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Optimal Choice of Travelling System Structure depending on Design Parameters of Hoisting System in Drilling Units of Oil and Gas Wells

Dr. Mahmoud M. Hadid[1], Ahmed A. Mohammed[2,*]
Petroleum Department / Chemical and Petroleum Engineering College /AL Baath University / Homs, Syria
[2,*]Corresponding Author E-mail: ahmmaadiiiii@gmail.com
[1]Email: m-hadid@scs-net.org

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Abstract

Most drilling rigs are designed based on the max static load on the hook of great travelling system structure as 6×7. But when change the depth of the well, the load on the hook changes, so it was necessary to determine the travelling system structure, which ensures the best design indicators of hoisting system.

This research studied the impact of travelling system structure on design parameters of hoisting system and the best indicators of hoisting systems at less drilling lines number suitable with max allowable load on hook for oil and gas wells drilling units.

In this work, A methodology depending on graphical solution for hoisting system indicators curves has been developed. (MATLAB) has been used in order to develop a program that facilitates the application of this methodology and accelerate the work. The most important technical parameters for different drilling unit, in addition to the allowable hookload, by using the most important design indicators that positively or negatively affecting the system with changing travelling system structure. This program depending on graphical solution for set of these indicators in relation with number of drilling lines by finding equilibrium point between positive and negative effects that has the algebraic sum of the slopes is as close as possible to zero. This point represent optimal drilling lines compatible with hookload at practical technical parameters for drilling units.

This study achieves the best indicators for hoisting system working at ideal travelling system and decrease the time required for drilling by increasing hook velocity rate by 12% and the efficiency of hoisting system by 10%. In addition, the lengths of drilling line rate decreased by 40% that cause reduction in material cost and achieving better economic feasibility in comparison with design travelling system.

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Keywords: Design Indicators, Drilling Unit, Drilling lines, Hoisting System, Hook load, travelling System.

الاختيار الأمثل لتركيبة منظومة الكابلات اعتماداً على المؤشرات التصميمية لمجموعة الرفع في وحدات حفر الآبار النفطية والغازية

الخلاصة:

تصمم معظم وحدات الحفر على أساس الحمولة الحدية المسموح بها على الخطاف من تركيبة منظومة الكابلات أي المنظومة 7×6، ولكن مع تغير العمق من بئر لآخر سوف تتغير الحمولة على الخطاف، لذلك كان لابد من تحديد منظومة الحبال المعدنية المتوافقة مع الحمل والتي تضمن عمل مجموعة الرفع وفق أفضل المؤشرات التصميمية.

يتناول هذا البحث تأثير تركيبة منظومة الحبال المعدنية في المؤشرات التصميمية لمجموعة الرفع ويعطي الإجابة الواضحة على السؤال التالي: ما هي أفضل مؤشرات عمل مجاميع الرفع عند أقل منظومة للحبال المعدنية متوافقة مع الحمولة القصوى على الخطاف في وحدات حفر الآبار النفطية والغازية؟

تم في هذا البحث تطوير منهجية عمل بالاعتماد على الحل المشترك البياني لمنحنيات مؤشرات مجموعة الرفع، وتم الاستعانة بالأدوات البرمجية المناسبة (برنامج MATLAB) لتطوير برنامج يسهل تطبيق هذه المنهجية وتسريع العمل، من خلال برمجة أهم المتغيرات التقنية لوحدات الحفر المختلفة، وكذلك حساب الحمولة الحدية على الخطاف، مع إدخال أهم المؤشرات التصميمية المؤثرة في مجموعة الرفع، والتي تتأثر سلباً أو إيجاباً عند تغيير تركيبة منظومة الحبال المعدنية، ويعتمد هذا البرنامج على الحل البياني لجملة هذه المؤشرات بالعلاقة مع عدد الخطوط العاملة، من خلال إيجاد نقطة التوازن بين مختلف التأثيرات السلبية والإيجابية والتي يكون عندها المجموع الجبري لميول المنحنيات البيانية أقرب ما يمكن إلى الصفر، حيث تمثل هذه النقطة عدد الخطوط العاملة المثالية المتوافقة مع الحمولة على الخطاف عند بارامترات تقنية معينة لوحدات حفر مختلفة.

