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MODELLING OF THE OPERATING PERIOD OF A COMPRESSOR UNIT ON A SHIP FROM THE SEISMIC INDUSTRY I PART

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ABSTRACT
A possibility of extending the time between overhauls period of a compressor unit on a ship from the Seismic Industry by using pre-synthesized predictive mathematical models is considered. The latter are created by processing experimental data and refer to cases of before and after overhaul of the Seismic compressor. In part one, results of synthesizing predictive mathematical models of the relationship between the duration of the operating time of the Seismic compressor and the pressure change in the first stage – screw compressor are proposed. In Part Two, results of synthesizing predictive mathematical models of the three piston stages of the Seismic Ship compressor are proposed.
KEYWORDS: *Offshore Oil Industry, Seismic Vessel, Seismic Air Compressor, Synthesizing Predictive Mathematical Model, Least Squares Method, Regression Analysis*

1. CHARACTERISTICS AND FEATURES OF THE RESEARCH OBJECT

Two are the most important characteristics of the Seismic Vessel: safety in navigation to guarantee the possibility of manoeuvring and the normal functioning of the seismic equipment with which the ship fulfils its purpose. Examining the problem of mathematical modelling of the operational period of the seismic compressors of a Seismic Ship is required by considerations of realizing the possibility of using prognostics for extending the operational time. According to the manufacturer's recommended schedule, the operating time of the screw compressor is 12,000-16,000 operating hours, after which it should come in for a major overhaul. The overhaul of the piston part of the Seismic compressor is carried out every 8000 working hours. The seismic vessel is a complex equipment operating in harsh conditions. Extending the time between overhauls period is desirable to realize savings. [3, 5, 7, 8].

Three NEA GROUP SAPS-62E seismic compressors with a maximum compressor power of 406 kW and a nominal power of the drive electric motor of 1100 kW are installed on the Seismic Vessel. The maximum working pressure is limited to 175 bar. The rotation speed of the compressors is regulated by frequency converters, and when starting, the idle speed is limited to 600 min-1, and the maximum rotation speed is 1200 min-1. The maximum flow rate of the compressor is 62.7 m3/min at 1200 min-1 [5, 9]. Fig. 1 shows the complete compressor unit.

Fig. 1 Seismic Compressor NEA GROUP SAPS-62E

The seismic compressor has four compression stages. The first stage is a Kaeser Kompresoren GmbH screw type of compressor model Sigma 5 – G, and the second, third and fourth stages are a NEUMAN&ESSER V-shaped piston compressor model 3SEV63-162/142/78 [5].

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The first stage of the reciprocating compressor is located independently on a crankpin of the crankshaft. The second and third stages are mounted on the other crankpin. Since the piston of the second and third stage is a complex type, the two cylinder blocks for second and third stage are located on top of each other [5].

The screw compressor consists of two screws that compress the air to a pressure of 12-15 bar. The compressed air together with the oil that lubricates the screw compressor passes through an oil separator, where the oil is separated from the air, passes through an oil cooler and filter, and then is returned to the screw compressor at a temperature of 95 °C. The compressed air, in turn, passes through an air cooler and then enters the first stage of the piston compressor, where it is compressed to 32-36 bar.

2. INFORMATION PROVISION OF THE STUDY

Seismic Compressor 1 parameters of interest to the study were collected using the Seismic Compressors operation and control software "Phoenix Contact". The parameters were recorded at a fixed mode of operation of the Seismic Compressor with a rotation speed of 1059 min-1 during the operation of the vessel in Seismic mode. Data recording was done every 10 days at the same time of the day. 20 data records were collected before the overhaul period of Seismic Compressor 1 and 20 data records after the overhaul period.

In the screw compressor, the air pressure and temperature change slightly at the end of the study period.

