TECHNICALUNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue Special III, November, 2022

MONITORING TEMPERATURE, HUMIDITY AND AIR VELOCITY LEVELS IN A FACTORY IN THE AUTOMOTIVE COMPONENT MANUFACTURING INDUSTRY

Constanța RÎNJEA (COSTACHE), Anamaria Ioana FEIER, Oana Roxana CHIVU, Claudia BORDA, Marilena GHEORGHE

Abstract: *The aim of this case study is to determine the values of microclimate parameters and their effects on the health of employees in the automotive component manufacturing industry. During the study, data were collected from several areas of the factory: production, production lines, workbenches (operation), warehouse, prototype laboratory, rest area and sitting area. These are the areas where many employees work. Measurements were made over several days to see the evolution of the recorded data.*
The results on the detection of microclimate parameters showed that the values are occasionally exceeded for short periods of time.
Key words: *temperature, humidity, air speed, working environment, health.*

1. INTRODUCTION

The workplace microclimate is characterized by temperature, humidity, air velocity, heat radiation in work areas and airborne dust in workplaces. These have a significant impact on employee health [1].

The automotive component manufacturing industry is one of the largest manufacturing sectors in the European Union and the automotive value chain covers many activities such as design and engineering, manufacturing, maintenance and repair and handling of end-of-life vehicles. They are the most advanced in terms of environmental performance in areas such as energy and resource efficiency, emissions or supply chain management [2].

Long-term body activity in an environment where optimal microclimate conditions have been exceeded can lead to human fatigue in the work process. During work, the temperature, humidity and airflow velocity values in the work and ancillary rooms containing the workplaces must be appropriate to the process.

Given the methods, work activities and tasks that are carried out in the work process, indoor air must be fresh for the smooth running of the work and the maintenance of employee health [3].

2. EXPERIMENTAL RESEARCH AND DEBATES

In this case study we monitored the following microclimate parameters: temperature, humidity and airflow velocity.

2.1. Description of measuring instruments

The instrument used to measure the parameters is the KIMO LV 110 Anemometer in Figures 1 and 2. The measurement unit for temperature is degrees Celsius(°C) and for air current velocity (m/s). Humidity is the ratio in percent (%) of the actual water vapor pressure to the maximum pressure corresponding to the current air temperature.

To determine the velocity of air currents, we made measurements directly at the source, ventilation ducts, grilles and ventilation anemostats. Air movements are developed in the ventilation ducts. To measure air currents, the measuring instrument is attached directly to or inside the ventilation duct.

Figure 3 shows the temperature inside a production section using an indoor thermometer, and Figure 4 is a Digital Thermometer and Hygrometer showing temperature and humidity simultaneously.

The areas chosen for the measurements: production lines, workbenches (operation), prototyping lab, storeroom, relaxation area, sitting area inside the production area.

Furtehrmore, Table 1 and Table 2 show the measurements made in the above mentioned areas of the factory.

Fig. 1. KIMO LV 110 anemometer.

Fig. 2. KIMO LV 110 anemometer during measurements.

Fig. 3. Indoor thermometer.

Fig. 4. Thermometer and Digital Hygrometer.

Table 1.

Measurement of air velocity, temperature and humidity on production lines and workbenches.

Zone	Air velocity [m/s]	Temperature [°C]	Humidity [% Rh]
Production: Line 1	0.06-0.10	24.9	44.8
Production: Line 2	0.09-0.11	24.8	44.9
Production: Line 3	0.08	24.9	44.7
Workstation No. 1	0.02-0.06	25	45
Production: Line 4	0.17	25.1	45
Production: Line 5	0.02-0.13	25.2	45.1
Production: Line 6	0.05-0.13	25.3	45.2
Production: Line 7	0.04-0.07	27	44.7
Production: Line 8	0.17-0.21	26.7	44.5
Production: Line 9	0.19-0.24	26.1	44.2
Production: Line 10	0.03	27	44.9
Production: Line 11	0.03-0.05	27.3	44.7