حققت هذه الدراسة أفضل مؤشرات عمل مجموعة الرفع عند التركيبة المثالية، وساهمت في تقليل الوقت اللازم لإنجاز البئر من خلال زيادة سرعة رفع الخطاف بنسبة 12%، وزيادة معامل المردود المفيد لمجموعة الرفع حوالي 10%، إضافة إلى تقليل طول حبل الحفر المستخدم بنسبة تصل إلى 40%، مع المحافظة على بقية المؤشرات ضمن الحدود المسموح بها، وهو ما يعكس توفير في الكلفة المادية لعملية الحفر، وتحقيق جدوى اقتصادية أفضل بالمقارنة مع تركيبة منظومة الكابلات التصميمية.

الكلمات الدالة: البارامترات التصميمية، وحدة الحفر، الخطوط العاملة، مجموعة الرفع، الحمولة على الخطاف، منظومة الحبال المعدنية.

1. Introduction

Travelling system is a main part of hoisting system, which includes the travelling blocks, crown blocks, and drilling line. This system must be reeved before starting drilling process by strung drilling line on crown and travelling sheaves to get optimal drilling lines for each well has been drilled.

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These *optimal drilling lines* based on two main factors: the max hook load and the design indicators of hoisting system, which mainly related to the technical parameters of drilling units [1]. This research performed in order to achieve economic feasibility and reduce the technical and technologic problems during drilling process.

Reviews of related have been studied of the design indicators such as the efficiency factor for each travelling system structure [2], [3], and explained the relation between load on derrick and number of drilling lines which the load decreased as the lines increased [4], as well as some researches have been studied the moment torque in relation with travelling system and were proven that increased the number of lines ought to decrease the torque of draw works [5] ,in addition to decrease the hook velocity [6], other researches have been tried to study the possibility of adding idler sheaves between the drum and crown blocks and explained its effect on the efficiency and the fast line tension [7], on the other hand many researches have been proven that use 12 of drilling lines improved the life bearing and the fast line tension (positively affects) whereas the other indicators were affected negatively such as the efficiency and hook velocity [8], [9].

However, all these previous researches have been studied the design indicators independently of each other without taking into consideration the load on hook; therefore, this research focused on developing a methodology to study such indicators considering the hookload to determine the ideal travelling system structure that secures the best indicators of hoisting system at certain hookload with specific technical parameters of drilling.

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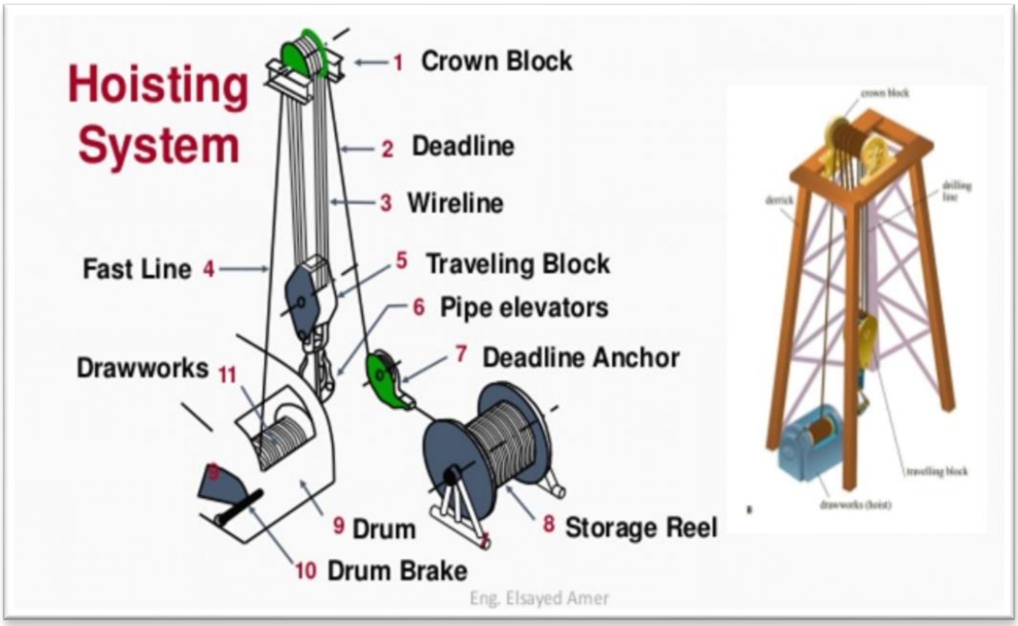