3. DATA PROCESSING FROM THE NEA GROUP SAPS-62E SEISMIC COMPRESSOR EXPERIMENT

The experimental-statistical study of the dependence between the length of the time of operation of Seismic Compressor 1 and the pressure variation is considered in two cases: when the compressor has undergone an overhaul and before it. The number of data collected during a certain period of time in both cases is the same-20 times and is considered as Factor X =[1 2 3 ....18 19 20]. The results of the operation of the compressor in both cases differ by the time of the experiment - before the overhaul PK1pr(1) and after it PK1sr(1).

3.1 Modelling the dependency: operating time of Seismic compressor 1 - pressure change PK1(1), bar

The results of the scientific search for a qualitative, workable model giving the relationship between the operating time of Seismic Compressor 1, considered as Factor X and its effect on the pressure change PK1(1), during that time is denoted by “**y**”. The search for a high-quality, workable model presupposes the study of many models and choosing among them the best compromise: accuracy and simplicity of its structure.

3.1.1 Dependency Modelling: operating time - pressure change after overhaul PK1sr(1), bar.

The following experimental data for the pressure variation in first stage PK1sr(1) were used, written as a row vector
PK1sr(1) =[10.8 10.6 10.9 10.6 10.9 11.2 11.3 11.2 11.5 11.4 11.5 11.6 11.8 11.7 11.9 11.8 11.9 12 11.9 12];
The results of the research of the influence of Factor X on the pressure change of Seismic compressor 1, after the overhaul PK1sr(1) are given in the following table.

Table 1: Results of the research of the influence of the operating time of Seismic Compressor 1, Factor X on the pressure, PK1(1) bar, after the overhaul PK1sr(1)

PK1sr(1)		
Model	PK1sr(1) = 10.6300 + 0.0757.x	PK1sr(1) =10.4638 + 0.1210.x - 0.0022. x2
Adequacy	Fem= 198.7336 F(0.05;1;18)=4.41 Conclusion: yes	Fem= 125.6297 F(0.05;2;17)=3.59 Conclusion: yes
Standard error SE	SE=0.1385	SE=0.12449
Jacques-Berra test for normality	JBem = 1.5601 JBт(0.05;2) = 5.99 Conclusion: normal distribution	JBem= 1.5931 JBт(0.05;2) = 5.99 Conclusion: normal distribution
Homoscedasticity according to Glejser test	FFem = 1.3658 Ft(0.05;1;18)= 4.41 Conclusion: yes	FFem=10.0464 Ft(0.05;1;18)= 4.41 Conclusion: no
Pearson's Ryx	R_lin =0.95757	R_lin= 0.9678

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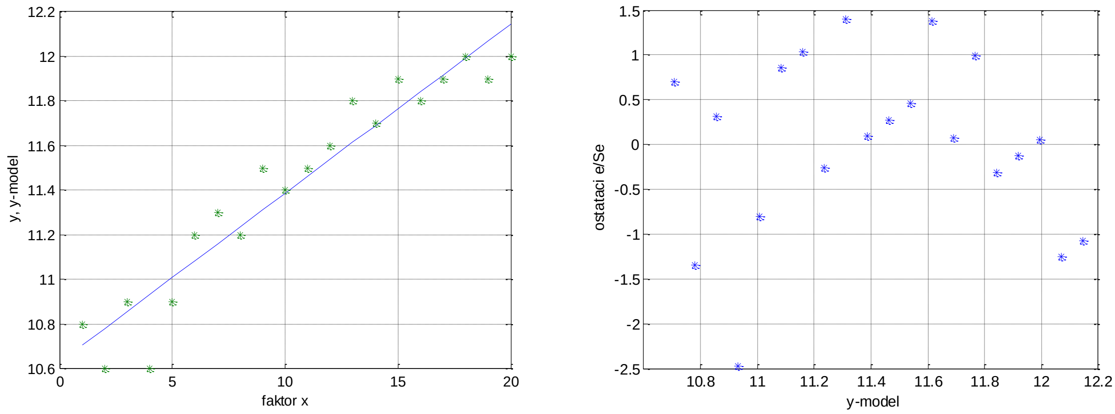
Correlation check by the Durbin-Watson test	d = 1.7586 1alfa=5%; dL= 1.201 dU= 1.4.14 dU<d<4-dU=2.59 Conclusion: no autocorrelation	d = 2.3286 3alfa=5%; dL= 1.201 dU= 1.411 dU<d<4-dU=2.59 Conclusion: no autocorrelation

In the first row of the table, the general appearance and structure of the model are shown, and in the following, its characteristics and the values of the criteria that must be satisfied for effective use of the Least Squares Method, respectively Regression Analysis [1]. The second column gives the results using a first-order model.

