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EXPERIMENTAL ANALYSIS OF HEAT DISSIPATION FROM THE ELECTRIC MOTOR

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Abstract: In order for an automobile company to survive on the market, it is necessary that their products comply with the specifications and requirements of customers. For the realization of specifications, it is necessary to constantly control the production process, as well as certain parameters that depend exclusively on customer requirements. In this paper, an electric motor named Colt is observed and analyzed. Three groups of motors and their heat dissipation to the environment were observed. Due to the construction and the position where the electric motor is installed in the vehicle, the impact of heat dissipation on the environment is extremely important, which is defined by the customer. In addition to enabling adequate data to be obtained, this analysis will allow for the accelerated approval of PPAP samples.
Keywords: electric motor, heat dissipation, PPAP

1. INTRODUCTION

The automotive industry is a complex manufacturing process that requires a reliable supply chain. It is important for a car manufacturer to have suppliers who can quickly and accurately respond to its requirements, to quickly adapt to developments in the automotive industry. Car manufacturers demand suppliers who have their processes under control, understand the specific requirements of their customers and focus on continuous improvement. In the current world market, both producers and consumers demand guarantees for the quality of products and services.

The subject of analysis in this paper is the DC motor. The motor consists of several components, such as housing, windings, brushes, bearings, rotors and permanent magnets. When current is allowed to flow through the windings, a magnetic field will be created around the windings. The magnetic field of the permanent magnet creates a repulsive force towards the windings which then rotate the motor shaft. One of the most important characteristics of electric motors is the way in which heat dissipation into the environment will be regulated. Many concepts of intensive heat dissipation from active parts of electric motors have been described in the literature. Many papers [1], [2], [3] talk about improvements in cooling technologies and thermal analysis of electrical devices. In paper [1] addressed the analysis of the main thermal phenomena in brushless permanent magnet machines, such as demagnetization of the magnets due to the heat created by losses. Several methods for mitigating complex loss components, magnet losses, and AC copper losses have been analyzed. The paper [2] proposes a cooling system for the realization of motor heat dissipation through the internal oil circulation and the external water circulation. In order to obtain the best cooling system parameters, an optimization framework is developed for heat dissipation optimization of the motor. Improvements in heat dissipation from electric motor windings are proposed in the paper [3].

In this paper, an experimental analysis was performed that monitors and observes 3 groups of motors marked as Group A, Group B and Group C. The purpose of the research is to compare the thermal performance of motor samples called KOLT before accepting and approving PPAP samples by the customer. Production Part Approval Process (PPAP) is a requirement o f ISO/TS 16949 standard in the automotive industry [4]. According to ISO TS 16949 the supplier is requested to perform a production process and product approval to achieve the release for series production [5]. PPAP defines the procedures governing the approval of parts and components for mass production, which is the basis for certification and approval of products and materials that make up the production process and control during production. If this control confirms all customer requirements that have been verified and specified in the product specification, then it should have a positive rating before being put into series production. PPAP checks whether the process has the potential to produce a product in series production so that customer requirements are met, in actual production volume and agreed production rate [6]. Effective implementation of PPAP will help the supply chain to improve the quality of the product, reduce the cost by optimal use of resources and maintain on time delivery at competitive cost [7].

Monitoring heat dissipation of electric motors is of great importance for long-term operation of electric motors. In addition, it will enable the reduction of quality costs, as well as the accelerated approval of PPAP samples. The maximum temperature in the electric motor must be determined to ensure that other components on the vehicle are not compromised during operation of the electric motor.

The paper is organized in the following way: Methodology is presented in Section 3. The results of the analysis are presented in Section 4. In Section 5, there is a discussion. Conclusion are given in Section 6.

2. METODOLOGY

This chapter describes the method of testing the heat dissipation of the Colt electric motor. This analysis observes the effect of copper loss on the increase in DC motor temperature in a shorter period of time. Copper losses are related to unwanted heat produced by electric current in the windings. This heat contributes to a larger and more pronounced increase in the DC voltage temperature of the motor.

