STUDIES ON DRILLING OF FIBROUS COMPOSITES

Maria OCNARESCU [1], Paulina SPANU [2], Aurelian VLASE [3], Constantin OPRAN [4]

ABSTRACT

Though adhesive bonding is a preferred method of joining fibrous composite, sometimes bolting of components is essential for operation, maintenance or inspection purposes. It is necessary to drill holes in fibrous composites for joining them by bolting. Drilling of fibrous composite presents many problems like - delaminating, fibre/resin pullout, excessive tool wear. In the present work, drilling of glass fibre/epoxy and carbon fibre/epoxy laminates is studied using high speed steel and tungsten carbide coated drills. The effect of cutting speed, feed and number of holes on tool wear, thrust and torque is studied.

KEYWORDS: composites, cutting, drilling, machining

1. INTRODUCTION

Advanced Fiber Reinforced Plastics Composites are being increasingly used in modern aerospace and other engineering applications.

This is mainly due to the high specific mechanical properties offered by these materials and the possibility of tailoring their performance.

Though composites have excellent performance characteristics, but when machined they tend to develop the following flaws:

I. Surface delimitation: separation of plies where the cutter enters and exits the material.

II. Internal delimitation: separation that develops between plies as a result of improper machining and drilling.

III. Fiber/resin pullout: tearing away of fiber/resin from the wall of the machined edge.

IV. Higher tool wear due to abrasion by hard fibers.

V. Lower flexural strength causes easy deformation of hole which subsequently leads to hole, shrinkage.

VI. Presence of powdery chip which is a health hazard and is difficult to handle.

VII. Lower thermal conductivity causing local heat accumulation leading to increase in tool drear.

2. STUDIES ON DRILLING

Machining characteristics of composites vary from metals due to the following reasons;

a. FRP is machinable in a limited range of temperature. Though fibers withstand higher temperature, the cutting temperature should not be exceeded to avoid softening of matrix.

b. The low thermal conductivity causes heat build up in the cutting zone during machining operation, since there is only little dissipation by the material. The greatest part of heat is carried away through the tool. On the surface layer of composite there is a significant rise in temperature.

c. The difference in the coefficient of linear expansion between the matrix and the fiber (carbon fiber has negative coefficient) gives rise to residual stresses and makes it difficult to attain high dimensional accuracy. Drilled holes show a smaller diameter than the drill used since, coefficient of linear expansion of plastics is more than metals, it increases friction between the tool and work and consequently the amount of heat produced.

d. Reinforcing fibers and fillers can cause a highly abrasive tool, w ear.

e. The change in physical properties by the absorption of fluids has to be considered while deciding to use a cool ant,

Mackeyll [2], Boldt and Chanan [3] and Miller [4] have tried different tool geometries in drilling of composites. Sakuma [5] have studied the relation between tool material and

wear behavior and also the effect of cutting conditions and tool material on hole quality.
In the present work, study is carried out on Carbon fiber/epoxy(CFRP) and Glass fiber/epoxy (GFRP) laminates using High Speed Steel(HSS) and Carbide tipped drills. The effect of drill speed, feed, drill geometry, no. of holes, on thrust, torque, footwear, hole shrinkage and hole finish has been studied.

The experiments have been made on samples of composites, reinforced with glass and carbon fibers, having 8 mm thickness
The tools were used at speeds varying from 56 to 1250 rot/min and a feed rate of 0,03 to 0,4 mm/rot. The HHS drill was used for 40 holes, and the carbide tipped drill was used for up to 400 holes.
The results of the experiments are the fallowing:

