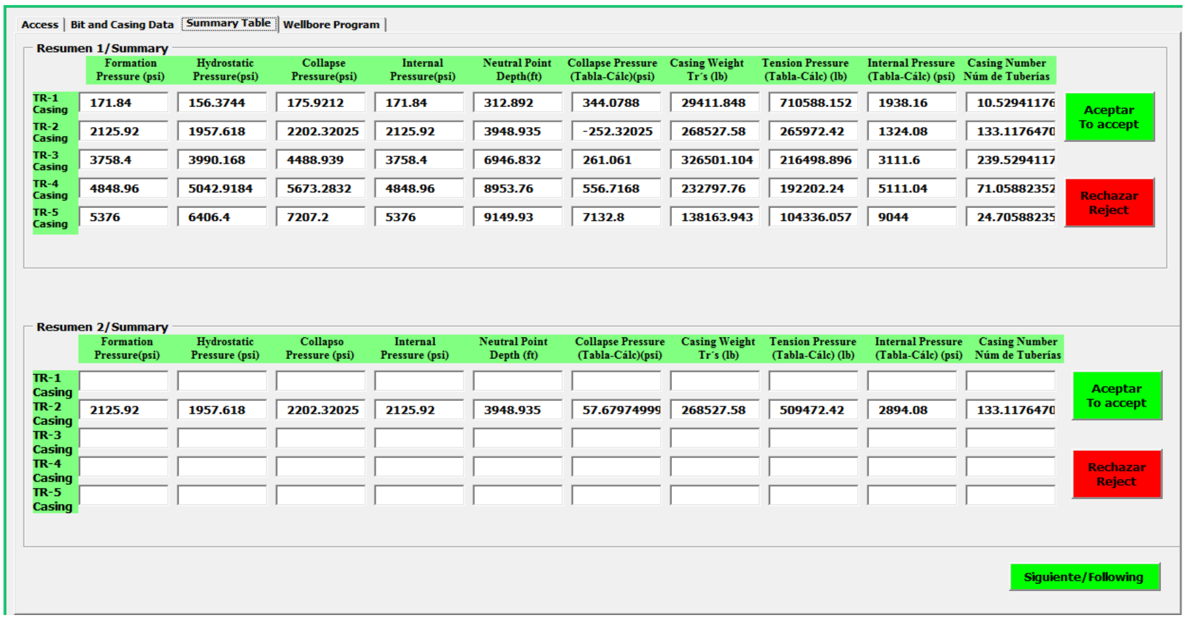
The lower central image of figure 3, “Casing-1, Casing-2, Casing-3, Casing-4, Casing-5”, corresponds individually to the results of the evaluation of the stages with the characteristics of their design. Depending on the numerical results, the program will issue a note box, for example: “La Pf > Ph, do you want to continue?”. It is up to the user to understand, justify and interpret the numerical results, giving "Accept" or making the numerical changes in the variables that he considers pertinent. Said explanation may be added in the white box.

In Casing-4 and Casing-5 there is a yellow box where the overlapping length of the pipes or liner is requested, which will be “parked/hanged”; this value is important, since at the end the number of pipe is determined according to its length and cost of operation.

In each of the casing evaluation labels, there is a box “Send Results to Summary 1” and “Send Results to Summary 2”, which send the results obtained to a concentrate, as shown in figure 4. The box “Send Results to Summary 2” should be used if at the time the first evaluations were carried out, some unforeseen or not considered results were observed; that is, the user suspects the validity of the results and decides to reconsider them: make numerical changes in some variable to reevaluate the stage or casing to later send the results to the concentrate in Figure 4. Once the results are accepted and the pipelines selected, casing, the final stage is continued, as shown in figure 5. Initially, the results of the casing are assigned an amount equivalent to the cost of the pipe and the service, which will be considered for the cost of the casing. Total casing selection and settlement.

The yellow box called "Percentage" is free and it is up to the user to assign the percentage that they consider as the cost of the selection and settlement of the pipes, based on their professional or academic experience, and thus finally obtain the total cost of drilling the well. . In the “Mechanical State” box, the mechanical state is outlined according to the diameters and depths of each of the stages that were evaluated, as shown in figure 6. The depths of the casing must be recorded in meters, for a schematic diagram scale.

