J. Marine. Sci. Appl. (2009) 8: 211-215
DOI: 10.1007/s11804-009-8045-9

Mathematically modeling the main dimensions of self-elevating drilling units

WANG Yun-long*, **JI Zhuo-shang and LIN Yan**

Ship CAD Engineering Centre, Dalian University of Technology, Dalian 116024, China

Abstract: The present status of self-elevating drilling units was analysed. Based on statistics of the main dimensions of self-elevating drilling units, a mathematical model was established using stepwise return procedures and a back-propagation neural network. Analysis of examples of calculations showed that the mathematical model is applicable and reliable. The model is useful for mastering the essential variations of the main dimensions of self-elevating drilling units and can be used for technical and economic analysis as well as in conceptual designs of drilling units.

Keywords: self-elevating drilling unit; main dimensions; single variable; multi-variable
CLC number: U661.4 **Document code:** A **Article ID:** 1671-9433(2009)03-0211-05

1 Introduction

Oil is the blood of economy, having sufficient oil resource and ensuring its supply is necessary for the economic development. In the 21st century, the world has gradually entered the era of energy scarcity, and many countries have turned their attention to the ocean, put a mass of manpower and resources into exploiting ocean energy[1]. At present, self-elevating drilling unit is one of the main ocean drilling equipments which have been broadly used worldwide, it is used primarily in the region of shoals and shallow sea, Maximal water depth is 500 ft (1 ft=0.305 m)[2-3]. Compared with drilling ship and semi-submersible drilling platform, self-elevating drilling unit has the advantages of low cost, less consumption of steels and being reusable. In addition, the ability to work stably under various sea conditions makes it become the main force in the shallow sea drilling operations.

In recent years, the number of self-elevating drilling unit is increasing, and our nation urgently needs to develop the abilities in the design, building, inspection and research for self-elevating drilling unit. Especially in the basic design of the self-elevating drilling unit, most of the technologies still have to depend on the foreign support. It is necessary that we should carry out relevant research to promote the design capability and improve the competition ability in self-elevating drilling unit design. It is of great significance to not only the exploitation of marine resource but also the development of ocean engineering[4-5]. During the design of self-elevating drilling unit, mathematical model for the main dimensions is not available at present. In this paper, the forecast model on the main dimensions of self-elevating drilling unit is established with the data of ship type and the theories in engineering system. The model can be used for the feasible design, it is helpful for mastering the essential variation rules on the main dimensions of self-elevating drilling unit and can be used for technical and economic demonstration during its design.

Received date: 2008-07-03.
Foundation item: Supported by the National 863 Plan Foundation under Grant No.2003AA414060.
***Corresponding author Email:** yunlongw@dlut.edu.cn

2 Mathematical modeling for the main dimensions of self-elevating drilling unit

2.1 Mathematical model for the main dimensions of self-elevating drilling unit based on single variable

During the design of self-elevating drilling unit, it is most important to decide the main dimensions-molded length L, molded breadth B, molded depth D and the length of spud legs l. In order to meet the work functions, environmental conditions and economic performance of self-elevating drilling unit, we often need to give a variety of feasible schemes, then compare and analyze them. At last, the best scheme is selected. Therefore, it is actually a gradual approaching and testing process to determine the main dimensions of self-elevating drilling unit. In this process, the establishment of a good predictive model for the main dimensions will be contributing.

The purpose of establishing the mathematical model for the main dimensions of self-elevating drilling unit is that: after determining the water depth in designing self-elevating drilling unit, its main dimensions can be roughly estimated in order to carry out the subsequently economic demonstration and the optimization of ship models. So the mathematical model is established with the single-variable of the water depth *d*. The method of statistics regressions is used in establishing the model. On the basis of the collation of currently existing self-elevating drilling unit data, 240 drilling units which were built from 1980 to 2004 are chosen. The data includes the following main ship parameters: model length *L*, model breadth *B*, model depth *D*, the leg length *l* and so on.

The determination of the main dimensions of self-elevating drilling unit is very flexible. It should not only meet functional requirements, but also consider correlative rules and laws, environmental effect, equipment of drilling unit, etc. Besides, it is still affected by the owner's subjective preferences. From the information of the collected ship types, it can be seen that the regularity between *L* and *d* is poor, and it is difficult to get mathematical model directly. Through analyzing, the regularity of the main deck model area *A* ($L \times B$) and model volume *V* ($L \times B \times D$) to *d* is apparent. So firstly the mathematical model could be established using the relation of the main deck model area *A*, volume *V*, breadth *B*, depth *D* and spud legs *l* to water depth *d*, and then the length *L* can be determined through ratiocination: $L = A/B$.