The analysis was performed on three observed groups: 3 basic sampled motors (constants) (Group A1), 3 samples before acceptance (Group B1) and 3 samples for PPAP (Group C1),motors completed at the prototype factory (Table 1).

Table 1. Observed groups of motors

No	Number of motors A group	No	Number of motors B group	No	Number of motors C group
1	Kolta1	4	Koltb1	7	Kolt-001
2	Kolta2	5	Koltb2	8	Kolt-011
3	Kolta3	6	Koltb3	9	Kolt-111

The test was performed in the test center, and according to which it was used in the test: Dawesoft Seruies, Dawesoft Krypton, Thermocouples type K, Keysight, Kambič KK-500 and Torque and speed meter. According to the defined groups and marked samples within the mentioned groups, the electric motors are placed in the thermal chamber, each separately, the results are obtained separately for each electric motor. The Dawesoft measuring system displays readings by collecting and processing data in the background using Q-DAS software. Q-DAS software is used for statistical data processing and analysis. The thermal chamber is thermally coated with special materials. The torque and speed meter is part of the measuring system. It shows the differences in the application of the two test conditions by sending a signal to the measuring system that the given conditions have been met. Based on that, the software prints the required temperature variables.

Table 2: Test conditions

First conditions	Second conditions
1) Temperature: +25°C	1) Temperature : +90°C
2) Test duration: 2h	2) Test duration: 2h
3) Module status: on	3) Module status: on
4) Operating point: E	4) Operating point: E
4.1) Torque: 0,77Nm	4.1) Torque: 0,77Nm
4.2) Nominal speed: 1000 rpm	4.2) Nominal speed: 1000 rpm
4.3) Operating voltage: 12V	4.3) Operating voltage: 12V

The analysis is performed at two different temperature points 25°C and 90°C. The heat dissipation test was performed under the conditions shown in Table 2.

The temperature of the electric motor is monitored by thermocouples. This electric motor has 5 thermocouples:

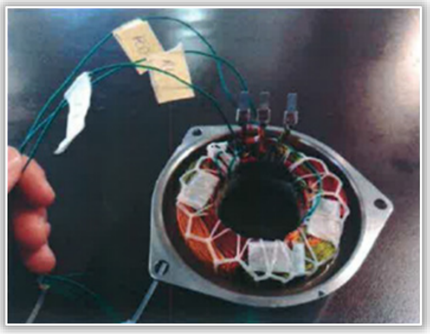
- 3 thermocouples on each phase inside the housing, near the rotor at the middle stator height (the position of the thermocouple may vary, depending on the available space in the winding during the insertion of the thermocouple) (Figure 1a)
- 2 thermocouples on the motor housing at the middle height of the housing and at the bottom (Figure 1b)

Table 3. Operating point

Operating point			
Speed numbers	Torque	Environmental temperature	Motor samples
1000 rpm	0,77 Nm	25°C	Table 1
		90°C	Table 1

The following Table 3 shows the operating parameters (operating point) of the electric motor during data collection.

Figure 1 shows the manner in which the installation of five thermocouples on the KOLT electric motor was performed.



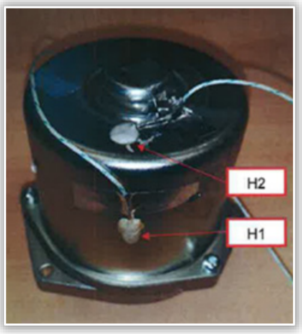


Figure 1. a) 3 thermocouples on phases b) 2 thermocouples at the bottom of motor housing