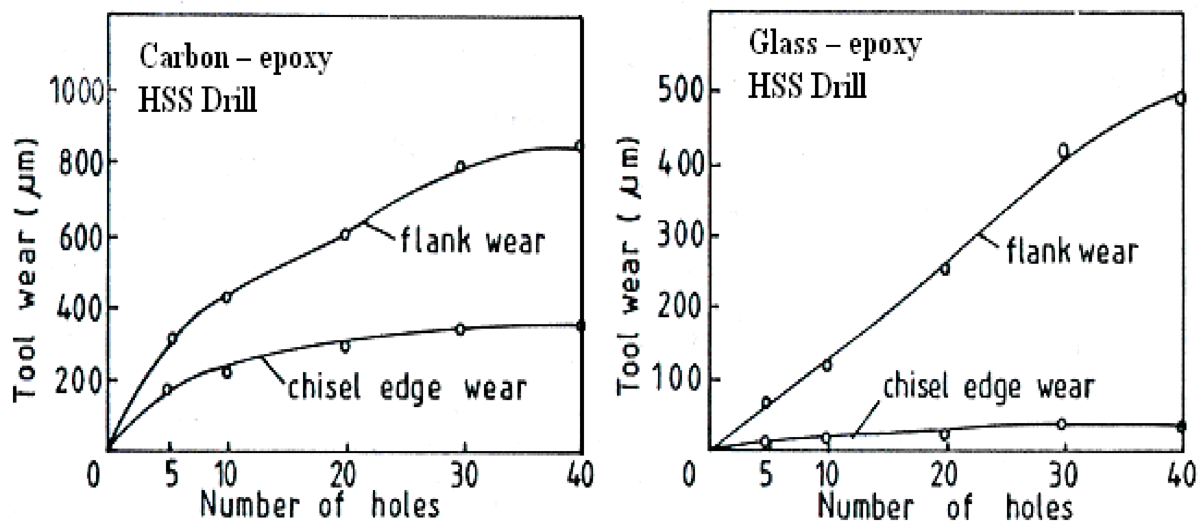

Fig.1. Variation of tool wear in accordance with the number of holes [6]

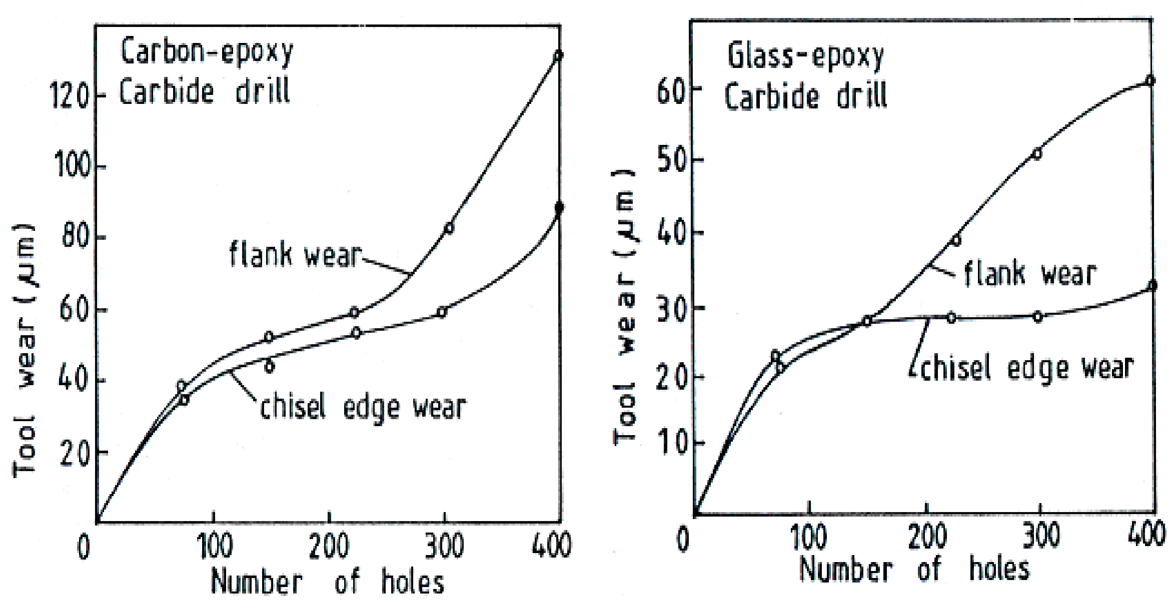

Fig.2. Variation of a carbide tipped tool wear in accordance with the number of holes [6]

