Krzysztof KOLANO
Politechnika Lubelska, Wydział Elektrotechniki i Informatyki,
Katedra Napędów i Maszyn Elektrycznych, Lublin, Poland
k.kolano@pollub.pl
Paweł LONKWIC
LWDO Lift Service S.A. Lublin, Poland
plonkwic@gmail.com

ANALYSIS OF THE EFFECT OF ELEMENTS INSULATING PASSENGER LIFT-DOOR-DRIVING MOTOR UPON THE LEVEL OF GENERATED SOUND

Key words

Passenger lift, door-driving motor, BLDC motor, vibro-insulation.

Abstract

The article presents selected relationships connected with the effect of vibro-insulating material upon the level of sound generated during the work of a motor driving the door of a passenger lift in steady state. We analysed the effect of geometrical parameters of insulating pads upon the sound level observed.

Introduction

Restrictions imposed upon the manufacturers of technical appliances by the European Authorities are more and more rigorous. This is caused mainly by the will to protect the persons staying near the appliances and the environment itself. Thus, the comfort of operating technical appliances consists not only of ergonomics, but also of the important aspect of silent running. Modernizing the existing appliances is aimed at improving safety for the users and increasing comfort, especially in the existing systems. The increasing requirements in the field of lift safety enforce the adjustment of existing appliances to the standards being currently in force [3].

The sources of sound are working machines, ventilation systems, means of transport, people, etc. The sound, which, due to the level, nature, place, and time of occurrence, becomes oppressive or harmful, and it is called noise. When measuring technical objects, it is assumed that there are three kinds of noise:

– <u>Noise of steady level</u>: The noise whose sound level A in a particular place changes not more than by 5 dBs;
– <u>Noise of transient level</u>: The noise whose sound level A in a particular place changes not more than by 5 dBs:
– <u>Impulse noise</u>: The noise that consists of one or several sound impulses, each of which lasts not longer than 0.2 s.

Sound source elimination is developed with the same intensity as the emission sources are created. Engineering knows many solutions for eliminating sound formation, e.g., soundproofing mats, insulating pads, acoustic screens, etc. [4].

In the described research model, which is the driving system of the passenger lift (lift), except the sound generated by mechanical sub-assemblies co-operating in the whole drive, the driving motor itself is a sound source. The development of the lift sector created by the market requires applying more energy-saving drives. Therefore, an engine was developed that uses permanent magnets, constructively divergent from the universally applied induction motor and fed with the voltage of 380 V.

For a few years there has been a noticeable tendency to develop energy--saving driving systems for cab doors with the use of engines with permanent magnets. Due to the high cost of absolute position encoders, which would have a substantial share in the price of the whole drive of the door, BLDC high-speed motors are applied coupled with a mechanical transmission gear. This gear is indispensable for reducing the rotations of BLDC motors (they range from 3000 to 6000 rotations/min) to the value that could be used for a wing drive (about 500 rotations per minute). The high dynamics of these motors is especially desirable when the passenger enters the inside diameter of the door during closing. Contrary to the traditional induction motor, the BLDC motor can make a fast reverse, restricting the force affecting the passenger. Unfortunately, applying a one-stage planetary gear in a motor with the power of about 200 W extremely adversely affects the energetic balance of the appliance. The gears of such size typically have the efficiency of about 60–70%, and their specific resistances impose applying higher force closing the door in a voltage-less state. Additionally, the cost of this kind of gear is comparable to the cost of driving motor, which significantly restricts the development of these appliances.

The desire to restrict energy consumption, as well as to improve the dynamics of cab doors makes us inclined to apply, just like in the case of main drives of the lift, the synchronous motor with permanent magnets together with an absolute position decoder. Unfortunately, such a solution, though it meets all technical assumption, would be very expensive. Using the resolver would make it possible to apply control through modulating the spatial vector "SVM," but it would significantly increase the costs of the whole driving system.

To connect the values of reductorless synchronic motors with the simplicity of controlling BLDC motors, we decided to use a prototype slow-speed BLDC motor [2]. An integral part of a direct current motor with permanent magnets is a shaft position sensor system. In BLDC motors, three position sensors are applied as standard, which can define 6 different states of rotor position. On this basis, the managing system connects an appropriate pair of transistors in the controlling bridge.