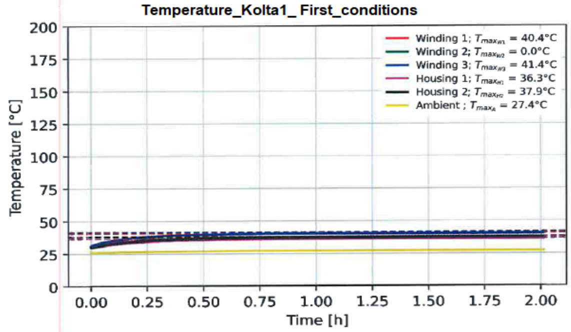
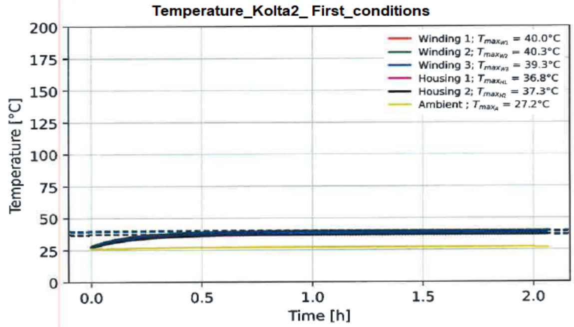
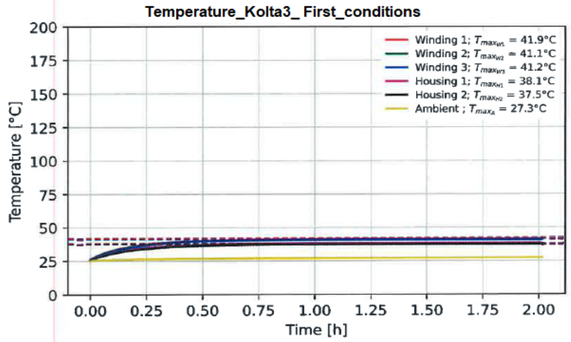
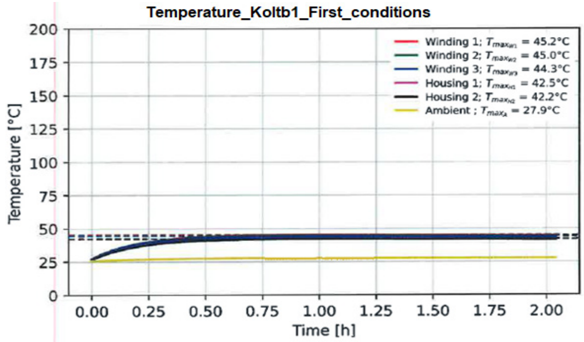
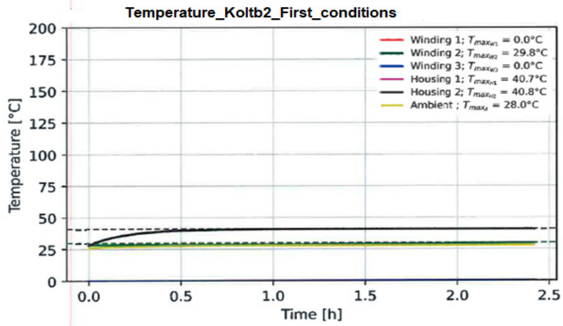
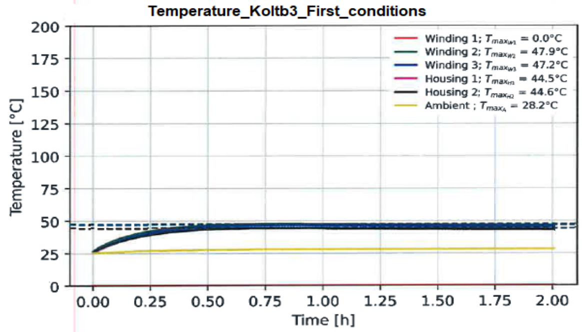
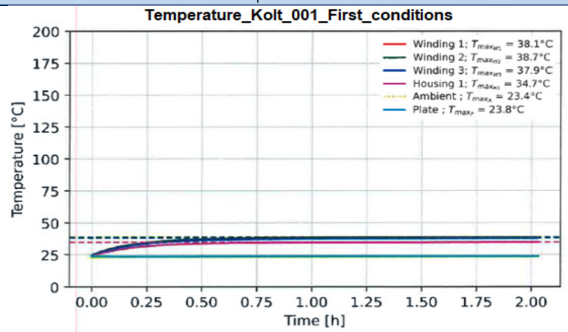
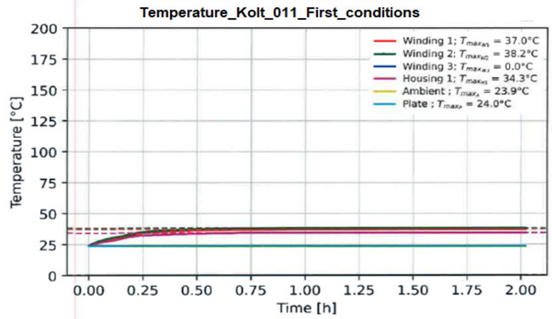
3. RESULTS