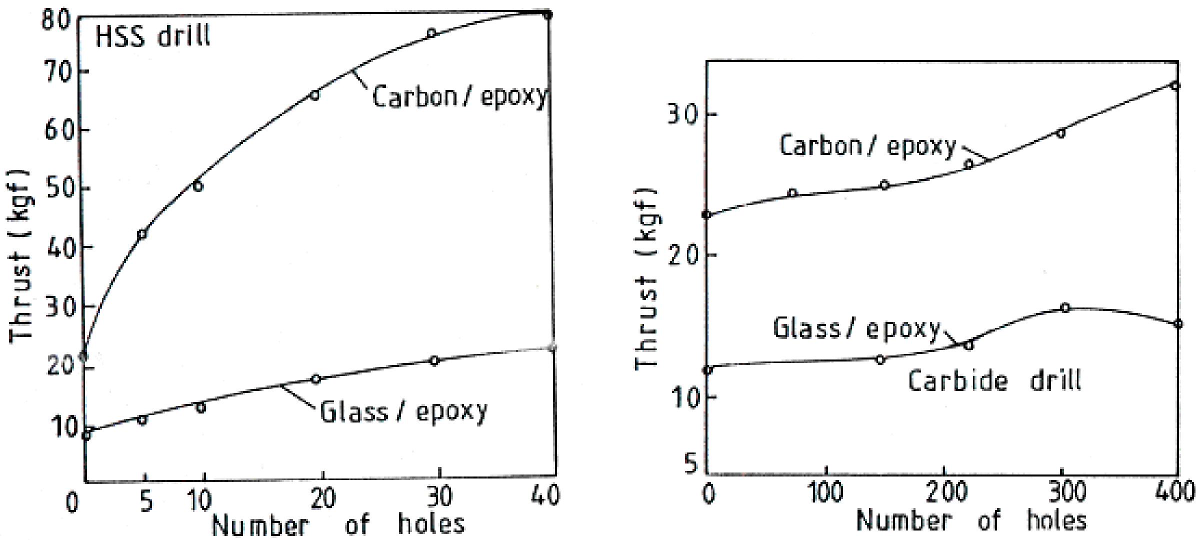

Fig.3. Variation of the axial force in accordance with the number of holes [6]

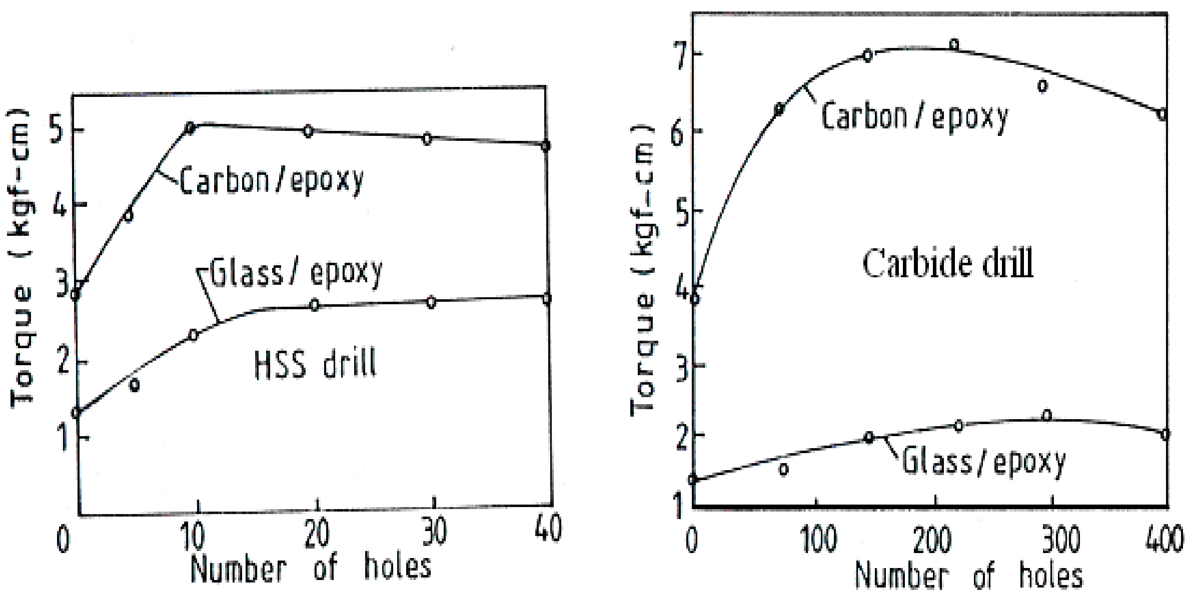

Fig.4. Variation of the torque in accordance with the number of holes drilled and the material of the tool [6]

From the charts we can see that the tool wear varies with the number of holes (Fig 1, a,b) and is higher in the case of CFRP laminates than in case of GFRP, because of the greater abrasiveness of the carbon fibers compared to the glass fibers.