The steps to build the mathematical model: At first, the data of the ship form are tabulated, analyzed and compared, removing irrational data. Secondly, the expression of the mathematical model is determined through the reference to other models of marine structure, and the scattered point diagram which shows the variables can be drawn by computer program. And then, the return mathematical model is got by more rational and scientific methods chosen from the existing return ways. Finally, the model should be verified.

Taking the model volume *V* of self-elevating drilling unit for example, it shows the establishing process of the mathematical model. First, the scattered figure, that is Fig.1, is drawn taking *d* as a variable. Then according to the distribution of the scattered points, some methods of the return formula are proposed, most of them are linear model, index model, logarithm model, multinomial model and power model. By analyzing the above return model, the most optimal model is chosen according to a criterion, which is the coefficient R^2 got by surveying broad samples[6]. (Note: the coefficient R^2 got by surveying broad samples is a numerical value which stands for the level of satisfaction by return. It is the ratio between the explained sum of squares of sample return and the sum of squares for total. The closer to the ratio of 1, the better is the result. In general, $R^2>0.7$ could be accepted.)

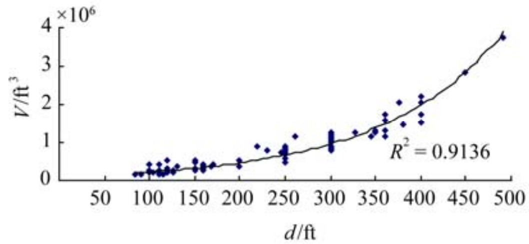

Fig.1 Model capacity vs water depth scattered point diagram and return curve

The following is the optimal mathematical model corresponding to Fig.1.

$$V = 101\,241 \times e^{0.007\,5d} \quad (\text{ft}^3).$$

In most cases the scattered figures show curve shape, the nonlinear model reflects its inherent nature. In some cases, the linear model is adequate. For example, the relationship between *l* and *d* is shown in Fig.2. From the figure, the linear distribution of the scattered points can be found. The linear model is highly precise and convenient to calculate.

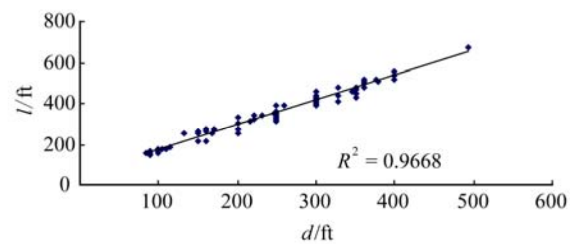

Fig.2 Leg length vs water depth scattered point diagram and return curve

The following is the optimal mathematical model corresponding to the above Fig.2.

$$L = 1.224\,8 \times d + 47.999 \quad (\text{ft}).$$

The following Figs.3~5 are respectively the scattered point diagram and return curves for *B* to *d*, *A* to *d* and *D* to *d*.

$$B = 0.516\,5 \times d + 35.719 \quad (\text{ft}),$$
$$A = 9879.8 \times e^{0.004\,6d} \quad (\text{ft}^2),$$
$$D = 0.057\,4 \times d + 7.288\,6 \quad (\text{ft}).$$

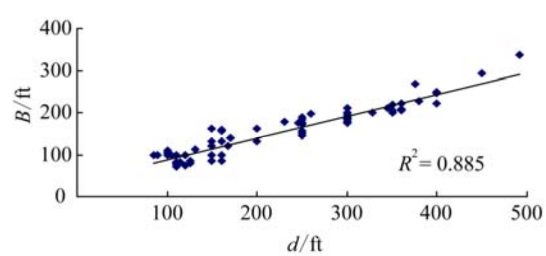

Fig.3 Model breadth vs water depth scattered point diagram and return curve

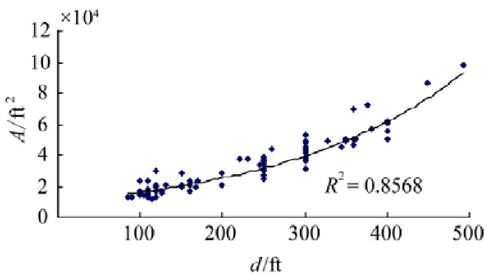

Fig.4 Main deck model area vs water depth scattered point diagram and return curve

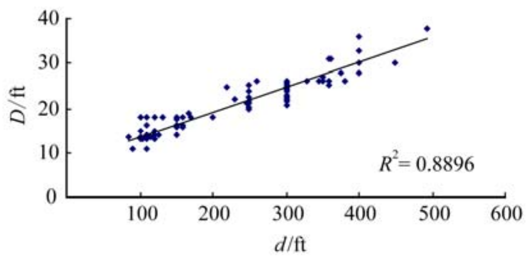

Fig.5 Model depth vs water depth scattered point diagram and return curve

2.2 Verification of the mathematical model based on single variable

Seven typical self-elevating drilling units with different water depths were chosen from the existing drilling units to verify the above mathematical models. Tables 1~2 clearly show that the calculated values and the initial data have little difference. The mathematical models can be used in the ship's technical and economic demonstration and in conceptual design.