Production: Line 12	0.01-0.02	27.1	44.5
Workstation Nr. 2	0.01	27	44.7
Production: Line 13	0.10-0.15	26.4	44.5
Production: Line 14	0.06	26.3	44.3
Production: Line 15	0.01-0.12	26.2	44.5
Production: Line 16	0.10-0.16	26.2	44.5
Production: Line 17	0.20-0.45	27.3	44.5
Production: Line 18	0.30-0.46	27.3	44.2
Workstation Nr. 3	0.13-0.20	27.1	44.4
Production: Line 16	0.05	26.2	44.6
Production: Line 17	0.15-0.19	25.5	44.7
Production: Line 18	0.13-0.16	25.4	44.8
Production: Line 19	0.07-0.08	25.4	44.7
Production: Line 20	0.16-0.19	25.5	44.6
Production: Line 21	0.20-0.22	25.6	44.6
Workstation Nr. 4	0.03-0.23	25.6	44.7
Production: Line 22	0.04	25.5	44.8
Production: Line 23	0.06-0.12	26.3	44.1
Production: Line 24	0.22-0.35	26.3	44.2
Workstation Nr. 5	0.01-0.09	26.4	43.8
Production: Line 25	0.18-0.25	26.3	43.8
Production: Line 26	0.04	24	44.8
Production: Line 27	0.08-0.15	24.4	44.6
Workstation Nr .6	0.04-0.15	25.9	44.3
Production: Line 28	0.03-0.35	25.9	44.4
Workstation Nr. 7	0.06-0.16	25.9	44.4
Production: Line 29	0.02	25.6	44.5
Production: Line 30	0.03-0.07	25.7	44.7
Production: Line 31	0.05-0.06	25.3	44.4
Workstation Nr. 8	0.07-0.35	25.6	44.4
Workstation Nr. 9	0.01-0.05	25.7	44.5
Production: Line 32	0.07-0.11	25.7	44.5
Workstation Nr. 10	0.10-0.16	27.1	44.1
Workstation Nr. 11	0.06	27.2	44.5
Production: Line 33	0.06-0.09	25.3	44.4

Table 2

Measurement of air velocity, temperature and humidity in different areas of the factory

Zone	Air velocity [m/s]	Temperature [°C]	Humidity [% Rh]
Prototypes	0.10-0.16	24.7	44.7
Store	0.26-0.50	23.7	44.7
Lounge area	0.14-0.18	25.5	44.5
Sitting area inside the Production area	0.02-0.12	24.8	44.9

Table 3

Measurement of temperature and humidity in different areas of the factory

Measured temperature[°C]	Measured humidity[%Rh]	Location factory	Date measurements	Time of effect of registrations
23.7	29	zone 1	09.04.2021	13:30
24.5	28.1	zone 2	09.04.2021	13:30

25.6	32.6	zone 3	09.04.2021	13:31
25.6	32.4	zone 4	09.04.2021	13:32
24.1	30.3	zone 5	09.04.2021	13:32
25.1	28.1	zone 6	09.04.2021	13:33
24.6	27.5	zone 7	09.04.2021	13:34
25	30	zone 8	09.04.2021	13:34
26.8	32.1	zone 1	19.04.2021	17:05
24	28.7	zone 2	19.04.2021	17:05
26.5	34.3	zone 3	19.04.2021	17:06
26.3	35.2	zone 4	19.04.2021	17:06
27.2	31.5	zone 5	19.04.2021	17:07
24.1	30	zone 6	19.04.2021	17:08
24	29	zone 7	19.04.2021	17:09
23.6	32.2	zone 8	19.04.2021	17:10
25.5	34.8	zone 1	25.05.2021	23:30
25.4	35.4	zone 2	25.05.2021	23:31
26	35.1	zone 3	25.05.2021	23:31
26.7	35	zone 4	25.05.2021	23:32
26.4	32.7	zone 5	25.05.2021	23:32
26.3	32.7	zone 6	25.05.2021	23:33
25	33	zone 7	25.05.2021	23:33
25.6	34.2	zone 8	25.05.2021	23:34

Measurements were made on several areas of the factory. An area represents several production lines that have the same process. The determination of the values in Table 3 were carried out over 3 days to cover the 3 shifts.

3. INTERPRETATION OF THE RESULTS OBTAINED

3.1. Experimental results

Below are the graphs made from the measurements.

In Figures 5, 6, 7, 8, 9 and 10 mentioned above, it can be seen the determination of temperature, humidity and air velocity from the production area (production lines and workstations), warehouse, rest area and sitting area inside the production area.

The determined values are partially within the limits, considering the increase of the values at temperature -25.5, 26.8, 27 °C, the speed of air currents >0.25 m/s- 0.28, 0.33, 0.54 m/s and the decrease below the limit at humidity below 30%- 26.2, 27, 28, 29 %.