The chart in Fig. 2 (a,b) represent the flank and cutting edge wear in the case of a carbide tipped drill. From this, the fallowing results:

- with these tools, as up to 10 times more holes can be drilled;
- maintaining the same drilling conditions (feed rate of 0,06 mm/rot and 1250 rev/min), tool wear is much higher for the carbon reinforced composites than for the ones reinforced with glass fiber.

From the analysis of the variation of the pressure needed for the feed of the drills (Fig 3, a,b) it has been seen that for the machining of composites reinforced with carbon fibers, higher values for pressure are needed than in the case of glass fiber, and these values are much higher in the case of a HHS drill than in a carbide tipped drill, even if the number of holes drilled is up to 10 times larger.
The circular motion of the drill implies the variation of torque that depends on:
- if different types of polymeric composites are machined with the same tool and in similar conditions, torque has been shown to be higher in the case of carbon fiber reinforced composites than in the case of glass fiber;
- the same difference occurs for the carbide tipped tools, for the same types of materials and work conditions, the value of the torque being almost the same for both the tool types

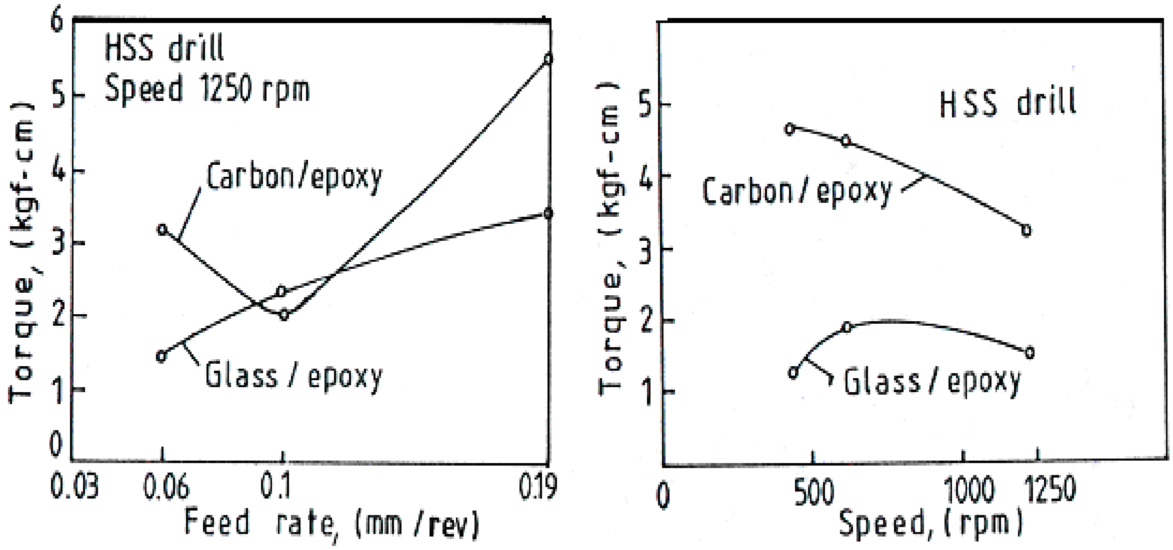

Fig.5. Variation of torque in accordance with the feed rate and rotation speed of the tool, as well as material type [6]

Analyzing the variation of the torque in the case of machining with the same type of tool and the same speed (Fig 5a), at a variation of the feed rate between 0,03 and 0,19 mm/rot, the diagram of the torque has a negative slope in the case of machining composites reinforced with carbon fibers (until um to 0.1 mm/rot feed), after which his value climbs reaching a value which is almost double the one obtained when drilling in glass fiber composites.
If the rotation speed grows from 0 to 1250 rot/min (Fig 5,b), the diagram of the torque has a maximum, after which it has a negative slope, for both glass and carbon fiber composites. In this diagram also it can be seen that torque is higher for CFRP than for GFRP. Analysing the diagram of pressure variation in accordance with the feed rate, from a value of 0.04 to 0.19 mm/rot, the fallowing can be noticed:
- when machining GFRP using a HSS drill, the value of the pressure doesn't rise very much
- in the case of CFRP, when using a HSS drill, the diagram of the pressure climbs with a much higher slope than in the case of GFRP, and the pressure reaches values as high as 30 kgf
In the case of torque variation in accordance with the speed, when the latter grows from 0 to 1250 rot/min, we can see that:
- for GFRP, the diagram of the pressure has a negative slope at the beginning, after which it starts to rise; this variation takes place within 10 kgf
- for CFRP, the diagram of the pressure has a positive slope at the beginning, after which it

starts to descend; it has been noticed that this variation also is not very large (between 20-25 kgf) - the pressure needed to drill into CFRP is higher, for the same value for speed, than for GFRP

