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Analysis of the Mechanical Performance Estimation of Electric Motors Used in the Drive of Deep Well Pumps

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ABSTRACT

V Vertical hollow shaft (VHS) deep well pumps are one of the pump types commonly used in agricultural irrigation. 3-phase asynchronous electric motors are used to drive these types of pumps. In this study, the main goal is to analyze the manufacturer's motor catalog data with Kloss formula and estimate the instantaneous rotor torque of these motors with the least error. For this aim, Nominal speed, breakdown torque and rotor speed at breakdown torque used in the study as the manufacturer's data. By this way, it became possible to estimate the mechanical performance of today's manufactured motors with the least possible measurement and error rate. Also, the results showed that the torque values which were calculated by using the Kloss formula given in the literature is giving us a chance a chance to easly make inferences from the manufacturer data efficiently.

RESEARCH ARTICLE

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INTRODUCTION

Deep well pumps constitute the pump type which is commonly used in agricultural irrigation. In these pumps, the pump body and the impellers are located in the well and driven by an electric motor located on a shaft placed vertically inside the discharge pipe. Electric motors that are used to drive deep well pumps are called vertical hollow shaft (VHS) motors (Fig 1).

In the vertical shaft (vertical turbine type) deep well-pumping units driven by VHS motors, the pumped water is also used for lubrication and cooling purposes. For this reason, compared to engines lubricated with oil, these systems have special importance for domestic or agricultural water use.

In deep well pumping units, water flow and pressure depend on the mechanical performance of the electric motor. The mechanical performance of the electric motor is dependent on the motor's load and efficiency as well as the electrical parameters such as the mains voltage.

Knowing the mechanical performance of electric motors is essential not only in selecting the proper motor for the machine but also in fulfilling the expected function.

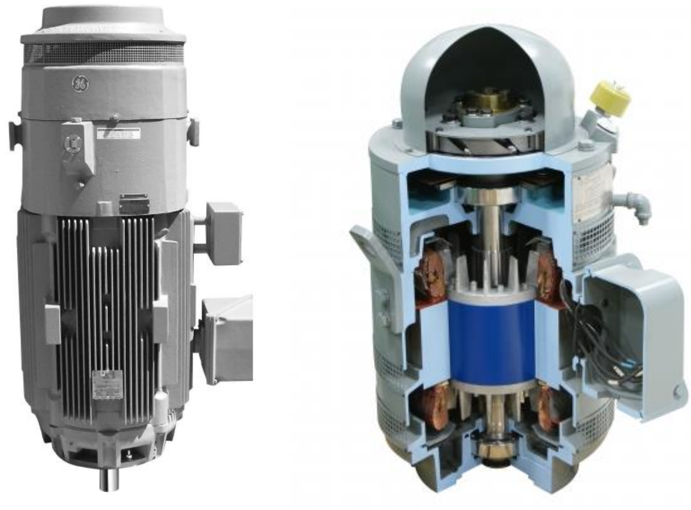

Figure 1. Vertical hollow shaft (VHS) electric motors (Anonymous, 2019).

In his book, Boduroğlu (1988), focused on the theory of asynchronous electric motors. The author gave information on the determination of load characteristics, especially in asynchronous electric motors, using the Kloss formula and calculation of the torque. The author also explained the different methods of removing the circle diagram of the asynchronous machines.

Buksnaitis (2011) analyzed the mechanical performance of three-phase asynchronous electric motors at a different frequency and voltage values. The analytical solutions based on the Kloss formula obtained have been tested with an asynchronous motor with a squirrel cage at a rated power of 4 kW. As a result, the Kloss formula can be used effectively enough without anticipating the mechanical characteristics of the asynchronous motor.

In the book of Çolak (2017), he gave information about the structure and working principles of synchronous and asynchronous motors. The author stated that the asynchronous motor changes the rotational moment corresponding to any shift value by the applied voltage. The authors also reported that asynchronous motors are manufactured as class A, B, C, D, E and F according to different designs of rotor assemblies to be able to resist the resistance of different loads and to obtain different rotational speed-torque characteristics.

Fitzgerald et al. (2014) describe electrical and multi-phase asynchronous machines, which have an important place in them. The simplicity, robustness, and relatively low cost of asynchronous motors with squirrel-cage; have provided some unrivaled advantages in use, the authors have stated that the most important drawback of these motors is their relatively low power factor (cos φ).

