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IMPACT OF HUMIDITY AND TEMPERATURE ON QUALITY OF AUTOMOTIVE PRODUCTS

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Abstract

In the automotive industry, maintaining optimal quality and performance for electronic components used in vehicles is crucial to meet consumer demands and regulatory standards. Humidity and temperature are pivotal environmental factors affecting automotive systems, influencing all essential electrical components. This article provides a study elucidating their effects on reliability, durability, and customer satisfaction. Additionally, it discusses the significance of controlling temperature and humidity in production areas and quality laboratories, highlighting their crucial role in ensuring the highest standards of quality and reliability in automotive manufacturing and analysis processes.

Key words: temperature effects on electronics, humidity impact on electronics, quality in automotive, environmental factors, production areas, quality laboratories, electronic product reliability

1. Introduction

In the automotive industry, ensuring optimal quality and performance of vehicles is paramount to meet the ever-growing demands of consumers and regulatory standards. Among the myriad factors influencing automotive quality, humidity and temperature stand out as crucial environmental variables with significant implications. Understanding the intricate interplay between these environmental factors and automotive systems is essential for enhancing product reliability, durability, and overall customer satisfaction.

Humidity and temperature exert profound effects on various components and systems within automotive vehicles, spanning from interior comfort features to critical mechanical and electrical systems. From the degradation of materials to the alteration of operational parameters, the influence of humidity and temperature permeates every aspect of automotive design, manufacturing, and operation [1].

This article provides an examination of the impact of humidity and temperature on automotive parts and system quality, drawing upon a synthesis of existing research findings and industry insights. Through an interdisciplinary approach, we delve into the mechanisms underlying the interactions between humidity, temperature, and automotive systems, elucidating both the challenges and opportunities they present.

2. Material and methods

The methodology of this study consisted in the exploration of the effects of temperature and humidity on electronic products, followed by the performance of experimental tests in which the temperature and humidity were measured in the manufacturing area and quality laboratory of an automotive company. The study was carried out for a period of 2 months in the interval 2023 May 15 – 2023 July 15.

2.1. Temperature effects on electronic products

Exposing electronic products from the automotive industry to high temperatures can create unique challenges when they are utilized in diverse applications, potentially affecting their performance and functionality. Normally electronic products have active or passive cooling systems to function correctly, but in some cases the cooling system is not necessary, not requested or is not desirable.

Elevated temperatures can affect the performance of electrical contacts, potentially altering their effectiveness and intensity. This may lead to changes in both chemical processes, such as corrosion, and physical processes, like stress relaxation [2].

Threshold for low and high temperatures can present more definition by vary domain where the products will be used. For example, the high temperature value can be acceptable for some products applications up to 140° C but for others may be maximum 40° C. Again, for low temperatures the range of values may be from –40° C up to 10° C for example. Most commonly automotive products have a broad range of temperature where they work correctly. Research reveals that the production hall temperature significantly impacts the quality of automotive components [3].

2.2. Humidity effects on electronic products

The effects that high humidity may have on electronic products from automotive industry are corrosion and/or rust. A high value of humidity in the air can cause various damages to the interior or exterior of electronic products and affect the overall reliability and lifetime of the electrical components of the manufactured products.

Water and water vapors residing on contact surfaces could lead to increased galvanic corrosion [4]. Humidity may also conduct electrical failures if even a small amount of water reaches the sensitive parts of the products. One common electrical failure created by humidity is short circuits.

These values are related to the functionality of these products, but we must consider the temperatures and moisture of production halls and quality laboratories where the products are manufactured respectively analyzed and measured.

The stringent control of temperature and humidity levels within production areas and quality laboratories is imperative, as deviations in these environmental factors can profoundly impact the integrity and performance of electronic components, underscoring the critical need for meticulous control to ensure the highest standards of quality and reliability in the manufacturing and analysis of electronic products employed in automotive applications.