From the analysis of the table, it can be seen that all the criteria for this model are satisfied. Below are plots of the real data (*) and the model data with solid line as a function of Faktor X, as well as the stochastic distribution of the normalized residuals e/Se, the second plot. The model is qualitative and used for prognosis. This was done in a prognostic horizon of 5 values:

y_prognoza1_ PK1sr(1)=[12.22 12.2957 12.3714 12.4471 12.5229];



The last column of the table gives results for a second-order parabolic model. It does not satisfy the conditions for homoscedasticity according to the Glejser test [4]. A check was also made according to a second criterion for checking homoscedasticity according to the Breusch-Pagan criterion, which is also negative FFem = 5.4134 > 4.41 [6].

3.1.2 Dependency Modelling: operating time - pressure change before overhaul PK1pr(1), bar.

The results of the research of the influence of Factor X on the pressure variation of Seismic Compressor 1, before overhaul PK1pr(1) is given in table 2. The following data were used for the modeling, PK1pr(1):

PK1pr(1) =[11.2 11.3 11.2 11.6 11.7 11.5 11.8 12.2 12.4 12.3 12.4 12.9 13. 13.1 13.6 13.5 14.0 14.2 14.6 15.4];

Table 2: Results of the research of the influence of the operating time of Seismic Compressor 1, Factor X on the pressure, PK1(1) bar, before the overhaul PK1pr(1)

PD3pr		
Model	PK1pr(1)= 10.5989 + 0.1996.x	PK1pr(1) =11.1968 + 0.0366.x + 0.0078. x2
Adequacy	Fem= 300.1132 F(0.05;1;18)=4.41 Conclusion: yes	Fem= 440.9659 F(0.05;2;17)=3.59 Conclusion: yes
Standard error SE	SE=0.29715	SE=0.17677
Jacques-Berra test for normality	JBem = 4.5895 JBт(0.05;2) = 5.99 Conclusion: normal distribution	JBem= 0.9411 JBт(0.05;2) = 5.99 Conclusion: normal distribution
Homoscedasticity according to Glejser test	FFem= 0.2474 Ft(0.05;1;18)= 4.41 Conclusion: yes	FFem=2.2954 Ft(0.05;1;18)= 4.41 Conclusion: yes

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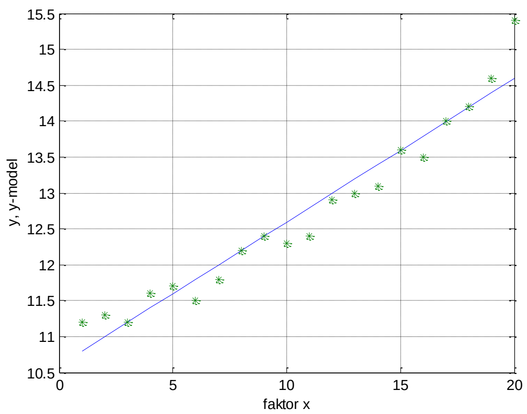
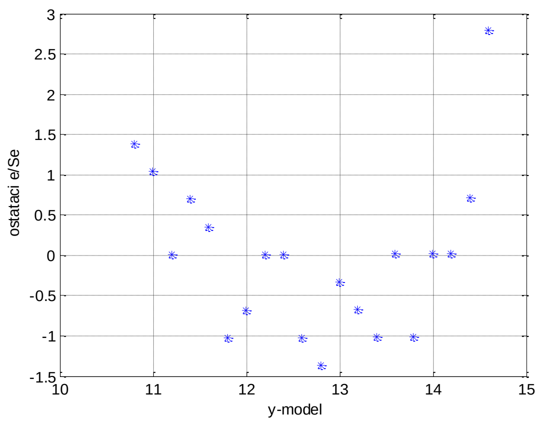
Pearson's Ryx	R_lin = 0.9713	R_lin= 0.9905
Correlation check by the Durbin-Watson test	d = 0.7804 1alfa=5%; dL= 1.201 dU= 1.4.14 0<d<dL Conclusion: positive autocorrelation	d = 1.8862 3alfa=5%; dL= 1.201 dU= 1.411 dU<d<4-dU=2.59 Conclusion: no autocorrelation