Figura 4. Concentrado de una o dos evaluaciones del diseño de tubería



Resumen 1/Summary

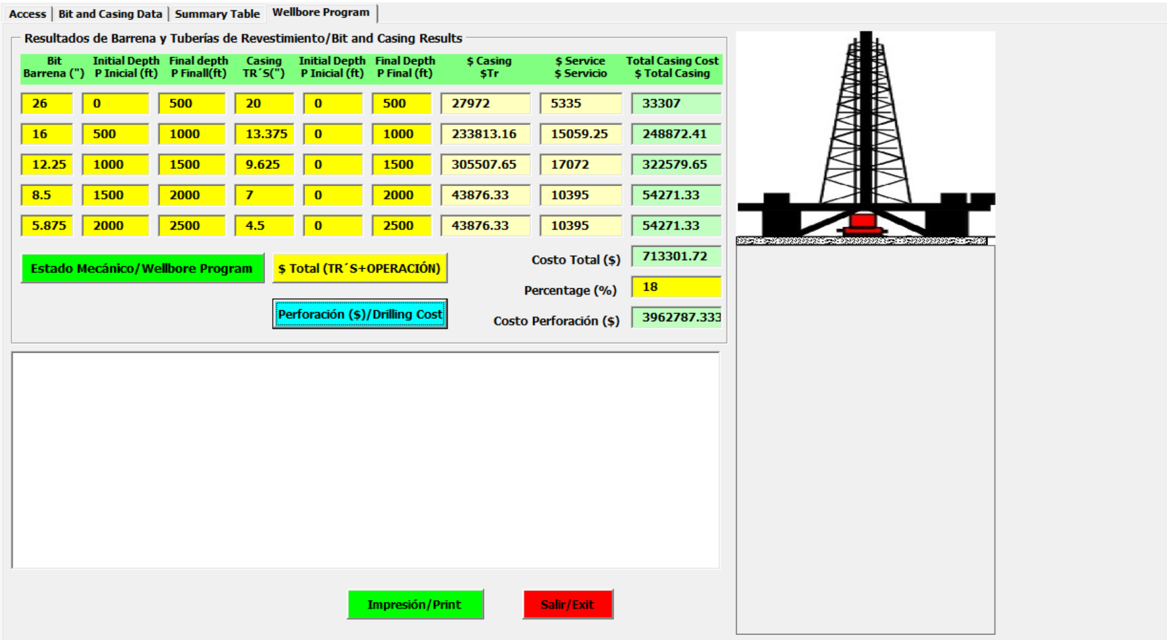
	Formation Pressure (psi)	Hydrostatic Pressure(psi)	Collapse Pressure(psi)	Internal Pressure(psi)	Neutral Point Depth(ft)	Collapse Pressure (Tabla-Cálc)(psi)	Casing Weight Tr´s (lb)	Tension Pressure (Tabla-Cálc) (lb)	Internal Pressure (Tabla-Cálc) (psi)	Casing Number Núm de Tuberías
TR-1 Casing	171.84	156.3744	175.9212	171.84	312.892	344.0788	29411.848	710588.152	1938.16	10.52941176
TR-2 Casing	2125.92	1957.618	2202.32025	2125.92	3948.935	-252.32025	268527.58	265972.42	1324.08	133.1176470
TR-3 Casing	3758.4	3990.168	4488.939	3758.4	6946.832	261.061	326501.104	216498.896	3111.6	239.5294117
TR-4 Casing	4848.96	5042.9184	5673.2832	4848.96	8953.76	556.7168	232797.76	192202.24	5111.04	71.05882352
TR-5 Casing	5376	6406.4	7207.2	5376	9149.93	7132.8	138163.943	104336.057	9044	24.70588235

Resumen 2/Summary

	Formation Pressure(psi)	Hydrostatic Pressure (psi)	Collapso Pressure (psi)	Internal Pressure (psi)	Neutral Point Depth (ft)	Collapse Pressure (Tabla-Cálc)(psi)	Casing Weight Tr´s (lb)	Tension Pressure (Tabla-Cálc) (lb)	Internal Pressure (Tabla-Cálc) (psi)	Casing Number Núm de Tuberías
TR-1 Casing										
TR-2 Casing	2125.92	1957.618	2202.32025	2125.92	3948.935	57.67974999	268527.58	509472.42	2894.08	133.1176470
TR-3 Casing										
TR-4 Casing										
TR-5 Casing										