Fig. (1): Hoisting system components.

The basic idea of this research was adopted through a mathematical method based on algebraic sum of graphs slopes that represent the relation between the design indictors and number of drilling lines, given that the sum is equal to zero or as close as possible to zero due to some curves have positive slopes and the others have negative slopes, so this sum represented the point of equilibrium for the various design indicators of hoisting system that expressed optimal drilling lines. Then it has proven the positive effects achieve economic feasibility by reducing the cost and time of drilling process while the negative effects are within the allowable limits and do not lead to problems during drilling process.

2. Material and Methods

A data-processing program was designed [10], [11] to obtain the travelling system structure at a specific load on hook by entering casing program of oil or gas wells and calculating the max hook load as shown in Table (2), in addition to programming and entering the technical parameters of drilling rigs presented in Table (3), then plotting the graphs of design indicators mentioned in Table (1) using MATLAB program according to the following flowchart as shown in Figure (1).

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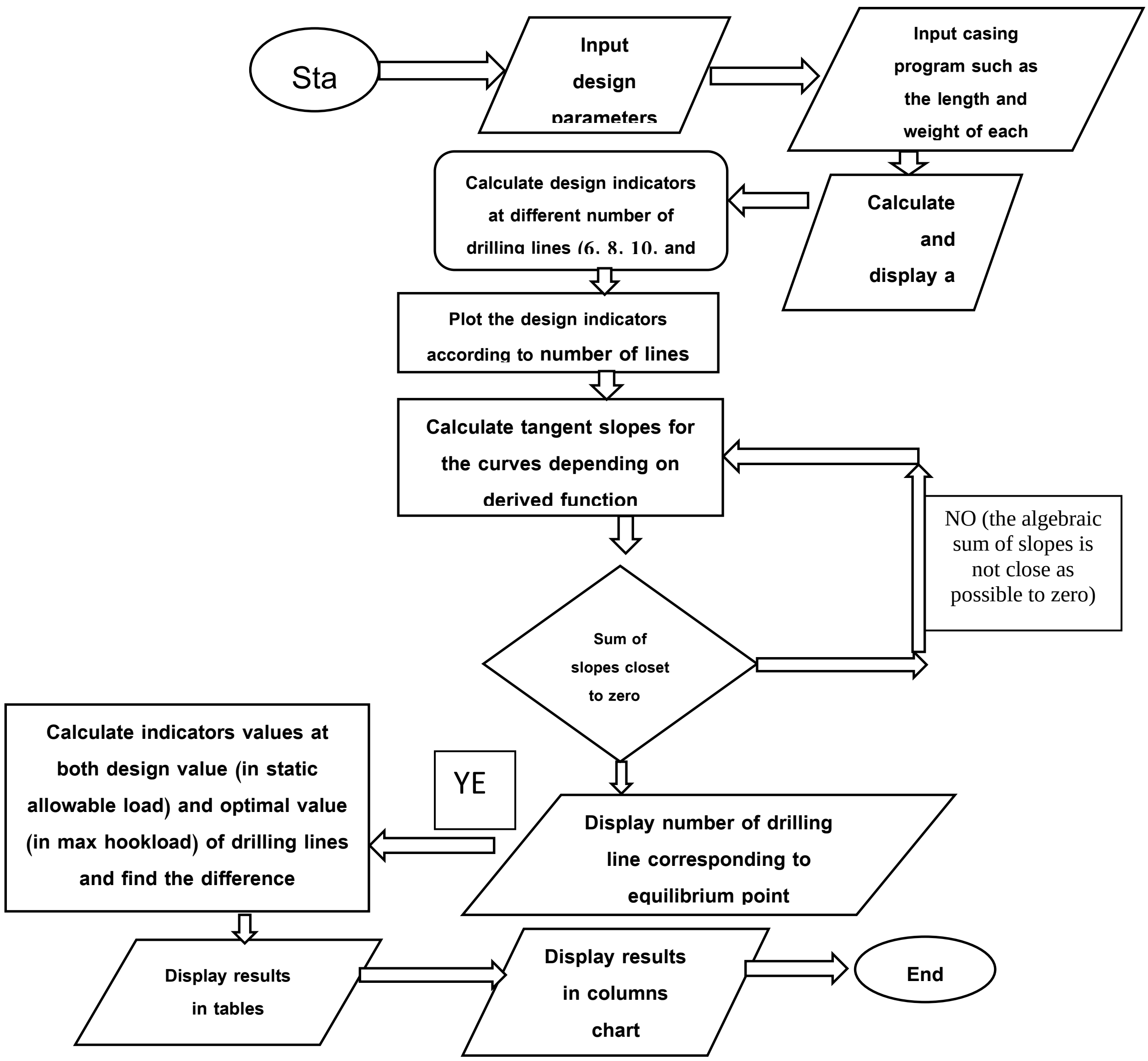

