# Comparison Between Results of Numerical Simulation of Electromagnetic Forming Applied on Metallic Workpieces Using Different Software


Tomşe Marin*, Paşca Sorin*, Apostolos Kokkosis**

* University Of Oradea, Faculty of Electrical Engineering and Information Technology
1 Universitații St., 410087 Oradea, Romania, E-mail: mtomse@uoradea.ro
** Technological Educational Institute of Piraeus, Greece.



***Abstract* - Modelling by equivalent schemes the complex electromagnetic and mechanical phenomena wich take place during the electromagnetic forming of a metal workpiece offers distinct advantages. Such schemes give an intuitive picture of the field phenomena making them accessible to the engineer's methods. The schemes facilitate the study by modelling methods. In this paper we present comparison betwen results of numerical simulation of electromagnetic forming applied to compression of tubular conductor using PSPICE and FLUX2D software.**



***Keywords:* electromagnetic forming, numerical simulation of electromagnetic forming.**


## I. INTRODUCTION

Electromagnetic forming is an unconventional technology of metal working by plastic deformation at room temperature. The principle consists in the deformation of thin metallic pieces by intense impulsive forces acting on the conductor placed in a rapidly varying magnetic field.

A rigorous analysis of the system must take into account the non-uniform distribution of the current density within conductors - transient skin effect. In addition, the movement of the workpiece determines induction effects in conductors, modifies the magnetic field distribution, resulting a strong coupling between magnetic and mechanical phenomena.

An exact study require the solution of the equations of mediums in motion coupled with the eguation of motion supplied by the mechanics of continuos media, process very difficult to modeling it..

In [1] electromagnetic forming is modeled by a theoretical model of an electromagnetic forming installation takes into account the induction effects with in conductors, the induction effects of work piece motion, and the dynamic behaviour of workpiece material. This model can be simulated with software as PSPICE.

In this paper we present comparison betwen results of numerical simulation of electromagnetic forming applied to compression of tubular conductor using PSPICE and FLUX2D software.

## II. MODELS FOR ELECTROMEGNETIC FORMING INSTALLATION

*A. The electrical equivalent scheme with concentrated parameters for electromagnetic forming installation. Implementation in PSPICE.*

The electrical equivalent scheme with concentrated parameters for electromagnetic forming devices obtaining in [1] is prezented in Fig. 1.

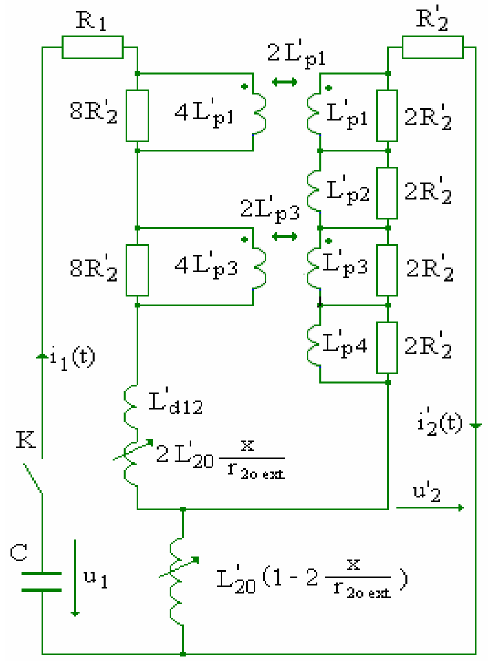


Fig. 1. Equivalent circuit diagram for compression of thin wall tubes

We use voltage and current controlled source for taking into account the coupling between mechanical and electromagnetic phenomena.

Start from the equivalent circuit from Fig. 1 we obtain the PSPICE implementation wich is shown in Fig. 2.