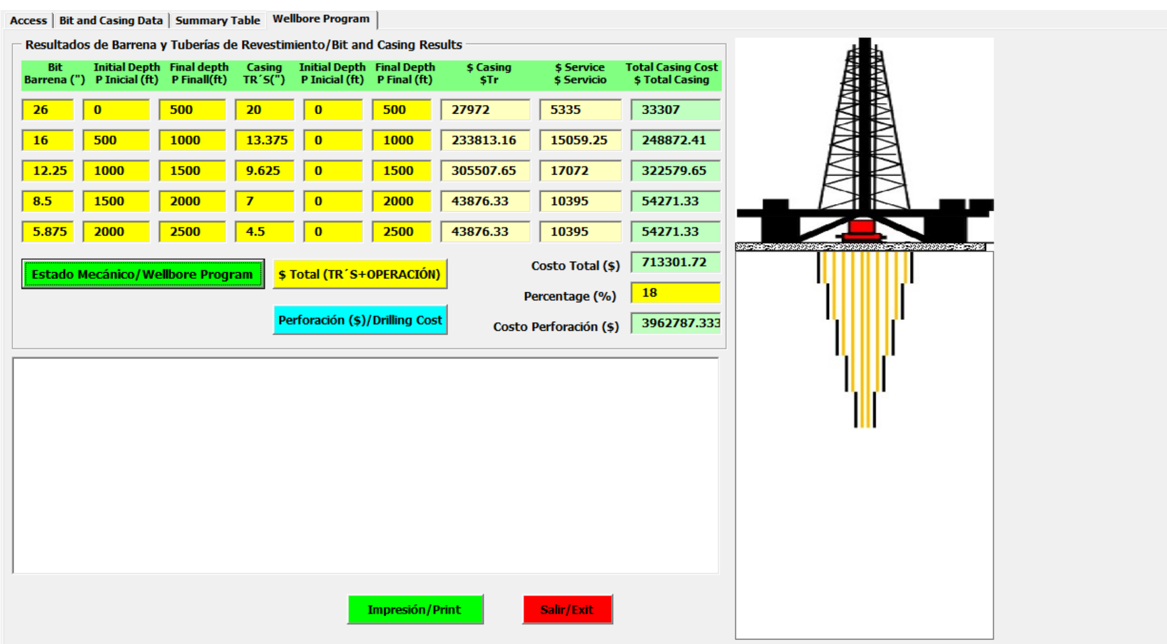
Fuente: *Software* educativo TREM

Figura 5. Resultados finales para el estado mecánico y costos aproximados



Fuente: *Software* educativo TREM

Figura 6. Estado mecánico y costo aproximado de la perforación.



Fuente: *Software* educativo "TREM"

Results

To demonstrate the capabilities of the computer program, an illustrative example has been selected whose design characteristics are shown in Table 1, with nomenclature shown in Table 6; It starts with the bit diameters, outside and inside diameter, weight, length, mechanical properties and grade of each casing/casing pipe, initial and final depth of each of the stages. Table 2 presents the data of the different types of drilling fluids, real density, fracture gradient and safety factor for the evaluation of the efforts to which the casing is exposed at the settlement depth.

The numerical results shown in table 3 correspond to the values obtained from the evaluation of the different efforts that were presented when positioning and settling the pipes in each of the stages. Subsequently, these results are automatically compared with the design data reported in table 1. Table 4 shows the values of the final efforts, which gives the user the opportunity to accept, reject or make the pertinent adjustments of the variables according to corresponds to the stage and the efforts.

In Casing-2, the Collapse Pressure=-252.3202 psi, which means that the 13 3/8” × 12.415”, K55, 68 lb/ft pipe would not withstand the collapse pressure. When consulting the table of pipes in the Tenaris Tamsa file (2013), it is observed that the grade after K55 is M65. Therefore, the next action was to evaluate the M65 grade pipe in each of the efforts. Once this was done, the following was obtained: Collapse Pressure Resistance = 2260 psi, and the estimated value to which the pipe will be exposed is: 2202.32025 psi, which gives a Pressure difference = 57.6797 psi in favor, that is, M65 grade pipe is acceptable for the second stage. Additionally, this pipe presents greater resistance to internal pressure and tension pressure, as shown in table 5.

Figure 7, for its part, shows the mechanical state for the sample exercise, according to the design data, three casings that start from the surface to their corresponding settlement depth and two hanging "parked" with 100 fr of overlap The values corresponding to the cost of casing and services are random, it will be up to the user to use real or estimated information according to their experience and information available to them.

It is very important that the user or the person in charge of the design and evaluation of the pipelines pay attention to the technical-operational considerations, since these will allow them to be able to disagree between the results concerning the integrity-engineering calculations of the intervention and the financial considerations. in the cost of the pipes and design that could be considered and presented.