Data were collected from the measuring device with the support of software for graphical data display. First, data were collected for the first condition, and then for the second condition for observing the heat dissipation of electric motors in the environment, by observing all three groups of motors separately. In this way, data from 5 temperature points were obtained, which were checked using thermocouples type K. Tables 4 and 5 show the results for the first test conditions by groups A1, B1 and C1 (25 ° C, 2x, 0.77Nm, 1000rpm).

The temperature T_{H2} at the bottom housing of motor was not monitored or measured in group C1. If there is no temperature data in the data, it means that the thermocouples have failed.

Tables 6 and 7 show the results for second test conditions by groups A2, B2 and C2 (90°C, 2x, 0.77Nm, 1000rpm).

Table 4. Test results for the first conditions by groups A1, B1 and C1

Group A1 Kolta1	Group A1 Kolta2
	
Group A1 Kolta3	**Group B1 Koltb1**
	
Group B1 Koltb2	**Group B1 Koltb3**
	
Group C1 Kolt-001	**Group C1 Kolt-011**
	

Group C1 Kolt-111

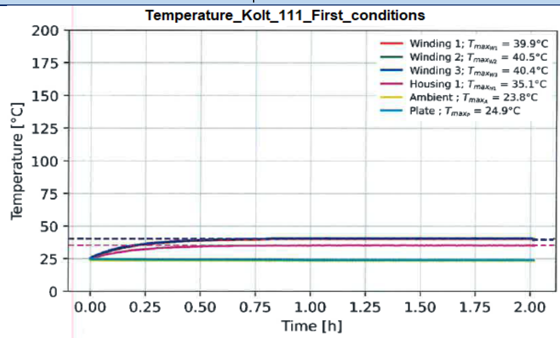
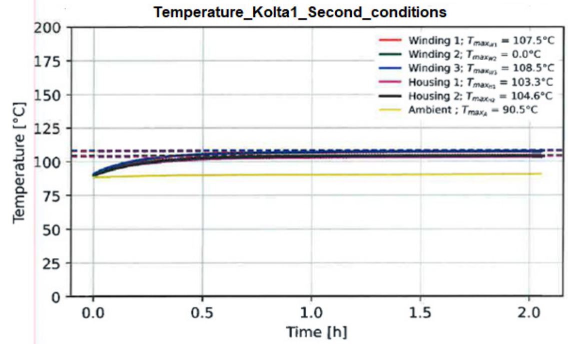
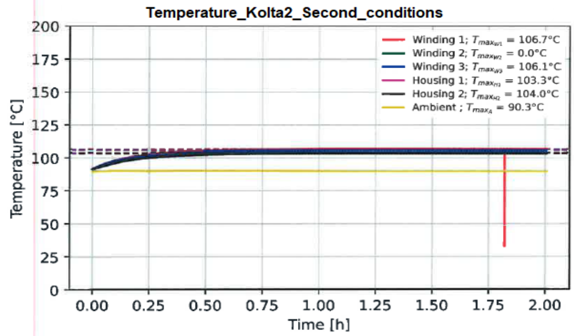