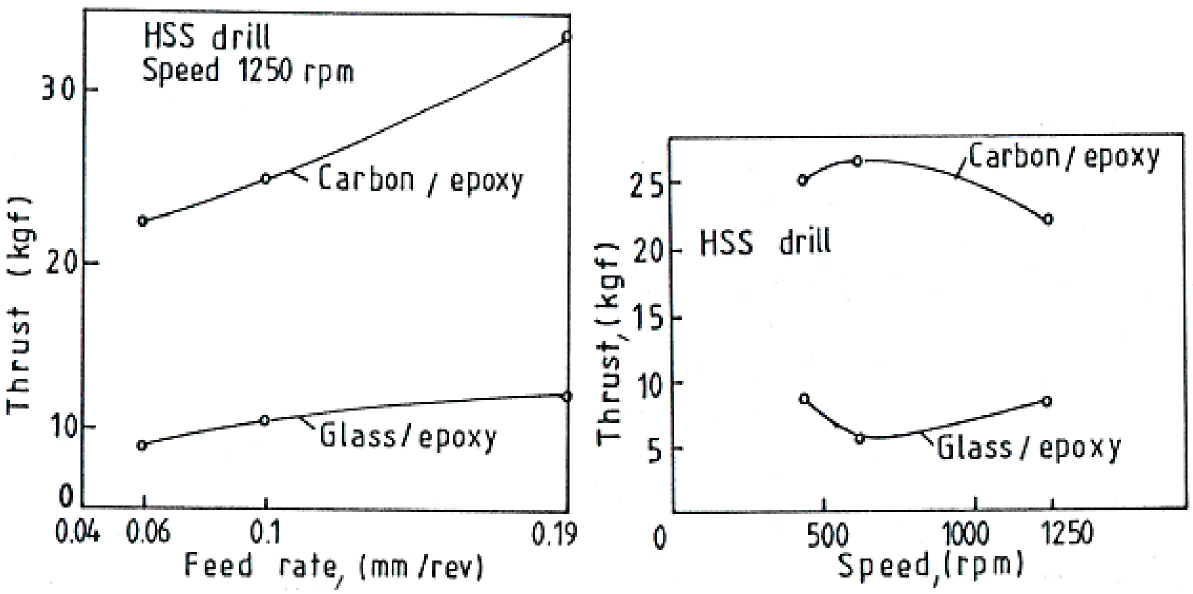

Fig.6 Variation of the axial force in accordance with the feed rate and the speed, as well as the material [6]