Tabla 1. Datos técnicos de las tuberías de revestimiento de cada una de las etapas

Characteristic	Casing-1	Casing -2	Casing -3	Casing -4	Casing -5
$\emptyset_{Bit}$(in)	26	16	12 ¼	8 ½	5 7/8
$\emptyset ext_{Tr}$(in)	20	13 3/8	9 5/8	7	4 ½
$\emptyset int_{Tr}$(in)	19.124	12.415	8.681	6.276	3.826
°Tr	K55	K55	N80	P110	P110
W_{Tr} (lb/ft)	94	68	47	26	15.10
L_{Tr}(ft)	34	34	34	34	34
R_c(psi)	520	1950	4750	6230	14 340
S_T(lb*1000)	1480	1069	1086	850	485
R_{Int}(psi)	2110	3450	6870	9960	14 420
D_{Med}(ft)	358	4526	8144	10 460	10 958
DV_T(ft)	358	4429	7830	10 102	11 200
D_{Star}(ft)	0	0	0	8144	10 460
D_F(ft)	250	4526	8144	10 460	11 200

Fuente: Elaboración propia

Tabla 2. Densidades de los fluidos de perforación, gradiente de fractura y factores de seguridad

Fluid type	Densities range (lb/gal)	Test density (lb/gal)	Fracture gradiente (psi/ft)	Esfuerzo	Security facture
Type 1	8.4 – 8.7	8.4	0.48	Tensión	2
Type 2	8.5 – 10.4	8.5	0.48	Colapso	1.125
Type 3	9.8 – 11	9.8	0.48	Interno	1
Type 4	9.6 – 9.9	9.6	0.48		
Type 5	10 – 11	11	0.48		

Fuente: Elaboración propia

Tabla 3. Determinación de presiones de operación sobre las tuberías de revestimiento

	Casing-1	Casing-2	Casing-3	Casing-4	Casing-5
Formation pressure (psi)	171.84	2125.92	3758.4	4848.96	5376
Hydrostatic pressure (psi)	156.3744	1957.618	3990.168	5042.9184	6406.4
Collapse pressure (psi)	175.9212	2202.32025	4488.939	5673.2832	7207.2
Internal pressure (psi)	171.84	2125.92	3758.4	4848.96	5376
Neutral point depth (ft)	312.892	3948.935	6946.832	8953.76	9149.93

Fuente: Elaboración propia

Tabla 4. Determinación de presiones totales sobre las tuberías de revestimiento

1.ª Evaluación	Casing-1	Casing-2	Casing-3	Casing-4	Casing-5
Collapse pressure (psi)	344.0788	-252.3202	261.061	556.7168	7132.8
Weight casing (lb)	29 411.848	268 527.58	326 501.104	232 797.76	138 163.943
Tension pressure (lb)	7 105 881.15	265 972.42	216 498.896	192 202.24	104 336.057
Internal pressure (psi)	1938.16	1324.08	3111.6	5111.04	9044
Casing number	10.5294	133.1176	239.5294	71.0588	24.7058

Fuente: Elaboración propia

Tabla 5. Resultados de presiones para una segunda evaluación de la Tr propuesta

2.ª Evaluación	Collapse pressure (psi)	Weight casing (lb)	Tension pressure (lb)	Internal pressure (psi)	Casing number
Casing-2	57.6797	268 527.58	509 472.42	2894.08	133.1117