Fig. (2): Methodology Flowchart.

This algorithm requires the following data set:

2.1. Design and kinetic indicators of hoisting system: This indicator [12] severely affects the efficiency of drilling unit as can be shown in Table (1). The present work covered a set of design indicators that may be affected negatively or positively with increasing or decreasing the travelling system (drilling lines number).

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- Contact pressure (p) of the main brake [13] is compatible to rotational moment of the drawwork shaft that decreases as the travelling system increases (positive effect).
- Drilling line length (L_W) in drilling rig that increases as the travelling system increases (negative effect).
- Bearing life (L_h) that increases as the travelling system increases (positive effect).
- Hook velocity (V_h) at drawwork horsepower that decreases as the travelling system increases (negative effect)*.
- The load on derrick (F_{DV}) compatible to the fast line tension that decreases as the drilling lines number increases (positive effect).
- Efficiency factor of travelling system ($\eta_{t.s}$) that decreases as the drilling lines increase (negative effect).

Table (1) Explain the most important design indicators of hoisting system.

Symbol	Hoisting system Design indicators	Equation
L_W	Drilling line length	$L_W = H(m+2) + lp(m+1) + lf$
v_h	Hook Velocity	$v_h = \frac{\eta_{t.s} . N_e \; . N_D}{G_h}$
$\eta_{t.s}$	Efficiency	$\eta_{t.s} = \frac{\beta^m - 1}{m.\beta^m(\beta - 1)}$
L_h	Bearing life	$L_h = \frac{10^4 . D_b . \pi . \eta^3 . C^3 . m^2}{288 . V . {G_h}^3}$
p	Braking contact pressure	$p = \frac{2 . G_h \; . D . e^{\mu.\propto}}{B . {D_t}^2 (e^{\mu.\propto} - 1) . m}$
F_{DV}	Derrick load	$F_{DV} = (1 + \frac{2}{m}) . G_h$

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2.2 Well casing program: of some wells in Syrian oil fields [14] at different depth to compete the maximum load on the hook at each depth depending on the metric weight of intermediate casing as shown in Table (2). A safety factor of hook load up to (120%) for backing off drill string was considered.