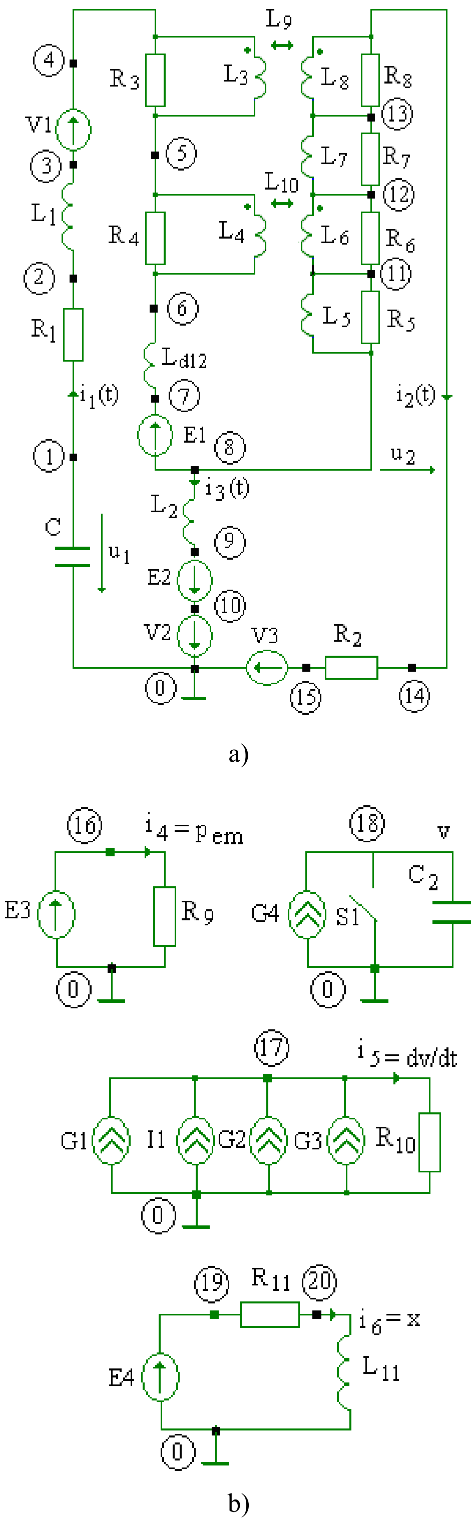


Fig. 2. Implementation of equivalent circuit in PSPICE:
a) equivalent circuit of electromagnetic phenomenon;
b) calculus of electromagnetic pressure $p_{em}$, acceleration a, strain rate v and deformation x.

The values of circuit components are calculated with relations presented in [1].