Engineers must consider these factors during design and operation to ensure reliable and efficient systems [5].

2.3. Experimental study in company

The results presented in this study are focused on the influence and control of temperature and humidity in quality laboratories and production areas.

It is also necessary to record the temperature and humidity in the production areas as well as in the quality laboratories where the automotive products are analyzed and measured.

To achieve superior quality in the manufacture of electronic products, it is essential that in the production hall the temperature and humidity to be maintained by control systems which could ensure proper conditions for the production equipment. This is required because large fluctuations in temperature or humidity can affect not only the final quality of the products, but also that of the equipment used in manufacturing.

In the case of quality laboratories these factors can influence the results of the tests carried out on finished products, sub-assemblies, or raw materials.

This research is based on experimental measurements on the humidity and temperature control of the production hall as well as for a quality laboratory where the endurance and functionality tests of the products are done.

3. Results

The first measurements were carried out for the manufacturing area. In the explored period of 2 month, it was registered every day, at the same time, the values of temperature and at the same time the values of humidity. In table 1 are available the measured values of production area.

Table 1: Measurement of temperature and humidity in production area

ROOM TEMPERATURE			ROOM HUMIDITY		
Time	[°C]	Status	Time	[%rH]	Status
15.05.2023	21,969	Normal	15.05.2023	42,971	Normal
16.05.2023	21,944	Normal	16.05.2023	40,406	Normal
17.05.2023	22,000	Normal	17.05.2023	34,327	Normal
18.05.2023	22,069	Normal	18.05.2023	39,348	Normal
19.05.2023	21,979	Normal	19.05.2023	33,062	Normal
20.05.2023	21,943	Normal	20.05.2023	29,870	Normal
21.05.2023	22,051	Normal	21.05.2023	38,421	Normal
22.05.2023	22,034	Normal	22.05.2023	40,134	Normal
23.05.2023	22,012	Normal	23.05.2023	34,478	Normal
24.05.2023	21,943	Normal	24.05.2023	27,996	Normal
25.05.2023	22,047	Normal	25.05.2023	30,727	Normal
26.05.2023	22,032	Normal	26.05.2023	30,843	Normal
27.05.2023	22,025	Normal	27.05.2023	28,336	Normal
28.05.2023	21,964	Normal	28.05.2023	20,513	Normal
29.05.2023	21,943	Normal	29.05.2023	23,982	Normal
30.05.2023	22,035	Normal	30.05.2023	33,222	Normal
31.05.2023	22,032	Normal	31.05.2023	23,878	Normal
01.06.2023	22,031	Normal	01.06.2023	28,202	Normal
02.06.2023	21,991	Normal	02.06.2023	40,083	Normal
03.06.2023	21,949	Normal	03.06.2023	40,842	Normal
04.06.2023	21,987	Normal	04.06.2023	24,745	Normal
05.06.2023	21,988	Normal	05.06.2023	24,827	Normal
06.06.2023	22,011	Normal	06.06.2023	28,652	Normal
07.06.2023	21,964	Normal	07.06.2023	33,025	Normal
08.06.2023	21,958	Normal	08.06.2023	31,991	Normal
09.06.2023	21,942	Normal	09.06.2023	26,832	Normal
10.06.2023	22,054	Normal	10.06.2023	26,735	Normal
11.06.2023	21,978	Normal	11.06.2023	31,037	Normal
12.06.2023	22,034	Normal	12.06.2023	34,985	Normal
13.06.2023	21,986	Normal	13.06.2023	32,869	Normal
14.06.2023	21,946	Normal	14.06.2023	37,030	Normal
15.06.2023	22,033	Normal	15.06.2023	36,620	Normal
16.06.2023	21,982	Normal	16.06.2023	29,056	Normal
17.06.2023	22,070	Normal	17.06.2023	22,978	Normal
18.06.2023	21,971	Normal	18.06.2023	25,997	Normal
19.06.2023	21,946	Normal	19.06.2023	26,344	Normal
20.06.2023	22,003	Normal	20.06.2023	25,204	Normal
21.06.2023	22,076	Normal	21.06.2023	26,048	Normal
22.06.2023	22,001	Normal	22.06.2023	26,325	Normal
23.06.2023	20,630	Normal	23.06.2023	30,153	Normal
24.06.2023	19,867	Normal	24.06.2023	31,376	Normal
25.06.2023	19,944	Normal	25.06.2023	35,507	Normal
26.06.2023	20,299	Normal	26.06.2023	39,421	Normal
27.06.2023	20,280	Normal	27.06.2023	41,147	Normal
28.06.2023	19,703	Normal	28.06.2023	37,588	Normal
29.06.2023	19,184	Normal	29.06.2023	34,597	Normal
30.06.2023	18,967	Normal	30.06.2023	34,498	Normal
01.07.2023	18,864	Normal	01.07.2023	34,772	Normal
02.07.2023	18,645	Normal	02.07.2023	34,812	Normal
03.07.2023	18,900	Normal	03.07.2023	37,088	Normal
04.07.2023	21,918	Normal	04.07.2023	28,509	Normal
05.07.2023	21,969	Normal	05.07.2023	39,034	Normal
06.07.2023	22,034	Normal	06.07.2023	36,921	Normal
07.07.2023	21,976	Normal	07.07.2023	27,714	Normal
08.07.2023	21,959	Normal	08.07.2023	30,885	Normal
09.07.2023	22,011	Normal	09.07.2023	36,237	Normal
10.07.2023	21,944	Normal	10.07.2023	26,484	Normal
11.07.2023	21,942	Normal	11.07.2023	17,988	Normal
12.07.2023	21,942	Normal	12.07.2023	17,355	Normal
13.07.2023	22,058	Normal	13.07.2023	19,684	Normal
14.07.2023	22,039	Normal	14.07.2023	20,407	Normal
15.07.2023	22,054	Normal	15.07.2023	21,229	Normal