Table (2) The max hook load for each well drilled in middle area of Syria according to well program.

Well name	Total Depth (m)	Depth of intermediate casing (m)	Max hook load (ton)
ALBREIJ-4	2550	2185	**185**
ABO RABAH-20	2800	2550	**200**
QARA-3	3570	3200	**236**
SADAD-9	3775	3430	**260**

2.3. Templates of Russian or American drilling rigs, which have particular technical parameters, presented in Table (3) [15], [16] and [17]:

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Table (3) Technical parameters for several drilling rigs.

Technical parameters		National 1320UE	National 110-M	National B-80	BU5000L 32 DGO.I.	Uralmash 4500\270 BM-EK	Uralmash 3900\225 BM-EK
Max static hookload (ton)		454	360	220	320	270	225
Drilling Depth(m)		6069	4877	3000	5000	4500	3900
Horsepower rating(KW)		2237	1119	750	1100	900	750
Max line pull(KN)		680	354	317	288	288	288
Drilling line diameter(mm)		31.8	31.8	32	32	32	28
Main brake	Diameter of band brake drum (mm)	1270	1270	1160	1450	1450	1450
	Band width(mm)	263	263	263	230	230	230
Drilling lines		12	12	10	12	12	10
Sheaves diameter(mm)		1120	1120	1000	1120	1120	1000
Derrick	Max load(kN)	6030	4780	3750	5000	3750	3750
	Height(m)	43.3	43.3	45	45	45.3	45.3
Drawwork Drum Diameter(mm)		800	685	635	990	800	700

3. Results & Discussion

In this study, the following steps are followed to analyze the data, pursuant to the methodology algorithm:

1. Design graphical user interface using MATLAB software [11] as shown in Figure (3) simulates input technical parameters of oil rigs as shown in Table (3) and well casing as shown in Table (2) in order to plot graphs of design indicators of hoisting system to get optimal drilling lines number.

2. Calculate the ideal indicators of hoisting system when drilling rig operation at max static hook load, drawwork horsepower rating, number of drilling lines, sheaves diameter, derrick height, and brake dimeson).

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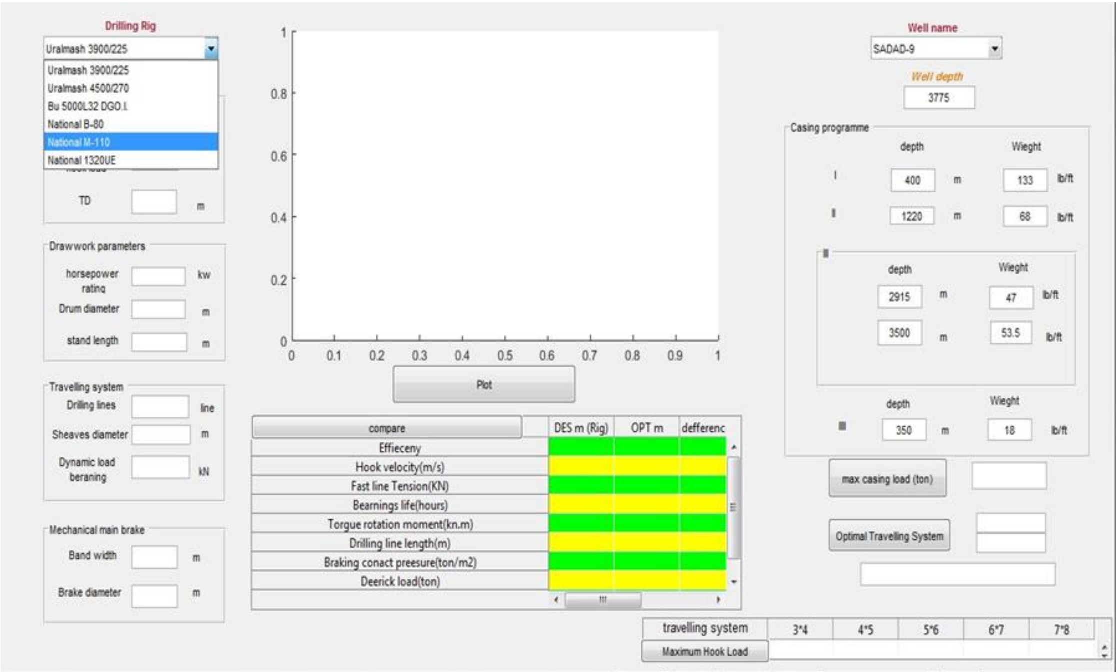