The comfort threshold for temperature is 14-25°C and for humidity 30-70%. Both consider the activity. The measurements showed that the values were exceeded in some areas for the three microclimate parameters: temperature, humidity, and airflow velocity.

Following the measurements, we found that some of the employees who worked in areas with temperatures above 25°C, humidity below 30% and air velocity above 0.25 m/s showed the following symptoms: tiredness, impaired ability to concentrate, irritated eyes, dry throat, feeling thirsty, rashes, eczema, shortness of breath, headaches and dehydration. Employees who worked in areas with a temperature below 25°C also experienced discomfort due to the increased speed of air currents (headaches, dry neck).

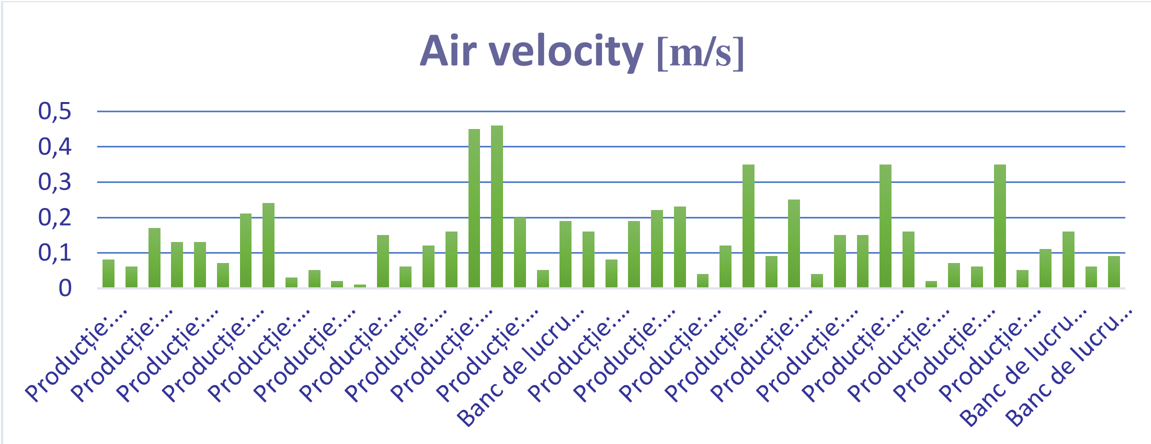

Fig. 5. Air velocity on production lines and workstations.

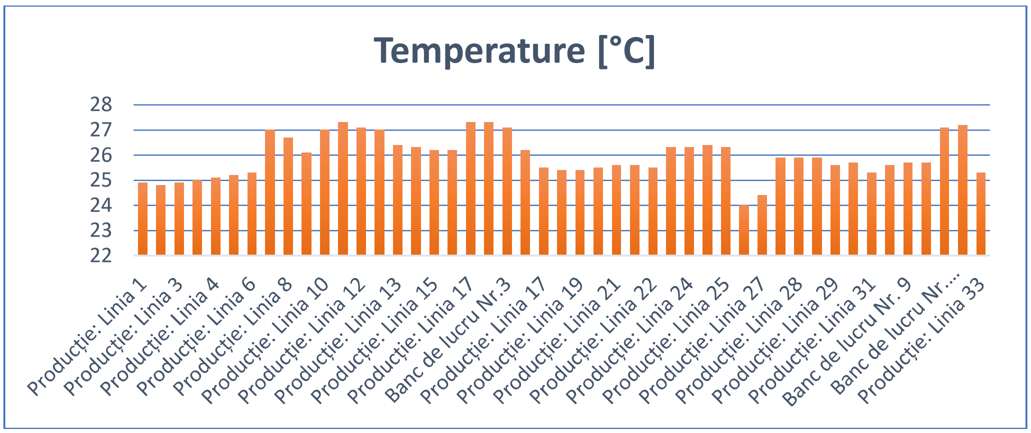

Fig. 6. Temperature on production lines and workstations.