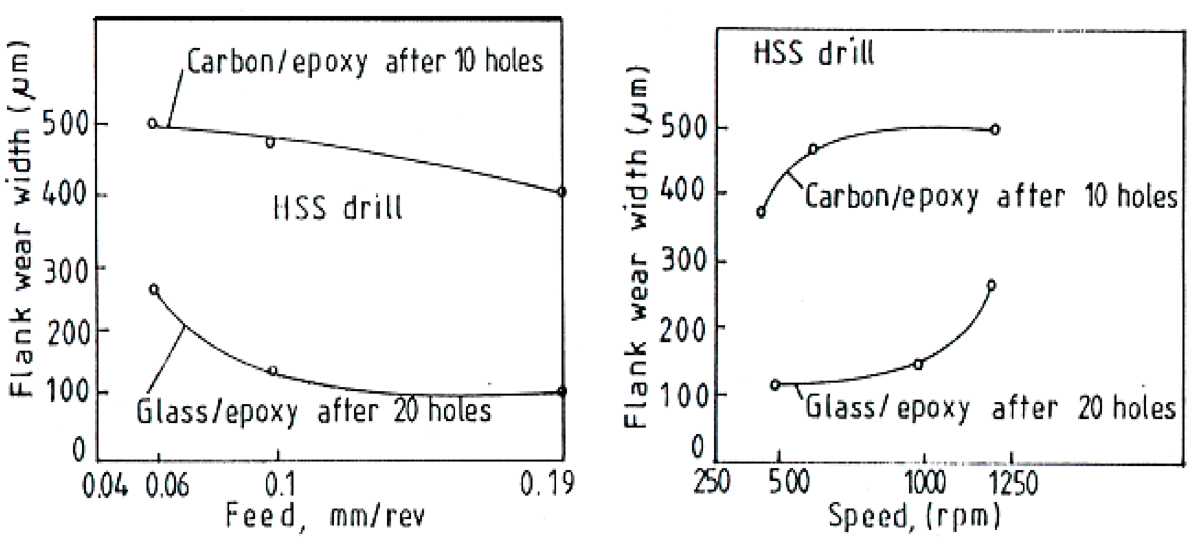

Figura7. Variation of flank wear of the tool in accordance with feed rate, speed and material [6]

-When drilling in CFRP, flank wear of the tools is slightly reduced as feed grows from 0,06 to 0,19 mm/rot, as for GFRP, the reduction in flank wear is much higher (speed is constant at 1250 rot.min). (Figure 7,a)

-For CFRP, flank wear grown when the speed exceeds 1000 rot/min, while for GFRP, flank wear doesn't vary much after speed exceeds 600 rot/min, (at a constant feed rate of 0,06 mm/rot) (Figure 7,b).

- Both chisel edge wear and flank wear increase with the number of holes. Flank wear is much more compared to the chisel-edge wear. The difference is more pronounced in case of GFRP.
- Tool wear is more for CFRP laminates as compared to GFRP. This is due to greater abrasiveness of carbon fibres compared to glass fibress.
- Carbide tipped drill performs much better that HSS drill both for GFRP and CFRP. With carbide drill, tool wear even after 400 holes is not excessive. While in the case of HSS drill, tool wear is very large after 40 holes itself.
- In drilling of CFRP flank wear reduces a little as feed is increased from 0,06 to 0,19 mm/rev. while in case of GFRP reduction in flank wear is more pronounced.

CONCLUSION

- tool wear grows with the number of holes drilled
- tool wear is higher in the case of drilling in CFRP than in GFRP. This is due to the higher roughness of the carbon fibers than of glass fibers
- carbide tipped drills behaves much better than HSS, for both CFRP and GFRP. Tool wear is up to 10 times lower for the former than the HSS, at the same number of holes.
- When drilling in CFRP, flank wear is slightly reduced when feed rate grows from 0.06 to 0.19 mm/rev, as for GFRP, the reduction is much higher (speed is constant at 1250 RPM)
- For GFRP, flank wear grows when speed exceeds 1000 RPM, while for CFRP, flank wear does not vary much after speed exceeds 600 RPM

REFERENCE:

[1] B. MACKEY - "A practical solution for machining of accurate, clear, burr free holes in Kev1ar composites", 37th Annual Tech. Conf.1992, Reinforced Plastics/Composites Institute, SPI, Inc.;
[2] B.A. MACKEY - “How to drill precision holes in reinforced plastics in a hurry” Plastics Engineering (1990) pag. 22-24;
[3] J.A. BOLDT, J.P. CHANANI - "Solid state machining and drilling", Northrop Corpn.;
[4] J.A. MILLER - "Drilling graphite/epoxy at Lockheed", Lockheed “Corpn.;
[5] YoKo SAKUMA, M. SETO - "Study on drilling of GFRP and CFRP”, Bull.,of JSMB, V-27, p. 228, June1994;
[6] S.K. MALHOTRA - “Some studies on drilling of fibrous composites”, Journal of Materials Processing Technology, 24 (1990), pag. 291-300;
[7] C. DUMITRAŞ, C. OPRAN – Prelurabilitatea materialelor compozite, ceramice şi minerale; Ed. Tehnică1994.

AUTHORS:

Drd. Eng. Maria OCNĂRESCU,
“Doamna Stanca” High school, ROMANIA,
E-mail: ocnarescu_maria@yahoo.com,
Drd. Eng. Paulina SPÂNU,
University POLITEHNICA of Bucharest,
Dr. Eng. Aurelian VLASE,
Professor,University POLITEHNICA of Bucharest, ROMANIA ;
Dr. Eng. Constantin OPRAN
Professor,University POLITEHNICA of Bucharest, ROMANIA;