Fig. (3) Shows MATLAB GUI for research program.

3. Curves for most important indicators, specific hook load and drilling rigs parameters mentioned in tables(1, 2 and 3 respectively) can been drawn as an be shown in Figure (4).

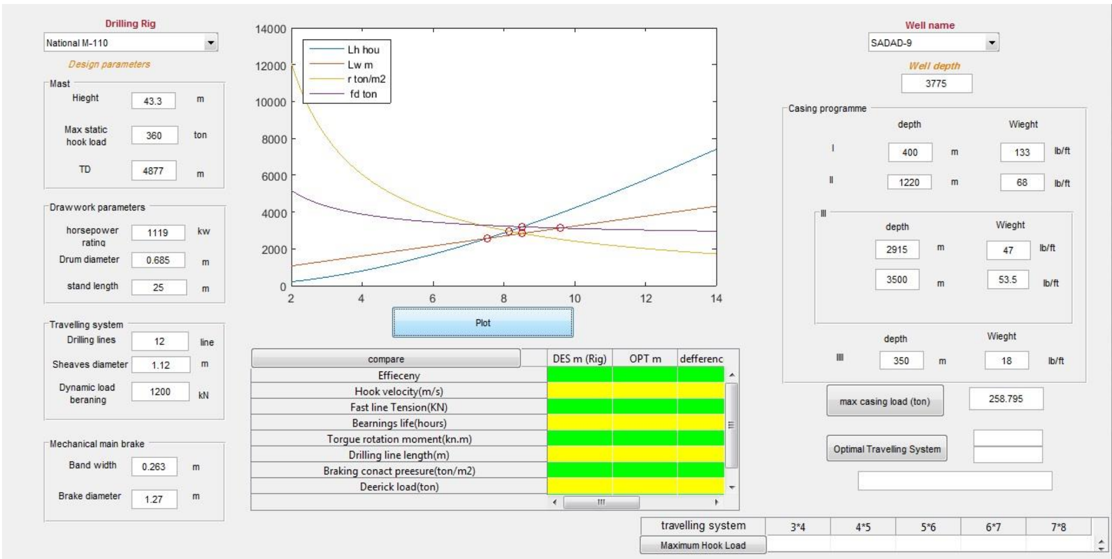

Fig. (4) Shows the diagrams for design indicators while drilling SADAD-9 by National-110M rig according MATLAB program.

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4. Calculate tangent slopes for each curve based on the derived function, and find point, which the algebraic sum of the slopes as close as possible to zero, which expresses the point of equilibrium between different design indicators that affected negatively or positively with the alteration of travelling system structure. The number of drilling lines is optimum for drilling unit at this load.

Table (4) Explain ideal drilling lines for Russian or American units at max hook load of drilling wells.

Drilling Rigs / Max HKl		Uralmash 3900/225 BK-EM	Uralmash 4500/270 BK-EM	DGO Bu5000 L32.I.	National B-80	National 110 M	National 1320UE
ALBREIJ-4	185 t	8	8	6	8	6	6
ABO RABAH-20	200 t	10	8	8	10	6	6
QARA-3	236 t	-	10	8	-	8	6
SADAD-9	258 t	-	12	10	-	8	8

The optimal travelling system structure at a certain well for American and Russian units was presenter in Table 4. The trustiness of this methodology had been showed by increased the lines number when the hook load raised ,as well as the variation in drilling lines number at the same hook load according to technical parameters of each drilling unit, for example, the optimal travelling system at (236) ton is (4×5) for Bu5000L32I.D.G.O unit, but it is (3×4) for National 1320UE respectively, because the American rig had a derrick height , drawwork capacity, pulley diameters and main brake dimeson better than Russian one as shown in Table (3).