2.3 Mathematical model for the main dimensions of self-elevating drilling unit based on multi-variable

During the design of self-elevating drilling unit, water depth is the most important influencing factor on its main dimensions, and at the same time, there're also some other influencing factors: general arrangement, capacity of cabins, water depth, maximum drilling depth, variable deck load, cantilever load, rig load, power equipments, rig ability, liquid mud, bulk mud/cement, drill water, potable water, fuel oil, lifting system, sacks, height of double bottom and so on. After full-scale analytical discussion, the major factors affecting the main dimensions of self-elevating drilling unit can be concluded: water depth, variable deck load, bulk mud/cement, sacks, drill water, maximum drilling depth, potable water and fuel oil. With the development of the design, more information has been conformed, and the multi-variable forecast model should be used to get more accurate main dimensions of self-elevating drilling unit.

Table 1 Verification of mathematic model of self-elevating drilling unit based on single variable-original data

Platform names	d/ft	V/ft^3	A/ft^2	D/ft	l/ft
Prisa112	100	208 884	16 068	13.0	165.0
GP-14	120	227 233	17 346	13.1	195.0
Parker25-J	215	538 560	24 560	26.0	316.8
ENSCO95	250	736 717	34 539	21.3	355.0
ENSCO60	300	854 856	37 200	23.0	414.0
SagarShakti	350	1 313 512	48 649	27.0	425.9
Galaxy Ⅰ	400	2 196 000	61 000	36.0	540.0

Table 2 Verification of mathematic model of self-elevating drilling unit based on single variable-calculated values

Platform names	d/ft	V/ft^3	A/ft^2	D/ft	l/ft
Prisa112	100	214 327	15 650	13.0	170.5
GP-14	120	249 013	17 158	14.2	195.0
Parker25- J	215	507 757	26 562	19.6	311.3
ENSCO95	250	660 174	31 202	21.6	354.2
ENSCO60	300	960 548	39 271	24.5	415.4
SagarShakti	350	1 397 589	49 427	27.4	476.7
Galaxy Ⅰ	400	2 033 480	62 209	30.2	537.9

Back-propagation neural network can be used to build the forecast model with multi-input multi-output variables[7-9]. The back-propagation neural network which is used to predict the main dimensions of self-elevating drilling unit is built with the model length, model breadth, model depth and leg length as output variables, and water depth, variable deck load, bulk mud/cement, sacks, drill water, maximum drilling depth, potable water and fuel oil as input variables. The three-layer artificial neural network model is employed with nine input units, thirty units in hidden layer, and four output units. The number training a step is 500, the step length takes 50, and the error curve of pursuing is shown in Fig.6.

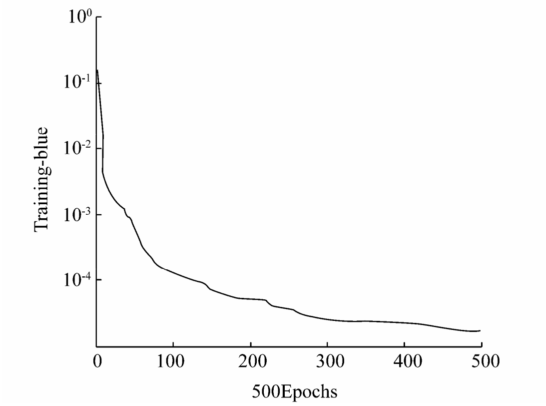

Fig.6 Error curve of training

2.4 Verification of the mathematical model based on multi-variable

After the training of the neural networks, 10 typical self-elevating drilling units with different water depths are chosen from the existing drilling units to verify the forecast models. Tables 3~4 clearly show that the calculated values and the initial data have little difference. The models can be used in the design of self-elevating drilling unit. At the same time, the results of the forecast show that the application of BP neural network to simulating design system is convenient, precise and satisfactory in predicting the main dimensions of self-elevating drilling unit.