Direct current brushless motors with permanent magnets (BLDC) are included in the group of machines characterized by high-energy transformation efficiency. The application of high-energy permanent magnets of rare-earth elements leads to obtaining a high energy density indicator per volume unit. The high value of an energy density indicator falling upon a volume unit allows decreasing the machine dimensions, preserving the remaining operation parameters, e.g. rated power referred to other types of machines. In such motors, cylindrical structure motors with high-energy durable magnets are applied. In such structures, there is a problem with the tap (catch) moment. The basic component of electromagnetic moment pulsations in brushless motors with permanent magnets is tap (catch) moment. The pulsations cause significant problems connected with rotation speed control and, especially in the case of passenger lifts, are the reason for undesirable vibrations, and noise [5].

While traveling in a passenger lift (colloquially called "lift") cab, one can notice that during opening and closing the door, with badly made regulations or excessive damage, the sound generated during that operation is quite unpleasant. While trying to optimize the structure, the level of noise can be easily influenced during designing new appliances, it is frequently very difficult in the case of those already in operation. [2].

The application of BLDC-type motors in cab door drives is caused mainly by the following two aspects: energy saving and decreased heat emission during intense work. Figure 1 shows comparative characterizations of averaging power values of BLDC-type motors and of induction motors fed with the voltage of 380 VAC for various powers of driving system-working states.

Figure 2 presents a graph of measuring the temperature to which an engine heats up during intense work.

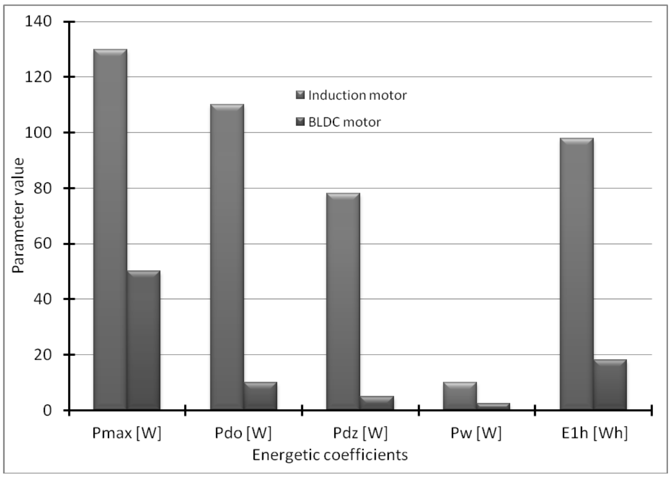

Fig. 1. Results of measuring energetic parameters of cab door power transmission system, where E_{1h} – amount of energy consumed by the whole power transmission system within 1 hour, P_w –power taken up by the controlling system , P_{do} – power taken up by the whole power transmission system during the production of pressure moment for open door P_{dz} – power taken up by the whole power transmission system during producing pressure moment for closed door, P_{max} – maximum power taken up when the door is being opened [1]

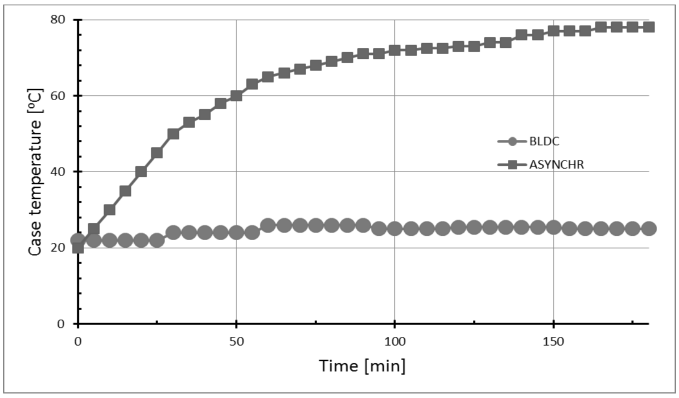

Fig. 2. Comparing motor case temperatures during 210 minutes of work [1] 180 minutes is enough time to achieve the established temperature value for the complex intensity of power transmission system operation

1. Description of empirical studies, methodology of studies

The conducted empirical studies were aimed at collecting the data for determining the relationships between the type of insulating material and the level of generated sound. To perform the studies, a measuring stand was put together, which is shown in Figure 3.