Based on the recorded values in table 1, a time series graphical representation was created. Figure 1 represents in green color the values of humidity together with the lower and upper limits of acceptable humidity in the manufacturing area. The blue color shows the recorded temperature values together with the lower and upper limits.

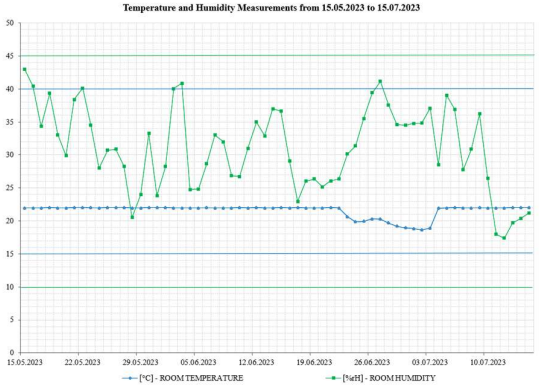

Fig. 1: Temperature and humidity measurements for production area

Next measurements were performed in the quality laboratory form studied automotive company. The measurements were carried out in the same 2 months of the study period when the values for temperature and humidity were recorded. Table 2 presents the measurements recorded.

Table 2: Measurement of temperature and humidity in laboratory area

ROOM TEMPERATURE			ROOM HUMIDITY		
Time	[°C]	Status	Time	[%rH]	Status
15.05.2023	20,096	Normal	15.05.2023	41,784	Normal
16.05.2023	19,994	Normal	16.05.2023	41,679	Normal
17.05.2023	19,929	Normal	17.05.2023	40,644	Normal
18.05.2023	19,849	Normal	18.05.2023	40,230	Normal
19.05.2023	20,117	Normal	19.05.2023	39,280	Normal
20.05.2023	20,044	Normal	20.05.2023	39,509	Normal
21.05.2023	20,256	Normal	21.05.2023	38,490	Normal
22.05.2023	19,921	Normal	22.05.2023	38,972	Normal
23.05.2023	20,051	Normal	23.05.2023	39,096	Normal
24.05.2023	20,118	Normal	24.05.2023	39,500	Normal
25.05.2023	20,122	Normal	25.05.2023	39,713	Normal
26.05.2023	20,320	Normal	26.05.2023	39,518	Normal
27.05.2023	20,154	Normal	27.05.2023	39,262	Normal
28.05.2023	21,590	Normal	28.05.2023	40,934	Normal
29.05.2023	21,618	Normal	29.05.2023	39,705	Normal
30.05.2023	20,417	Normal	30.05.2023	39,919	Normal
31.05.2023	20,193	Normal	31.05.2023	39,792	Normal
01.06.2023	21,561	Normal	01.06.2023	39,790	Normal
02.06.2023	20,260	Normal	02.06.2023	39,157	Normal
03.06.2023	21,419	Normal	03.06.2023	40,119	Normal
04.06.2023	20,291	Normal	04.06.2023	40,590	Normal
05.06.2023	21,573	Normal	05.06.2023	39,935	Normal
06.06.2023	21,553	Normal	06.06.2023	39,536	Normal
07.06.2023	20,521	Normal	07.06.2023	42,039	Normal
08.06.2023	20,258	Normal	08.06.2023	39,291	Normal