5. Emulation procedure between the values of design indicators according to (step 2) and the values indicators at optimal travelling system and specific hook load at the same other technical parameters via column chart display by MATLAB as shown in Figure (5).

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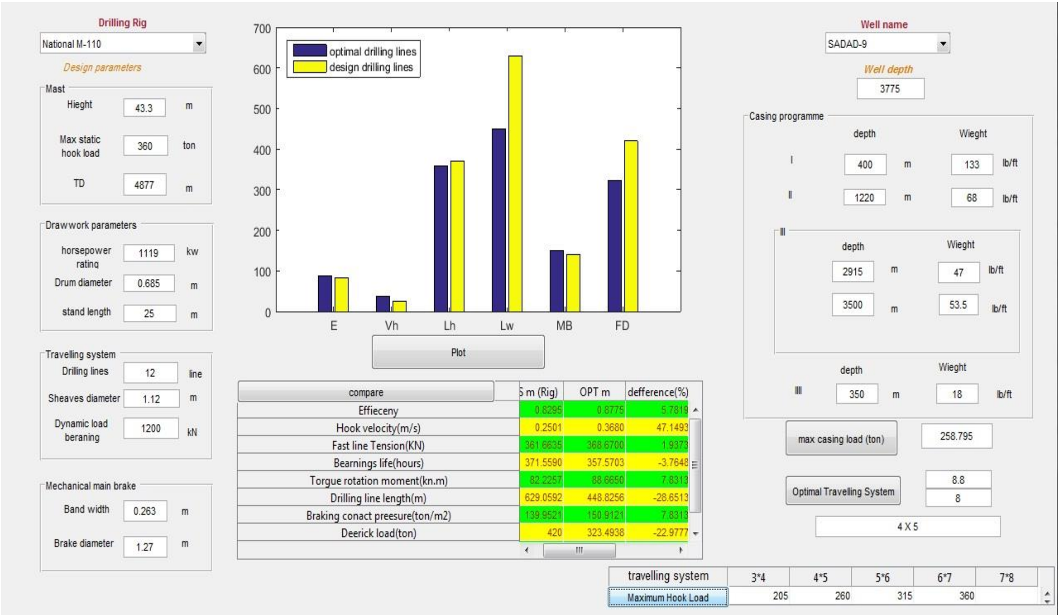

Fig. (5) Shows the column chart by MATLAB program according to pervious algorithm.

6. The most important results obtained from this analysis can be summarized in Table (5) that explained the ideal travelling system were secured the best design indicators of hoisting system at less number of drilling lines.

Table (5) The influence of drilling lines number on design indicators of hoisting system of different oil drilling units.

Drilling rigs	**BU5000L32 DGO.I**		**National 110M**	
Travelling system / **Design Parameters**	**m=12** $G_h = 320$	**m=10** $G_h = 260$	**m=12** $G_h = 360$	**m=8** $G_h = 260$
Efficiency	0.829	0.853	0.829	0.877
Hook velocity(m/s)	0342	0.364	0.346	0.371
Bearings life (hours)	1684	1708	1484	1428
Drilling line length (m)	652	559	629	448
Braking contact pressure (ton $/m^2$)	158	153	140	151
Derrick load (ton)	373	310	420	323

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Figure (5) and the results presented in Table 5, shows that the hook velocity, efficiency and increase by (10%) and (3%) respectively while the drilling line length reduce to 14% which indicates a reduction in cost and drilling time comparing with design travailing system (6×7) . However, the torque and the derrick loads decreased by 17 %while the bearing life increases by 12 % , (These indicators remain within the optimum limits for hoisting system working at design travelling system structure (6×7) and allowable static load when using (BU5000L32 DGO.I) for drilling (SADAD-9) with optimal travelling system (5×6).