Table 6: Test results for the second conditions by groups A2, B2 i C2

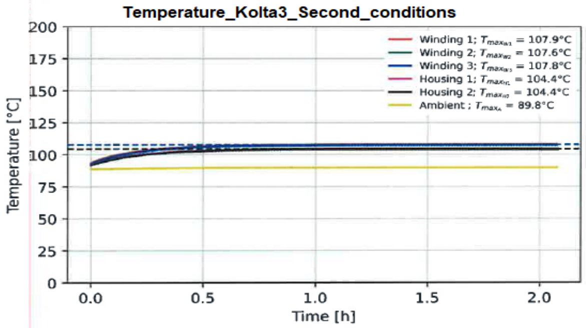
Group A2 Kolta1



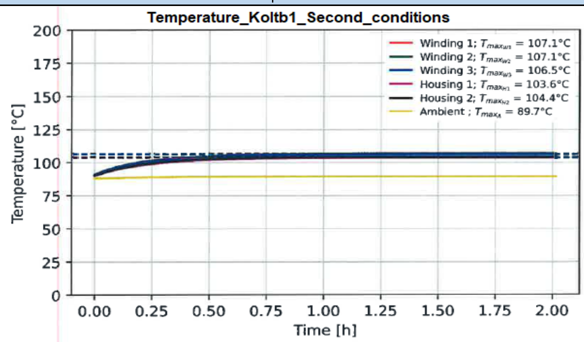
Group A2 Kolta2



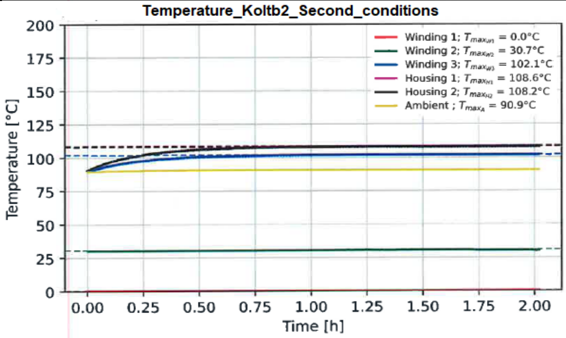
Group A2 Kolta3



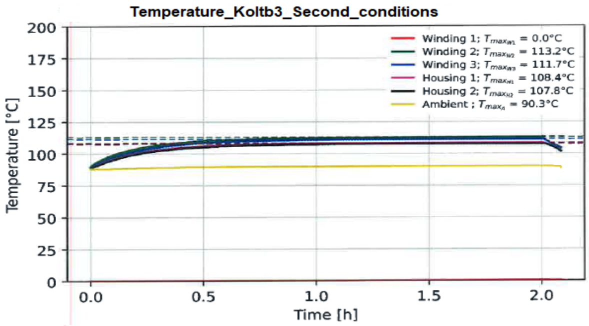
Group B2 Koltb1



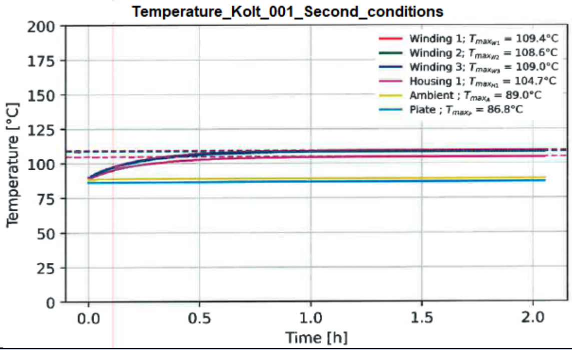
Group B2 Koltb2



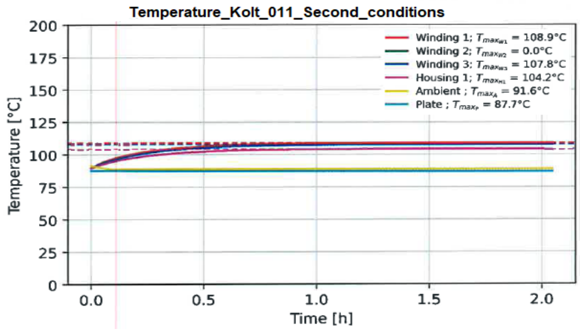
Group B2 Koltb3



Group C2 Kolt-001



Group C2 Kolt-011



Group C2 Kolt-111

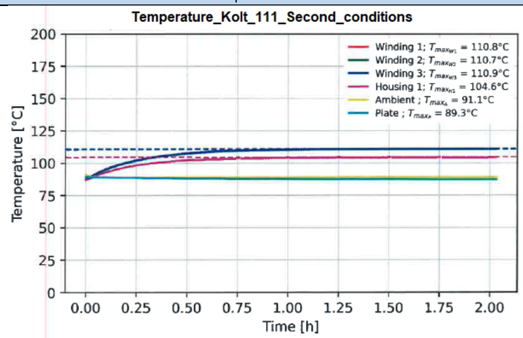


Table 5. Presentation of data for the first test condition

KOLT First test conditions							
Group	Motor No.	Tmax W1 [°C]	Tmax W2 [°C]	Tmax W3 [°C]	Tmax H1 [°C]	Tmax H2 [°C]	Tmax A [°C]
A1	Kolta1	40,4		41,4	36,3	37,9	27,4
	Kolta2	40,0	40,3	39,3	36,8	37,3	27,2