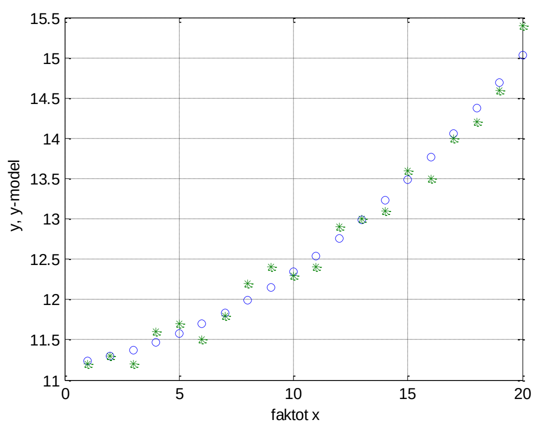
The second column gives the results of the first-order synthesized model. Analysis of the table shows that the Durbin-Watson test for correlation of residuals is not satisfied [2]. Below are the plots that resulted from the research. The model is of poor quality and cannot be used for prognosis.

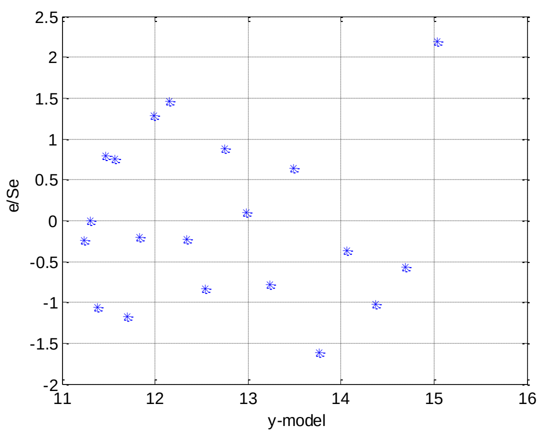




The second figure, giving the distribution of the standardized residuals e/Se, as a function of the value of the model shows a non-linearity, which gives us information that the mathematical model wanted has a non-linear form.

The last column of the table shows the results for a second- order parabolic model. The model satisfies all the requirements for applying the Method of Least Squares and Regression analysis. Below are plots of the real data (*) and the model data with (o) as a function of Faktor X, as well as the stochastic distribution of the normalized residuals e/Se, the second plot [1].





According to the second-order model, a prognosis was made in a prognostic horizon of 5 values:

y_prognoza2PK1pr(1) = [15.3889 15.7593 16.1452 16.5467 16.9637];

4. CONCLUSION

- As a result of the scientific search for a qualitative mathematical model approximating the relationship between the seismic compressor operating time, Factor X and the pressure change in first stage, after the overhaul PK1sr(1) , a first-order model was chosen. It meets the requirements for implementing the Regression analysis. The model prognosticates the pressure variation of Seismic Compressor 1, after overhaul PK1sr(1), depending on the compressor operation time.

- A second-order mathematical model of the connection: time of operation - change of pressure in first stage, before the overhaul PK1pr(1) was also obtained. A prognosis was made on it.

- From the analysis of the primary data, a significant increase in the pressure of this compressor before the overhaul, PK1pr(1) was found. This relates to the nature of its operation. An increase in the temperature PK1(5) of the screw compressor is also observed in this case. The statistical relationship between them has been determined, the correlation coefficient is very high, R= 0.9763.

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