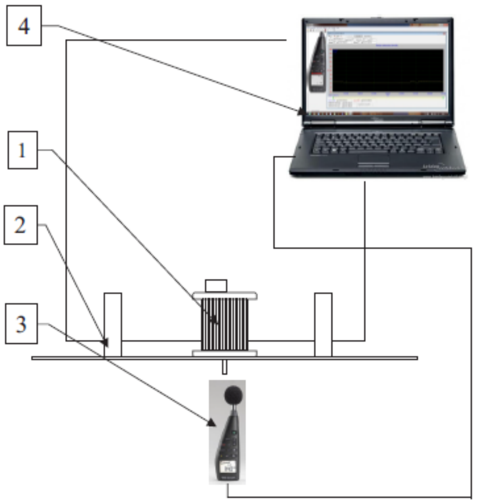

Fig. 3. Scheme of test bed: 1 – measuring engine, 2 – carrier of passenger lift door drive, 3 – CENTER 390 directional microphone, 4 – computer for data acquisition

The examined power unit of a passenger lift door was interchangeably equipped with an induction motor using a voltage of 380 V and a BLDC motor with permanent magnets. During measurements, the drive motor was attached to the main carrier with a flange with the use of three screws, which is shown in Figure 4. The measurements were recorded with the use of CENTER 390 directional microphone, and a short characterization of which is presented in Table 2. Measurements were performed with the engine attached to the carrier without the sleeves insulating the engine collar (Fig. 4), with 2mm thick polyurethane pads (Fig. 5), with 4 mm polyurethane pads (Fig. 6), and with 6 mm thick rubber pads (Fig. 7). The geometry and material of the pads (washers) were selected based on experience gained during many years of working at designing lift appliances. During measurements, the motor was loaded with a moment resulting from motor feeding, without additional external loading moments in the form of belt pulleys, rope pulleys, and other ways of loading. Recording the motor sound level was performed with the use of a sound level recording sensor, placed at the distance of 20 mm from the rotating motor axis in steady state. The measurements were automatically recorded by the microphone. After 10 s from starting the engine, the microphone started recording the sound level for the period of subsequent 30 s. The measurements were taken in accordance with the plan of studies presented below in Table 1.

Table 1. Plan of studies with the use of various insulating elements

	Without vibro-insulation	**Polyurethane 2 mm**	**Polyurethane 4 mm**	**Rubber 6 mm**
BLDC_20motor	X	X	X	X
BLDC_40motor	X	X	X	X
BLDC_60motor	X	X	X	X
BLDC_80motor	X	X	X	X
BLDC_100 motor	X	X	X	X
380 V_20motor	X	X	X	X
380 V_40 motor	X	X	X	X
380 V_60motor	X	X	X	X
380 V_80motor	X	X	X	X
380 V_100motor	X	X	X	X

8 characterizations were to be performed according to the above scheme, each of which (e.g. BLDC_20_4) was created by averaging 10 measurements performed sequentially. The particular tests were marked in the following sequence of symbols:

BLDC – type of motor; 20 – 20% of nominal speed; 4 – 4 mm thick polyurethane pad.