It was observed from the values mentioned in Table (5) that critical load for American rig (National 110M) is 260 ton .The results presented in Table 6 that the braking contact pressure increases by 7% whole the bearing life decreases by 4% with improvement of all other indicators .However, it is recommended to use travelling system structure capacity more than optimal one to ensure that hoisting system works with best indicators.

7. MATLAB program can be used for calculating the maximum allowable hook load at each travelling system structure for different oil rigs according to the previous algorithm. The obtained results are explained in Tables (6) and (7) support the drillers to find out hook loads that can be tension for backing off drill pipes, and find out the safety level for drilling unit working.

Table (6) Shows maximum allowable hook load for each travelling system relative to American drilling rigs.

	Travelling System	3×4	4×5	5×6	6×7
Max Hookload (Ton) For American rigs	National B-80	155	195	220	-
	National 110 M	205	260	315	360
	National 1320UE	255	320	385	450

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Table (7) Shows maximum allowable hook load for each Travelling system relative to Russian drilling rigs.

	Travelling System	3×4	4×5	5×6	6×7
Max Hookload (Ton) For Russian rigs	Uralmash 3900\225 BM-EK	160	200	225	-
	Uralmash 4500\270 BM-EK	155	200	240	270
	BU5000L32 DGO.I.	185	235	280	320

8. Table (8) shows the optimal hook velocity, the lifting time and the reduction in drilling cost.

Table (8) Shows saving in time and cost when select optimal drilling lines

	BU5000L32 DGO.I		National 110M	
Drilling lines	m=12 $G_h = 260$	m=10 $G_h = 260$	m=12 $G_h = 236$	m=8 $\boldsymbol{G_h = 236}$
Hook Velocity(m/s)	0.342	0.364	0.38	0.42
TD (m)	3775	3775	3570	3570
Lifting Time(hours)	3.34	3.13	2.83	2.57
Cost(550$ per hour)	1837	1721	1556	1413
percent	5.88%		10.2%	

4. Conclusions

The previous analysis leads to the following concluding remarks:

- The simulation using MATLAB program enables producing design charts and tables for each oil and gas rigs by using the most important design parameters.
- Using an optimal number of drilling lines for each rig proportional with the load on the hook lead to following:
- 1. Increase the hook velocity at drawwork horsepower by 12%.
- 2. Increase the efficiency of travelling system by 10%.
- 3. Reduce 40% of the length of drilling line.

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- 4. Keeping the bearing life and braking torque in ideal limits compared with the designed travelling system.
- Decrease the cost and the time for drilling hole.
- Saving work load of travelling system by determining the critical hook load at each travelling system structure for drilling units.

5. Future work

- It is necessary to apply these results in Syrian oil fields in order to evaluate field operation and to raise their efficiency through this research.
- Create database includes much of rigs and wells in order to increase the reliability of analysis and outcomes achieved. In addition to select, the suitable oil rig for each well by this program to improve the efficiency of drilling oil and gas wells.

Nomenclature and Abbreviations:

symbol	Definition	unit
H	Derrick Height	m
lp	Drilling line length strung on pulley	m
m	Drilling lines number	-
lf	Spare laps of drilling line	m
N_e	Drawwork Horsepower	KW
η_D	Efficiency of Hoisting system	η_D=0.97
G_h ,W	Hookload	KN
β	Pulley friction	-
D_b.	Pulley Diameter	m
η	Efficiency of Travelling system	-
C	Dynamic load on bearing	KN
V	Hook Velocity	m/s
D	Drawwork Drum Diameter	m
D_t	Band Brake Diameter	m
B	Width of the brake shoes	m
μ	Friction coefficient	0.35-0.65
$\propto$	Grip hold angel of the brake	Radian

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