	Kolta3	41,9	41,1	41,2	38,1	37,5	27,3
	Average	40,8		40,6	37,1	37,6	27,3
B1	Koltb1	45,2	45,0	44,3	42,5	42,2	27,9
	Koltb2				40,7	40,8	28,0
	Koltb3		47,9	47,2	44,5	44,6	28,2
	Average				42,6	42,5	28,0
C1	Kolt-001	38,1	38,7	37,9	34,7		23,4
	Kolt-011	37,0	38,2		34,3		23,9
	Kolt-111	39,9	40,5	40,4	35,1		23,8
	Average	38,3	39,1		34,7		23,7
ΔB=B1-A1	Koltb1	4,8		2,9	6,2	4,3	0,5
	Koltb2				3,9	3,5	0,8
	Koltb3		6,8	6,0	6,4	7,1	0,9
	Average				5,5	5,0	0,7
	Average %				14,8%	13,2%	2,7%
ΔCa=C1-A1	Kolt-001	-2,3		-3,5	-1,6		-4,0
	Kolt-011	-3,0	-2,1		-2,5		-3,3
	Kolt-111	-2,0	-0,6	-0,8	-3,0		-3,5
	Average	-2,4			-2,4		-3,6
	Average %	-6,0%			-6,4%		13,2%
ΔCb=C1-B1	Kolt-001	-7,1	-6,3	-6,4	-7,8		-4,5
	Kolt-011				-6,4		-4,1
	Kolt-111		-7,4	-6,8	-9,4		-4,4
	Average				-7,9		-4,3
	Average %				-18,5%		-15,5%