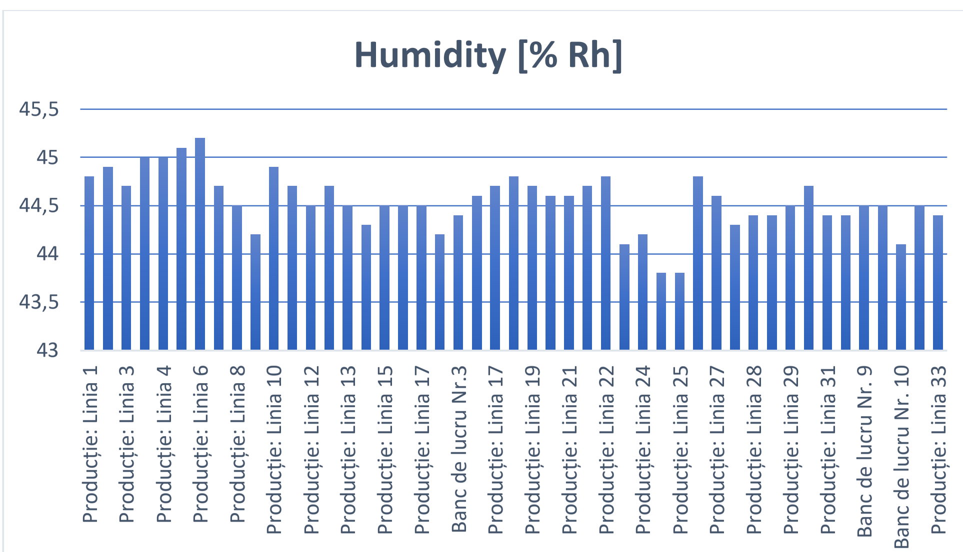

Fig. 7. Humidity on production lines and workstations.

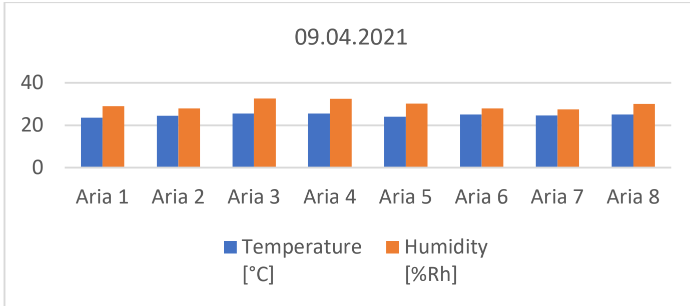

Fig. 8. Recorded values of temperature and humidity per area on 09.04.2021.

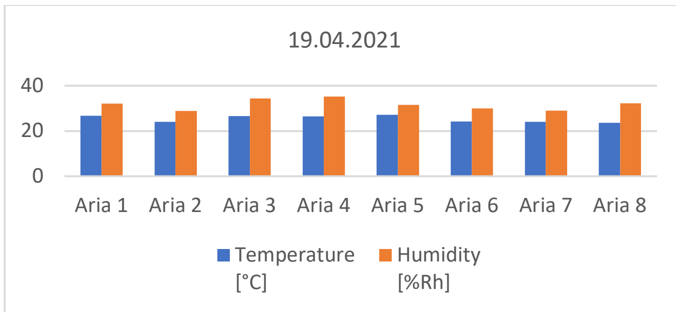

Fig. 9. Recorded values of temperature and humidity per area on 19.04.2021.

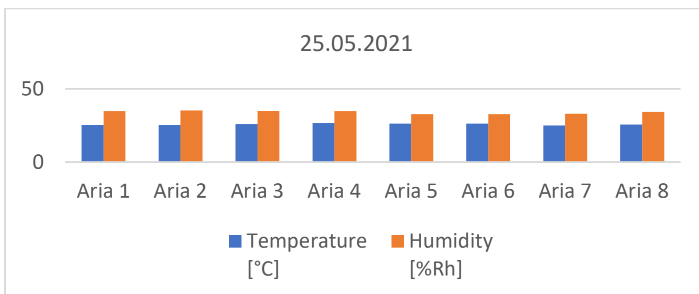

Fig. 10. Recorded values of temperature and humidity per area on 25.05.2021.

The values in Tables 1, 2 and 3 exceeding 25°C represent heat given off by production equipment, doors, open windows and air conditioning. Excessive indoor air movement can cause local thermal discomfort. SR EN ISO 7730/2006 recommends the following airflow velocities [4]:

1. For: lighter activity in season requiring heating, indoor temperature is 20-24° C, the standard recommends $v<0.15$ m/s
2. For: lighter activity in summer season, indoor temperature is 23-26° C, standard recommends $v<0.25$ m/s.

3.2. Causes identified

Humidity values below 30%, temperatures above 25°C and air velocity above 0.25 m/s represent a few problems with the plant's air conditioning and ventilation system.