BLDC motor Induction motor

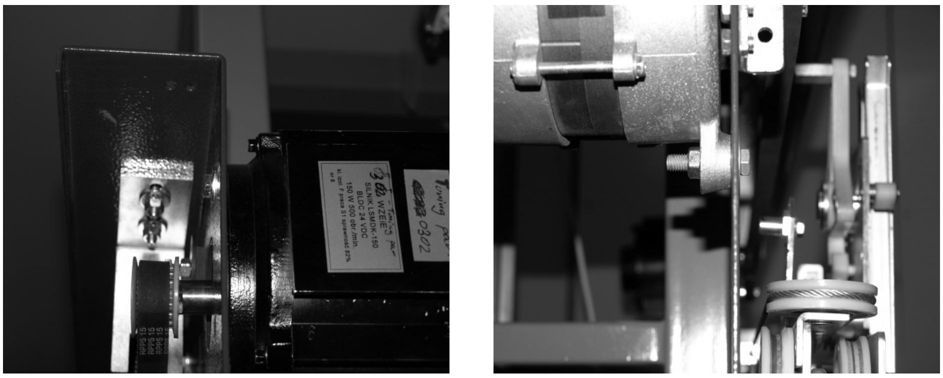

Fig. 4. Way of mounting the motor to the main carrier without insulating pads

BLDC motor Induction motor

Fig. 5. Motor attached with insulating pads made of 2 mm thick polyurethane

BLDC motor Induction motor

Fig. 6. Motor attached with insulating pads made of 4 mm thick polyurethane

BLDC motor Induction motor

Fig. 7. Motor attached with insulating pads made of 6 mm rubber

Table 2. Characterization of CENTER 390 measuring device

Number	Name	Range or value
1.	Frequency range	20 Hz – 8 kHz
2.	Level measurement range	30 – 130 dBs
3.	Weighed curves	A / C
4.	Microphone	Capacity
5.	Averaging modes	Fast (125 ms) Slow (1s)
6.	Dynamics range	100 dBs
7.	Accuracy	+/- 1.4 dBs for conditions of 94 dBs and 1 kHz
8.	Functions	OVER, UNDER, MAX, MIN
9.	Work temperature range	From 0 to 40 ^{o}C
10.	Work humidity range	From 10 to 90%
11.	Device category	2 acc.to IEC 61672-1

2. Study results and their analysis

Figures 8 to 10 below show the effect of the insulating pads material and their geometry upon the level of emitted sound during steady work. Figure 8 presents the differences in the intensity of the emitted sound for the motors, which were insulated with 6 mm thick rubber pads. The motors were accelerated to the nominal speed, which, in the case of the described studies, was 500 rotations/min. The graph shows that the intensity of BLDC motor sound is greater by about 4 dBs than that of induction motor. The observed difference is connected mainly with the structural differences between the motors.

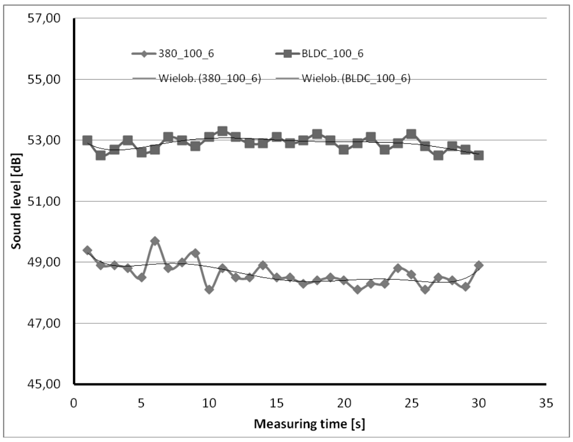

Fig. 8. Comparing the sound level for engines with 6 mm thick rubber pads with the velocity of 100% of the nominal speed (Wielob – its trend's line)

Similar relationships can be observed in Figure 9 for motors insulated by polyurethane pads with a diameter of 4 mm. In the described case, the engines also worked with the speed of 500 rot./min. Besides, comparing Figures 8 and 9, we can find differences between sound level for motors working at nominal speed but with pads of different thicknesses.

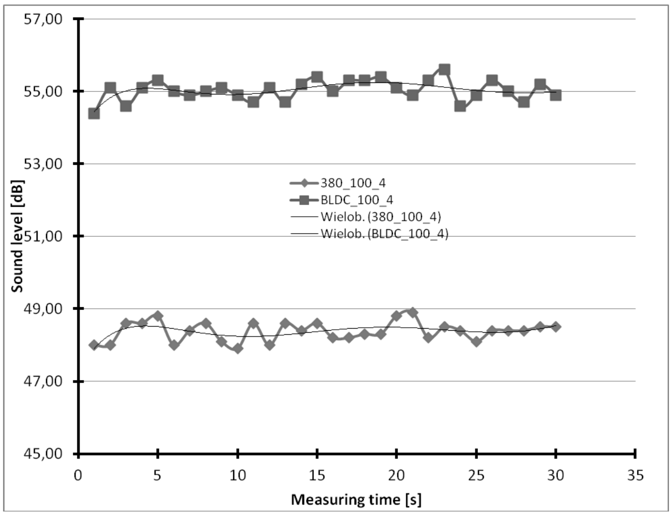

Fig. 9. Comparing sound level for motors with 4 mm thick polyurethane pads with velocity of 100% of the nominal speed (Wielob – its trend's line)