Table 7: Presentation of data for the second test condition

KOLT Drugi uslovi testiranja							
Grupa	Motor No.	Tmax W1 [°C]	Tmax W2 [°C]	Tmax W3 [°C]	Tmax H1 [°C]	Tmax H2 [°C]	Tmax A [°C]
A2	Kolta1	107,5		108,5	103,3	104,6	90,5
	Kolta2	106,7		106,1	103,3	104,0	90,3
	Kolta3	107,9	107,6	107,8	104,4	104,4	89,8
	Average	107,4		107,5	103,7	104,3	90,2
B2	Koltb1	107,1	107,1	106,0	103,8	104,4	89,7
	Koltb2			102,1	108,6	108,2	90,9
	Koltb3		113,2	111,7	108,4	107,8	90,3
	Average			106,8	106,9	106,8	90,3
C2	Kolt-001	109,4	108,6	109,0	104,7		89,0
	Kolt-011	108,9		107,8	104,2		91,6
	Kolt-111	110,8	110,7	110,9	104,6		91,1
	Average	109,7		109,2	104,5		90,6
ΔB=B2-A2	Koltb1	-0,4		-2,0	0,5	-0,2	-0,8
	Koltb2			-4,0	5,3	4,2	0,6
	Koltb3		5,6	3,9	4,0	3,4	0,5
	Average			-0,7	3,3	2,5	0,1
	Average %			-0,7%	3,2%	2,4%	0,1%
ΔCa= C2-A2	Kolt-001	1,9		0,5	1,4		-1,5
	Kolt-011	2,2		1,7	0,9		1,3
	Kolt-111	2,9	3,1	3,1	0,2		1,3
	Average	2,3		1,8	0,8		0,4
	Average %	2,2%		1,6	0,8%		0,4%
ΔCb= C2-B2	Kolt-001	2,3	1,5	2,5	0,9		-0,7
	Kolt-011			5,7	-4,4		0,7
	Kolt-111		-2,5	-0,8	-3,8		0,8
	Average			2,5	-2,4		0,3
	Average %			2,3%	-2,3%		0,3%

The temperature T_{H2} at the bottom housing of motor was not monitored or measured in group C2.

4. DISCUSSION

The increase in motor temperature is not the same throughout the Kolt motor. Some positions in the motor will have a higher temperature, while other positions will have a lower temperature. The maximum temperature in the Kolt electric motor must be determined in order to ensure that other components on the vehicle are not endangered during the operation of the electric motor. When comparing motors from groups A, B and C, the maximum temperatures from the group data were used to estimate the heat dissipation of the motor since almost steady state was reached during the assessment. According to the results, motors from group C show the same thermal performance compared to groups A and groups B in the analysis with two different temperature conditions but with the same test duration and with the same operating parameters of the motors. Temperature deviations are in the expected range (± 7), based on the conditions obtained by the customer. The group tables with data compared the percentage deviation of Group B and Group C in relation to Group A, which was observed as a constant. Then the comparison of Group C in relation to Group A and Group B, since Group C is also PPAP samples, it is a group of motors that will be sent to the customer for approval for further production. Also, it can be noticed that the temperature of the housing is always colder in relation to the temperature of the windings in the electric motor, because there is constant cooling, air circulation. This fact is necessary to be accurate and proven, because at the request of the customer, it is crucial in order to be able to form the production and the quality of the product itself.

5. CONCLUSION

The paper analyzes the heat dissipation of electric motors. Q-DAS software for data processing is used for the mentioned analysis, the data were automatically stored in the internal memory of the computer unit with a sensor via thermocouples, and after the tests, data processing and graphical display were performed. Monitoring the temperature dissipation of the electric motor is of great importance for the long-term operation of the electric motor, as well as the construction and the environment of the vehicle in which the mentioned electric motor is installed. The collected data will also be forwarded to the development team that develops and constructs the motors, based on these data and analysis in the coming period could potentially change the design of the vehicle at the customer. This analysis accelerated the approval of PPAP samples (Group C motors) by the highly demanding customer. The manner and method of data collection for this type of electric motor has enabled a reduction in quality costs. Also, in this way, faster and more efficient cooperation is enabled in the relationship between the logistics of the manufacturer and the customer, in the relationship between sales and procurement.

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