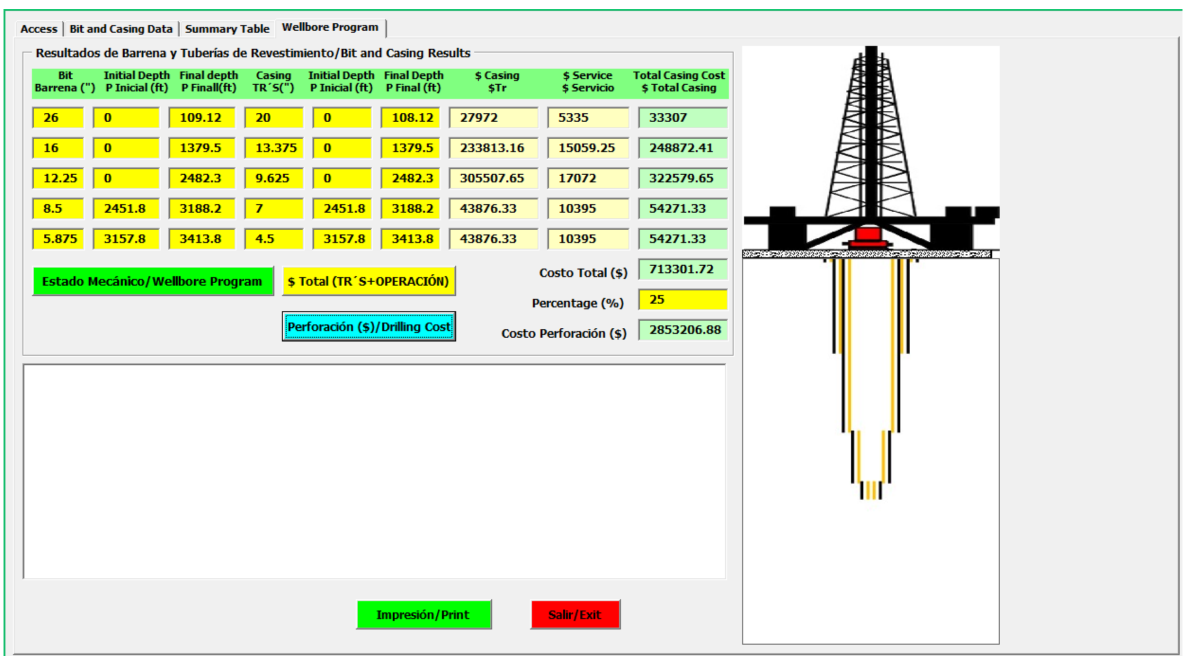
Fuente: Elaboración propia

Tabla 6. Nomenclatura correspondiente a la tabla 1

	°Tr: Casing grade	D_{Med}: Medium depth (ft)
$\emptyset_{Bit}$(in): Diameter bit	W_{Tr} (lb/ft): Casing weight	$DV_T(ft)$: True Vertical Depth
$\emptyset ext_{Tr}$(in): Outside diameter casing	L_{Tr}(ft): Casing length	$D_{Star}(ft)$: Starting depth
$\emptyset int_{Tr}$(in): Inner diameter casing	R_c: Collapse resistance	$D_F(ft)$: Final depth

Fuente: Elaboración propia

Figura 7. Estado mecánico, Casing (1-3), Casing (4-5) colgadas con 100ft de traslape



Fuente: *Software* educativo TREM

Discussion

The results show that the methodology allows the user to contrast the domain of the technical information of the pipes with the different parameters of the efforts considered in the design proposed for its evaluation. However, the existence of users/participants with a higher level of knowledge about the relationship between mean depth and true vertical depth could occur in order to have an approximation to the directional case, and in this case the program will not be able to outline the mechanical state, but its economic costs can be established based on the depth of settlement of the pipes of each of the stages. In the present work, the methodology used by Morán et al. (2009), Peñafiel et al. (2009), Salas et al. (2009), Fernández and Aguirre (2009), Molero (2012) and Recalde (2018), the evaluation process was streamlined and the user was given the opportunity to analyze and interpret the numerical results to finally decide on the schematization of the mechanical state and obtain an approximate cost of the operation.

Additionally, the user will assign the percentage of the cost of the cementing operation, as applicable or considered in its environment, since Halal et al. (1996), Jenkins and Crockford (1975) and Recalde (2018) have used a range between 10% and 35%.

Conclusions

The computer program developed in the Microsoft Excel macro environment is an efficient tool, the interface design is simple and intuitive, pleasant, with fast communication and easy adaptation between the program and the user. It was possible to combine the existing theory in the specialized literature with the activities carried out in the well design and field operations departments. The mechanical state mapping considers the scale relationships of the casing dimensions and their volumetric spaces. It should be remembered that initially the lengths of the pipes are in feet (ft) for mathematical operations, while, to outline the mechanical state, it is necessary to convert to meters (m) to obtain a schematic representation according to the equipment screen. of computation In the future, this tool will be enhanced to allow the user to make custom modifications based on experience or design criteria; for example, graphical generation of the operating window, representation of the drill string, volumetrics for vertical and directional wells, etc.

This tool aspires to become one of the most widely used free software in institutions that offer petroleum engineering careers. Additionally, to be an academic instrument in the delivery of training courses on the topics of well design, design, selection and settlement of casing and cementation, among others. The neutral point trial and error method is a viable methodology for optimizing economic and technical resources.

Future lines of research

Expand the applications of programs with Microsoft Visual Basic programming in the area of directional drilling, underbalanced, etc., always considering academic characteristics and experience in the field, in order to present comprehensive software in the drilling area in the short term with academic orientation and professional profile, and thus achieve a greater opportunity to reduce the lack of experience of graduates of the petroleum engineering career.

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