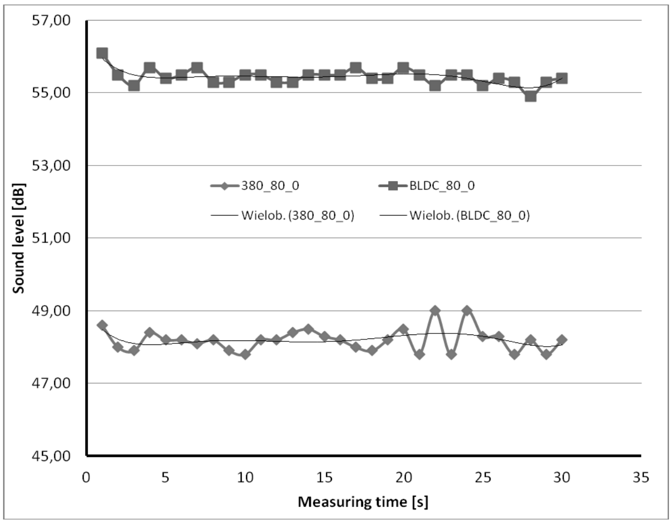

Fig. 10. Comparing sound level for motors without insulating pads and for the speed of 80% of the nominal speed (Wielob – its trend's line)

In Figure 10, the characterizations are shown, which were drawn based on measuring the motors working with the velocity of 80% of the nominal speed. These motors were attached directly to the main bearer of the door drive (without pads). Comparing the characterizations from Figures 8, 9 and 10, we can notice that a BLDC-type motor demonstrates higher susceptibility to changes connected with insulating and for various insulating materials (e.g. rubber or polyurethane) than an induction motor. These changes are caused by the structure of BLDC –type motor, which is based on permanent magnets, and the work itself is louder than that of an induction motor by a few decibels.

As a result of the conducted analyses of sound level variability in time for the examined engines and for various thicknesses of insulating materials, we decided to check the effect of the engine's working temperature upon the sound level. Using the graph presented in Fig. 2, we noticed that, during 180 minutes of operation, the induction motor heats up more, which is determined by its properties. Therefore, Figure 11 shows what sound values are achieved by the power transmission system with the induction motor insulated by a 6 mm thick pad (washer) for the established working temperature of 75°C.

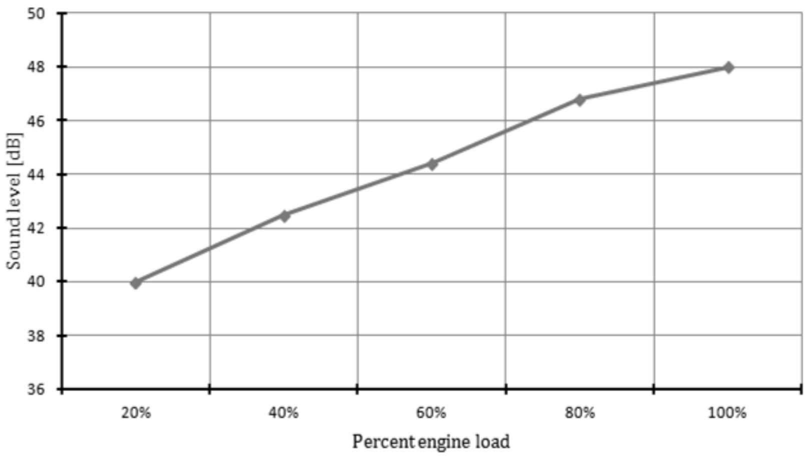

Fig. 11. Effect of temperature on the value of the engine sound at 100% load and washer insulation with a thickness of 6 mm. The diagram corresponds to the temperature of 75°C

Based on the performed measurements, a graph was prepared, which is presented in Fig. 11. The sound level value for 100% of the rated speed value is contained within 48 dBs. Figure 8 presents the sound intensity level measured for the same working speed of the induction motor for the temperature of 23°C, which is contained in the measurement range between 47 and 49 dBs. Measurements of temperature effect were performed in accordance with the description presented in the chapter: Methodology of Research.