- The air conditioning system dries the air; the humidity decreases Thus the warm air moves to the cold air;
- The air conditioning system does not serve the whole building;
- The air-conditioning system does not cope with the heat generated by production equipment (robots, electric motors, transformers, test benches with internal combustion engines);
- Doors and windows open in both hot and cold weather. This sharply decreases humidity inside the building;
- The air velocity supplied by the ventilation system is increased and can lead to employee illness.

3.3. Improvement measures

The main improvement measurements that should be taken into consideration are [5-8]:

- Installation of additional air-conditioning units throughout the plant. A more powerful air-conditioning system to bring the temperature to optimum comfort and keep the humidity within the reference values.
- Installation of humidifiers to preserve humidity; installation of humidity nozzles also related to the air-conditioning system.
- Introducing humidity into recirculated air (equipment that increases air humidity).
- Increasing the insulation of the building (windows, building envelope), use of energy efficient equipment.
- Maintain optimal temperatures on each production line, workstation.

4. CONCLUSIONS

The study investigated the effects of microclimate in the automotive component manufacturing industry.

Microclimate parameters were examined including relative humidity (%), wind speed (m/sec), and temperature (° C). Measurements in the study were performed with the heat sources on, in normal activity on 3 shifts.

The main source of heat is specific equipment in the production area and employee activity. Measurements were made by recording on certain hourly intervals on different days and plotting the data in graphs.

Comparing the results of the measurements carried out and presented in Tables 1, 2 and 3 to the limitations of the legislation in force, it is found that values exceeding the limitations are occasionally recorded for short periods of time.

In conclusion, the comfort of an employee working in the workplace may suffer from an inadequate microclimate. The purpose of each factory is to cool and heat the working areas according to the specific activity of each process.

Everyone can suffer when moving from a hot to a cold environment, but also from a cold to a very hot environment, which requires a balance between microclimate parameters. High or low values can affect the health as well as the comfort of employees.

The case study is to determine the values of microclimate parameters and their effects on the health of employees in the automotive component manufacturing industry. During the study data were collected from several areas of the factory: production, production lines, workbenches (operation), warehouse, prototype laboratory, rest area and sitting area.

In this case study the following microclimate parameters were monitored: temperature, humidity and airflow velocity, the case study results on the detection of microclimate parameters showed that the values are occasionally exceeded for short periods in time.

The measurements showed that some of the employees who worked in areas with temperatures above 25°C, humidity below 30% and air velocity above 0.25 m/s showed the following symptoms: tiredness, impaired ability to concentrate, irritated eyes, dry throat, feeling thirsty, rashes, eczema, shortness of breath, headaches, and dehydration.

Excessive indoor air movement can cause local thermal discomfort and SR EN ISO 7730/2006 recommends the following airflow velocities [4]:

1. For light activity in season requiring heating, indoor temperature is 20-24° C, the standard recommends $v<0.15$ m/s;
2. For light activity in the summer season, the indoor temperature is 23-26° C, the standard recommends $v<0.25$ m/s.

Future studies will be focused on the investigation of the working conditions and occupational health and safety characterizations in other industrial companies based on university-industry collaborations and technical consulting contracts [9]. Thus, companies could increase the workplace wellbeing, labor productivity [10] and competitiveness [11, 12]. In addition, special attention will be given to the employees training in the field of indoor air quality and the monitoring process of the main characterization parameters (e.g., using modern and dynamic training systems as presented in [13, 14]).

5. REFERENCES

[1] Plopeanu, E. F., *Experimental research on the capture and recovery of fine-grained oxide waste generated in*

the ceramic and refractory materials industry, Bucharest 2020.

[2] Gaudillat, P.F., Antonopoulos, I.S., Dri, P. Canfora, M., Traverso, M., *Best Environmental Management Practice for the Car Manufacturing Sector*, JRC Science for Policy Report, 2017.

[3] Official Gazette RS, number 21/2009, *Regulation on preventive measures for safe and healthy work in the workplace*, 2009.

[4] SR EN ISO 7730/2006, *Ambianţe termice moderate. Determinarea analitică şi interpretarea confortului termic prin calculul indicilor PMV şi PPD şi specificarea criteriilor de confort termic local.*

[5] Chivu, O. R., *Research and contributions on occupational health and safety in the field of industrial engineering,* Assoc. UPB, 2020.