Table 3 Comparison between network forecast and actual value of the main dimensions-original data

Platform names	*d*/ft	*L*/ft	*B*/ft	*D*/ft	*l*/ft
Parker15-J	100	156.0	110.0	15.0	173.0
GP-21	120	210.0	100.0	14.0	202.0
RBF152	150	157.0	120.0	16.0	217.0
PrideMississippi	200	157.0	132.0	18.0	270.0
NobleLyndaBossler	220	182.0	204.0	25.0	342.0
ENSCO95	250	199.0	174.0	21.0	355.0
ENSCO60	300	200.0	186.0	23.0	414.0
SagarShakti	350	243.0	200.0	26.0	475.9
Chile Galileo	360	225.0	208.0	25.0	517.0
GalaxyIII	400	224.0	250.0	36.0	560.0

Table 4 Comparison between network forecast and actual value of the main dimensions-calculated values

Platform names	*d*/ft	*L*/ft	*B*/ft	*D*/ft	*l*/ft
Parker15-J	100	153.9	112.9	15.0	170.8
GP-21	120	211.8	98.4	13.9	200.5
RBF152	150	157.9	123.4	15.5	219.1
PrideMississippi	200	155.7	134	17.9	268.9
NobleLyndaBossler	220	183.6	198.1	25.1	341.6
ENSCO95	250	196.5	171.4	21.6	352.6
ENSCO60	300	203.0	183	22.7	414.0
SagarShakti	350	237.7	207	26.2	480.8
Chile Galileo	360	226.7	200.9	25.4	515.5
GalaxyIII	400	223.9	249.7	35.7	561.1

3 Conclusions

The paper analyzes the current situation of the self-elevating drilling unit, on the basis of collecting and classifying the main dimensions of self-elevating drilling unit, the mathematical model for the main dimensions of self-elevating drilling unit is established using the methods of return computer procedures and back-propagation neural network. Analysis and calculation examples show that the mathematical model is applicable and reliable. It is beneficial not only to mastering the essential variation of the main dimensions of self-elevating drilling unit, but also to making technical and economic demonstration and to carrying out conceptual design. China has vast ocean resources, the design and construction technology of the ocean platform must be developed. More attention and researching work should be put on them. The establishment of the mathematical model will play a positive role in enhancing the level of design technology for the ocean platform.

References

[1] FANG Yinxia, BAO Gengsheng, JIN Xianglong. Prospects for the exploitation and utilization of deep-sea resources in the 21st century[J]. Marine Science Bulletin, 2000, 19(5): 73-78(in Chinese).

[2] LI Fen, ZOU Zaojian. Research condition and developmental tendency of the floating structures[J]. Journal of Wuhan University of Technology, 2003, 27(5): 682-685(in Chinese).

[3] GONG Min, TAN Jiahua. The analysis of jacket platform load[J]. China offshore Platform, 2005, 20(4): 20-23.

[4] JI Chunqun, SUN Chunchang. Analysis of stability against overturning and foundation bear force for jack-up rig[J]. Journal of Shanghai Jiaotong University, 1996, 30(3): 79-85(in Chinese).

[5] ZHAN Yiting, JI Zhuoshang, LIU Yindong. Research and development of a digital design system for hull structures[J]. Journal of Marine Science and Application, 2007, 6(2): 37-43.

[6] SUN Song. Study on ship form evaluate alternatives and intelligent decision-making methods[D]. Dalian: Dalian University of Technology, 2002: 21-34(in Chinese).

[7] CONG Shuang. Theory and application of the neural network tools in MATLAB[M]. Hefei: University of Science and Technology of China Press, 2003: 150-205(in Chinese).

[8] LOU Shuntian, SHI Yang. System analysis and design based on MATLAB−the neural network[M]. Xi’an: Xidian University Press, 2000: 20-180(in Chinese).

[9] SANG Song, LIN Yan. Study of math modeling on ship's principal particulars based on neural network[J]. Computer Engineering, 2002, 28(9): 238-240(in Chinese).

WANG Yun-long was born in 1978, and now he is a doctoral degree candidate at Dalian University of Technology. Research field: study on key technologies design of self-elevating drilling unit.

JI Zhuo-shang was born in 1938, and now he is a professor and PhD advisor at Dalian University of Technology. Research field: ship CAD/CAM.

LIN Yan was born in 1963, and now he is a professor and PhD advisor at Dalian University of Technology. Research field: shipform development, virtual ship design and digital technology and research of key technology for ocean platform overall design.

自升式钻井平台主尺度建模研究

王运龙，纪卓尚，林 焰

(大连理工大学 船舶CAD工程中心，辽宁 大连 116024)

摘要：在搜集整理自升式钻井平台船型资料的基础上，利用逐步回归计算机程序和BP神经网络分别建立了自升式钻井平台主尺度的单变量预测模型和多变量预测模型．经实船验证该模型是适用和可靠的，模型的建立有利于掌握自升式钻井平台主尺度要素变化规律，在进行自升式钻井平台设计初期的技术经济论证和方案设计时，可根据已知信息的多少，选择合适的模型进行主尺度的预测．

关键词：自升式钻井平台；主尺度；单变量；多变量