As during the measurements, the BLDC engine did not demonstrate temperature changes in a significant range (from 21 to 25°C), and the effect of this engine's temperature upon the sound level.

Conclusions

The conducted studies and their analyses allow formulating the following conclusions:

– While working under load, the BLDC- type motor demonstrates a lower value of case temperature than an induction motor. A BLDC – type motor reaches the temperature in almost a linear range on the level of almost 25 degrees Celsius for the period of 210 minutes, which is a very good result. The induction motor case heats up to the temperature of nearly 75-Celsius degrees within 210 minutes. Therefore, to decrease the temperature of an induction motor, additional case cooling must be applied, which in reality, increases its costs.
– Comparing the values of power shown in Figure 1 confirms that the BLDC--type engine demonstrates much better energy indicators than an induction motor. From the point of view of operation, the parameter E1h seems to be the most interesting. There, within an hour of work, the BLDC-type motor achieves average power, taken up to the level of about 20W, and the induction motor uses nearly 100W. Thus, the BLDC motor consumes 1/5 of the energy of induction motor.
– Figures 8, 9 and 10 present the characteristics of sound measurements during steady work during 30 seconds. In all the cases under discussion, it can be noticed that BLDC-type motor demonstrates larger sound emission during work. This results in increasing the noise of cab door drive, decreasing the comfort of the cab passengers.
– Figure 11 shows the effect of engine temperature within 75°C upon the sound intensity level at the speed equal to 100% of nominal speed and with the application of 6 mm thick insulating pads. The analysis of this graph reveals that the temperature increase in the presented measurements does not significantly affect the sound level. Therefore, the application of thermal engine cases is not necessary in the door drives for passenger lifts.
– In BLDC-type engine, we did not notice any influence of engine temperature on the sound level during its work. In the case of this engine, the measurements were performed for the same working conditions as for the induction engine, and the measured sound level achieved the value of 53 dBs at the engine temperature reaching 23°C.
– Application of insulating pads made of polyurethane and rubber affects the decrease of noise level by a few decibels in relation to engines mounted without pads.

– The rotational speed is also important, the change of which affected the level of the intensity of the emitted speed.

References

1. Kolano K.: Napęd drzwi kabinowych dźwigu osobowego z wysokowydajnym silnikiem BLDC/Passenger lift car door driving motor with heavy duty BLDC engine/ Przegląd Elektrotechniczny, 11b/2012 pp. 348.
2. Lonkwic P., Kolano K.: Nowoczesne silniki BLDC stosowane w napędach drzwi kabinowych/Modern BLDC engines applied in car door driving motors/; Magazyn /Magazine/ Dźwig, Wydawnictwo EWIT 12/2012.
3. Lonkwic P.: Modernizacja dźwigów Istniejących/Modernization of existing lifts/, Inżynieria Budownictwa nr XII (no.12), Wydawnictwo Polskiej Izby Inżynierów Budownictwa 2011.
4. Łukjaniuk A.: Pomiar poziomu hałasu emitowanego podczas pracy urządzeń mechanicznych. Instrukcja do zajęć laboratoryjnych /Measuring the level of noise emitted during work of mechanical appliances" Instructions for laboratory classes./ The Białystok Technical University, Department of production Management 2011.
5. Ziaeinejad, S., Sangsefidi, Y., Shoulaie, A.: Analysis of commutation torque ripple of BLDC motors and a simple method for its reduction Electrical Engineering and Informatics ICEEI), 2011 International Conference on Digital Object Identifier: 10.1109/ICEEI.2011.6021672 Publication Year: 2011, pp. 1–6.

Analiza wpływu elementów izolujących silnik napędowy drzwi dźwigu osobowego na poziom generowanego dźwięku

Słowa kluczowe

Dźwig osobowy, napęd drzwi, silnik BLDC, wibroizolacja.

Streszczenie

W artykule przedstawiono wybrane zależności związane z wpływem materiału wibroizolacyjnego na poziom generowanego dźwięku podczas pracy silnika napędzającego drzwi dźwigu osobowego w stanie ustalonym. Poddano analizie wpływ parametrów geometrycznych podkładek izolujących na obserwowany poziom dźwięku.