Kostic (2010) studied the performance of electric motors at partial loads. The investigator has proposed an estimation method based on the values of the two loaded points for the estimation of the partial overhead motor efficiency.

Vatandas (1995) in his research, has developed a method that can be used in the selection of a suitable electric motor for machines, taking advantage of the charging characteristics of three-phase asynchronous electric motors used in the operation of agricultural machinery. The validity of the method has been tested by the test data of five standard electric motors in the power range of 0.75-4.0 kW. It has been determined that the proposed method could be used with high accuracy from the loading characteristics obtained from a wide range of stator voltages and slip values.

Mechanical performance analysis of induction motors is simplified by using Kloss formula. Therefore, many studies based on this method are included in the literature (Gartner et al. 2001, Kodkin et al. 2014, Pejovski and Velkovski 2016, Sieklucki 2018).

Patel Vedant and Vekariya (2018) worked on performance evaluation of pressure head loads and pumping efficiency on electrical pump sets. They express that under the experiment it was found by them that the submersible pump efficiency varied according to increase in pressure while velocity head decreases at a certain point and over total head the efficiency drop drastically.

Kumar and Kumar Godara (2017) studied the attitude of farmers' towards the photovoltaic water pumping system in Haryana. They imply that the majority of the farmers of both categories, i.e. adopted and non-adopted had a favorable and positive attitude towards different kinds of pumping systems.

In the light of this literature, in this study, the manufacturer data of VHS type motors were analyzed by using two main analytical formula. In this way, it is aimed to estimate the mechanical performance of today's manufactured motors with the least possible measurement and error rate. The results obtained by the study will be able to serve a practical use regarding both engineers working in practice, and pump users.

MATERIAL and METHODS

The data of VHS type electric motors produced by domestic producers were used in the study. Nominal speed, breakdown torque and rotor speed at breakdown torque used in the study as the manufacturer's data. The nominal (rated) speed value is read from the nameplate of the motor, while others are from the catalog of the motor. Instantaneous torque values were calculated by using the formula given in the literature as Kloss formula by using the number of revolutions which is the mechanical parameter that can be measured easily in the application conditions of the electric motor.

This calculation,

$$M_i = 2 \times MD \,/\, [(s_i/s_D)] + [(s_D/s_i)] \qquad (1)$$

with the help of this formula (Boduroğlu 1988).

In this formula,

M_i : Rotor torque,

M_D : Break-down torque of the motor in nominal conditions,

s_i : The slip calculated for Mi,

s_D : The slip calculated for MD.

In Kloss formula, any unit can be used for moment and the slip is dimensionless, it is displayed in decimal. Using the Kloss formula, measured instantaneous speed, manufacturer's data for breakdown-torque and nominal speed can be used the calculation of instantaneous rotor torque. The calculation made is called "estimation", because it contains a certain error. However, since measuring the rotor torque of a pump directly in practical conditions requires special and expensive measuring devices, it is aimed to develop a practical approach to this problem with the study. Because pumps consume various power under different manometric height and flow conditions and demand torque and speed from the electrical motor. Here, the basis of calculating hydraulic parameters in the pumping unit is based on knowing the power taken from the electrical motor.

The nominal torque values calculated according to formula 1 and the torque values given by the manufacturers were analyzed using statistical methods. In this way, the degree of deviation between calculated and manufacturer's data evaluated from this formula (Bağırkan, 1993).

$$u^2 = \sum(F_t - O_t)^2 / \sum O_t^{\,2} \qquad (2)$$

In this formula,

u^2 : Degree of prediction,

F_t : Estimated value,

O_t : Measured value.

Since the calculated value of u2 is zero, which shows that there is no deviation between the measured value and the estimated value. The proximity of this value close to zero means that the predictive accuracy is high (Bagirkan, 1993).

RESULTS and DISCUSSION

The analysis results of the mechanical performance of VHS type electric motors used for the drive of deep well pumps are presented in Table 1.