09.06.2023	19,919	Normal	09.06.2023	41,532	Normal
10.06.2023	20,051	Normal	10.06.2023	42,204	Normal
11.06.2023	19,724	Normal	11.06.2023	41,426	Normal
12.06.2023	19,710	Normal	12.06.2023	39,190	Normal
13.06.2023	19,980	Normal	13.06.2023	40,038	Normal
14.06.2023	19,899	Normal	14.06.2023	39,791	Normal
15.06.2023	20,122	Normal	15.06.2023	39,269	Normal
16.06.2023	20,315	Normal	16.06.2023	39,250	Normal
17.06.2023	19,949	Normal	17.06.2023	41,072	Normal
18.06.2023	20,183	Normal	18.06.2023	39,400	Normal
19.06.2023	19,985	Normal	19.06.2023	41,358	Normal
20.06.2023	19,917	Normal	20.06.2023	39,697	Normal
21.06.2023	19,917	Normal	21.06.2023	38,999	Normal
22.06.2023	20,108	Normal	22.06.2023	37,092	Normal
23.06.2023	20,255	Normal	23.06.2023	40,180	Normal
24.06.2023	20,066	Normal	24.06.2023	40,595	Normal
25.06.2023	19,870	Normal	25.06.2023	38,874	Normal
26.06.2023	20,111	Normal	26.06.2023	42,020	Normal
27.06.2023	20,605	Normal	27.06.2023	40,365	Normal
28.06.2023	20,125	Normal	28.06.2023	40,194	Normal
29.06.2023	20,122	Normal	29.06.2023	39,413	Normal
30.06.2023	20,322	Normal	30.06.2023	42,138	Normal
01.07.2023	20,256	Normal	01.07.2023	39,084	Normal
02.07.2023	19,991	Normal	02.07.2023	40,596	Normal
03.07.2023	19,720	Normal	03.07.2023	40,992	Normal
04.07.2023	19,915	Normal	04.07.2023	42,054	Normal
05.07.2023	20,050	Normal	05.07.2023	38,173	Normal
06.07.2023	20,120	Normal	06.07.2023	40,459	Normal
07.07.2023	20,186	Normal	07.07.2023	41,130	Normal
08.07.2023	20,118	Normal	08.07.2023	42,207	Normal
09.07.2023	20,256	Normal	09.07.2023	40,489	Normal
10.07.2023	20,257	Normal	10.07.2023	39,273	Normal
11.07.2023	20,126	Normal	11.07.2023	38,325	Normal
12.07.2023	20,186	Normal	12.07.2023	39,756	Normal
13.07.2023	20,124	Normal	13.07.2023	41,753	Normal
14.07.2023	20,189	Normal	14.07.2023	40,353	Normal
15.07.2023	20,590	Normal	15.07.2023	39,278	Normal

In figure 2 it is represented the recorded values for temperature and humidity in the quality laboratory. It is visible that the situation regarding variations in the recorded parameters is different compared with the production area.