[6] Feier, A., Banciu, F., *Ergonomic aspects of real and virtual welding tools*, Acta Tehnica Napocensis/Series Applied mathematics, mechanics and Engineering, 64(1-S1), 2021.

[7] Dimitrescu, A., Babis, C., Alecusan, A. M., Chivu, O. R., Feier, A., *Analysis of Quality Problems in Production System Using the PDCA Instrument,* Fiability & Durability / Fiabilitate si Durabilitate, 1, pp. 286-292. 2018.

[8] Firu, A., Țăpîrdea, A., Chivu, O. R., Feier, A., Drăghici,G., *The competences required by the new technologies in Industry 4.0 and the development of employees' skills*, Acta Technica Napocensis Series-Applied Mathematics Mechanics and Engineering, 64(1-S1), 2021.

[9] Draghici, A., Baban, C. F., Ivascu, L. V., Sarca, I. (2015). *Key success factors for university–industry collaboration in open innovation*, Proceedings of the ICERI2015, ISBN: 978-84-608-2657-6, 7357-7365, IATED, 2015.

[10] Albulescu, C. T., Draghici, A., Fistiş, G. M., Trusculescu, A., *Does ISO 9001 quality certification influence labor productivity in EU-27?* Procedia of Social and Behavioral Sciences, 221, 278-286, 2016.

[11] Paschek, D., Rennung, F., Trusculescu, A., Draghici, A., *Corporate development with agile business process modeling as a key success factor*, Procedia Computer Science, 100, 1168-1175, 2016.

[12] Baesu, V., Albulescu, C.T., Farkas, Z.B., Draghici, A., *Determinants of the high-tech sector innovation performance in the European Union: a review,* Procedia Technology, 19, 371-378, 2015.

[13] Gogan, M. L., Sirbu, R., Draghici, A., *Aspects concerning the use of the Moodle platform – case study*, Procedia Technology, 19, 1142-1148, 2015.

[14] Draghici, A., Mocan, M., Draghici, G., *On-line training and certification solution for business process managers*. Proceedings of International conference on enterprise information systems (380-389). Springer, Berlin, Heidelberg, 2011.

Monitorizarea nivelurilor de temperatură, umiditate și viteză a curenților de aer într-o fabrică din industria producătoare de componente auto

Scopul cercetării prezentate (studiu de caz) este de a determina valorile parametrilor de microclimat și efectele asupra sănătății angajaților din industria de fabricare a componentelor auto. In timpul studiului au fost colectate date din mai multe zone ale fabricii: producție (linii de producție, bancuri de lucru), zonele de depozitare (magazii, depozite), laborator prototipuri, zona de relaxare și cea de sedințe. Acestea reprezintă ariile unde își desfășoară activitatea un număr mare de angajați. Măsuratorile au fost realizate în mai multe zile pentru a se vedea evoluția fenomenelor investigate. Rezultatele privind deteminarea parametrilor de microclimat au arătat că valorile sunt depășite ocazional pentru perioade scurte de timp.

Constanța RÎNJEA (COSTACHE), PhD Student, Industrial Engineering and Robotics Doctoral School, Politehnica University of Bucharest, rinjea.tatiana@gmail.com, +40740787199, 313 Splaiul Independenței, Sector 6, RO-060042 Bucharest, Romania.

Anamaria Ioana FEIER, PhD., Assoc. Prof., Politehnica University Timișoara, Materials and Manufacturing Engineering Department, ana-maria.feier@upt.ro, +40 741111858, 1 Mihai Viteazu Bd., 300222, Timișoara, Romania.

Roxana Oana CHIVU, PhD., Professor, Politehnica University of Bucharest, Faculty of Industrial Engineering and Robotics, virlan_oana@yahoo.co.uk, +40722219498, 313 Splaiul Independenței, Sector 6, RO-060042 Bucharest, Romania.

Claudia BORDA, PhD., Assoc. Prof., Politehnica University of Bucharest, Faculty of Industrial Engineering and Robotics, ctistere@yahoo.com, +40747970458, 313 Splaiul Independenței, Sector 6, RO-060042 Bucharest, Romania.

Marilena GHEORGHE, PhD.Lecturer, Politehnica University of Bucharest, Faculty of Industrial Engineering and Robotics, ghe_marilena@gmail.com, +40722323451, 313 Splaiul Independenței, Sector 6, RO-060042 Bucharest, Romania.