Table 1. Analysis results obtained for the nominal values of the torque

Efficiency level of electric motor	Number of poles	Synchronous speed (min^{-1})	Power range (kW)	Number of data	R^2	Means level (p)	Standard error (±) (N m)	u^2
IE1	2	3000	3.0-132.0	16	1.000	0.000	0.436	0.000813
IE1	4	1500	3.0-11.0	5	1.000	0.000	0.066	0.001334
IE1	4	1500	15.0-37.0	5	1.000	0.000	0.622	0.001332
IE1	4	1500	45.0-132.0	6	1.000	0.000	5.229	0.002535
IE1	4	1500	160.0-315.0	6	1.000	0.000	17.794	0.004798
IE1	4	1500	3.0-315.0	22	1.000	0.000	13.192	0.004484

Examination of the values of Table 1 reveals that the prediction of torque in 2-pole VHS motors can be estimated with a fairly low error when considering all motors manufactured in this group. However, relatively high error values were obtained when evaluating the data of the mechanical parameters of 4-pole and especially large powerful VHS motors. As a result of the grouping of the data of the near-power motors made to reduce the standard error, it is seen that the evaluations with the lower standard error and a higher degree of prediction can be made.

In the last line of the table, the results determined by evaluating all the data of the 4-pole motors are included. In all analyses, high level correlations were obtained at $p < 0.000$ and $R^2 = 1.000$ levels.

As the motor power increases, the torque will increase, so the standard error of the prediction increases. As can be seen from the table, the synchronous speeds of induction motors are standard (1500 and 3000 min^{-1}). Since the design and manufacture of the electrical motors are made according to the number of poles, the same grouping is based here.

CONCLUSIONS

In this study, the manufacturer data of VHS type motors were analyzed by using Kloss formula. In this way, it is aimed to estimate the mechanical performance (instantaneous torque and therefore instantaneous shaft power) of today's manufactured motors with the least possible measurement and error rate. The results obtained by the study will be able to serve a practical use regarding both engineers working in practice, and pump users. As a conclusion, the torque values which were calculated by using the Kloss formula given in the literature helped us to make inferences from the manufacturer data efficiently in a fast and optimum way.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Abdullah Beyaz: Writing - original draft, Methodology, Formal analysis, Review and editing.

Mustafa Vatandas: Writing - original draft, Methodology, Formal analysis, Investigation.

REFERENCES

Anonymous (2019). Vertical hollow shaft (VHS) electric motors. http://ime.eu (08.03.2019).

Boduroğlu T (1988). Electrical machinery courses (2nd Edition). Istanbul, Volume II, *Beta Press Release Distribution.*

Buksnaitis J (2011). Analytical determination of mechanical characteristics of asynchronous motors by varying the electric current frequency. *Electronics & Electrical Engineering, 6 (112): 3-6.*

Çolak İ (2017). Electrical Machines-2. *Seckin Publishing*, p.352, Ankara.

Fitzgerald A E, Kingsley C, and Umans SD (2014). Electric machines (Translation Editor: Sirri Sunay Gurleyik). Ankara, *Palme Publishing*, 698, Ankara

Gartner J, Halamka Z, Pavelka J (2001). The speed control of the induction motors by the change of supply voltage. *Silnoprouda Electro Technika A Elektroenergetika*, 41-44.

Kodkin VL, Anikin AS, Shmarin YA (2014). Effective frequency control for induction electric drives under overloading. *Russian Electrical Engineering, 85 (10): 641-644.*

Kostic MM (2010). Analysis of induction motor efficiency class change at partial load. *Electrical Engineering, 23 (3): 333-344.*

Kumar A and Kumar Godara, A (2017). Attitude of farmers' towards photovoltaic water pumping system in Haryana. *Agricultural Science Digest, 37 (2): 127-131.*

Patel Vedant C and Vekariya PB (2018). Performance evaluation of pressure head loads and pumping efficiency on electrical pump sets. *Indian Journal of Agricultural Research, 52 (4): 374-379.*

Pejovski D, Velkovski B (2016). Calculation of induction motor starting parameters using MATLAB. *Infotech-Jahorina*, 879-884.

Sieklucki G (2018). *An investigation into the induction motor of Tesla Model S Vehicle*. Proceedings of the 2018 International Symposium of Electrical Machines (SME), Poland.

Vatandaş M (1995). *Investigation of loading characteristics in electric motor-machine coupling*. 16th National Congress of Agricultural Mechanization Book of the Proceedings: 183-191, Bursa.