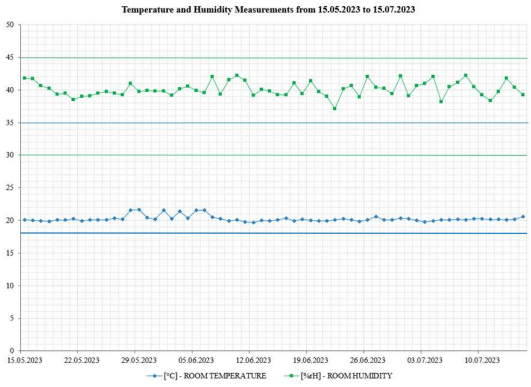

Fig. 2: Temperature and humidity measurements for laboratory area

The quality standards request for measurement laboratory to dispose of humidity regulators and controlled temperature with different special equipment installed on the laboratory.

After subjecting tested etalon automotive electronic products to varying temperature and

humidity conditions, the study revealed a significant variation in electrical contact resistance, with fluctuations of up to 12% and an accumulation of oxide layer that led do decreased flexibility in assembly by up to 0,3%. These findings underscore the critical impact of temperature and humidity on the quality and reliability of automotive electronic components, highlighting the need for robust design and mitigation strategies to ensure optimal performance in diverse environmental conditions.

4. Discussion

The interpretation of the humidity graph in figure 1 reveals the fact that the values are not stabilized. Our study revealed that the humidity is not controlled very well in the manufacturing sector but anyways the values recorded are within the limits. Considering this, no negative impact should be present on the electronic products manufactured in this zone.

In the quality laboratory the values of humidity and temperature are more stable as can be seen in figure 2. Constant values of both temperature and humidity are important for precise results of measurements and analysis of electronic automotive parts because the limits are very tight.

The investigation into temperature effects on electronic products reveals unique challenges posed by high temperatures in different applications within the automotive industry. It emphasizes the necessity of active or passive cooling systems for electronic products to function correctly, while acknowledging the varying thresholds for low and high temperatures depending on product applications. The study highlights the significant impact of production hall temperature on automotive component quality.

Regarding humidity effects on electronic products, the study identifies corrosion, rust, and electrical failures as potential consequences of high humidity levels. It stresses the importance of stringent control of temperature and humidity levels within production areas and quality laboratories to maintain the integrity and performance of electronic components.

In the measurements conducted in an automotive company, the study focuses on the influence and control of temperature and humidity in quality laboratories and production areas. It highlights the necessity of temperature and humidity control systems in production halls to ensure appropriate conditions for production equipment and assemblies and the significant impact of temperature and humidity fluctuations on the final quality of products and the results of tests carried out in quality laboratories. It emphasizes the importance of constant values of temperature and humidity for precise results in the analysis of electronic automotive parts.

3. Conclusions

We conclude that, both temperature and humidity, have a much greater variability in the manufacturing area, compared to the quality laboratory. This situation significantly impacts the performance, longevity, and functioning of automotive electronics.

By elucidating the complex relationship between humidity, temperature, and automotive quality, this article contributes to the advancement of knowledge in the field, offering valuable insights for automotive engineers, designers, and researchers. Ultimately, a deeper understanding of these environmental factors is indispensable for the development of innovative strategies to enhance automotive quality, performance, and resilience in the face of diverse operating conditions.

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