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*Electromagnetic forming for compression of thin
*wall tubes
.PARAM U0=1000V, r20ext=16m,r20int=15m
.PARAM d=1m, h1=29m, h2=29m, r1int=18m
.PARAM r1ext=26m, N=12, mu0=4e-7*pi
.PARAM, gamma=2720, ro2=3e-8, sigma2={1/ro2}
.PARAM taup={mu0*sigma2*d^2}, sigma0=2.5e7
.PARAM lamda=1.125e8, eta=0.037e8, delta=1/2
.PARAM pi=3.1416, alfan=0.0904, psin=0.78855
.PARAM r2={pi*(r20int+r20ext)/(sigma2*h2*d)},â
.PARAM L1={2*r2*taup/pi^2}, Rp={N^2*r2}
.PARAM Lp={N^2*L1},
 L220={pi*mu0*((r20int+r20ext)^2)*N^2/(4*h2)}
.
C1 1 0 500uF IC=1000V
R1 1 2 18u
L1 2 3 0.0234uH
V1 4 3 0
R3 5 4 {8*Rp}
R4 6 5 {8*Rp}
Ld12 7 6 {(r1ext^2/r20ext^2-1)*L220}
L3 4 5 {4*Lp}
L4 5 6 {4*Lp}
E1 7 8 VALUE={2*L220*V(15)*I(V1)/r20ext}
V2 0 10 0
L2 8 9 {L220}
E2 10 9 VALUE={-2*L220*V(15)*I(V2)/r20ext}
R5 11 8 {2*Rp*psin}
L5 11 8 {Lp*psin/alfan}
R6 12 11 {2*Rp}
L6 12 11 {Lp/9}
R7 13 12 {2*Rp}
L7 13 12 {Lp/4}
R8 14 13 {2*Rp}
L8 14 13 {Lp}
K1 L3 L8 1
K2 L4 L6 1
R2 14 15 {Rp}
V3 0 15 0
E3 16 0 VALUE={-I(V3)*(2*I(V1)-I(V3))}
R9 16 0 {2*h2^2/(mu0*N^2)}
G1 0 17 VALUE={-I(E3)/(gamma*d)}
I1 0 17 {sigma0/(-gamma*r20ext)}
G2 0 17  VALUE={-lamda*I(E4)/(gamma*r20ext^2)}
G3 0 17 VALUE={-eta*V(18)^delta/(gamma*
*r20ext^(1+delta))}
R10 17 0 1m
G4 0 18 VALUE={V(17)}
C2 18 0 1m
S1 18 0 0 18 SMOD1
.MODEL SMOD1 VSWITCH VON=1u RON=1u
           VOFF=-1u
*S2 18 0 0 14 SMOD1
E4 19 0 VALUE={V(18)}
R11 19 20 1u
L11 20 0 1
.tran 0 400u UIC
.probe
.end
```

The influence of the worhpiece deformation is simulated bz the voltage sources E1 and E2.The current $i_4$ represents the electromagnetic pressure on the workpiece walls:

$$i_4 = p_{em} = \frac{\mu_0 \cdot N^2}{2 \cdot h^2} \cdot i_2 \cdot (2 \cdot i_1 - i_2)$$

And it is simulated by a nonlinear controlled controlled voltage source in series with an equivalent rezistor.

The equations of motion for the workpiece included mechanical equations are simulated by the equivalent circuit comprising the sources G1, G2, G3 and I1.

The $i_5$ current and $v_{17}$ potential gives the total presure acting on the workpiece walls. The v18 potential represents the radial velocity v of the walls, and the i6 current represents the radial deformation x. The switch S1 is opened when the stress exceeds the yield point and the total pressure is pozitive (the elastic properties of the workpiece are negligible).

*B. The numerical model for electromagnetic forming installation implementation in FLUX2D..*

The computation domain for a typical magnetoforming application is shown in Fig 3.

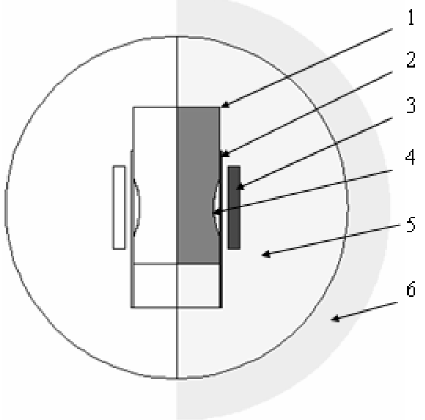


Fig. 3. The computation domain.
1 - shaped bar, 2 - conductive tube, 3 - forming coil, 4 - deformation zone, 5 – air, 6 – infinite Flux region

Fig. 4 presents circuit model with six turns coil - solid conductor.

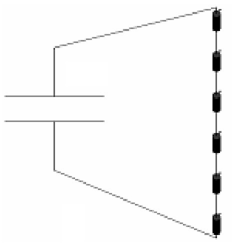

Fig. 4. Circuit models.

The application consists in the study of electromagnetic transient regime associated with the magnetoforming process of 1mm thin aluminum tube over an aluminum shaped bar in order to couple them. The computation domain is the same as in Fig. 3 and geometry dimensions are given in axial section in Fig. 5 a). We study the application corresponding at circuit shown in Fig. 4. The mesh characteristics for solid conductor coil are shown in Fig. 5 b), c), d).

The materials properties are as follows: the rezistivity $3 \cdot 10^{-8}$ Ωm for aluminum and $1.75 \cdot 10^{-8}$ Ωm for electrolytic copper of solid coil conductor. A Dirichlet boundary condition is considered for all external boundary of te computation domain. The initial (t = 0) voltage of the capacitor of 500 μF is $U_0$ = 1000 V.

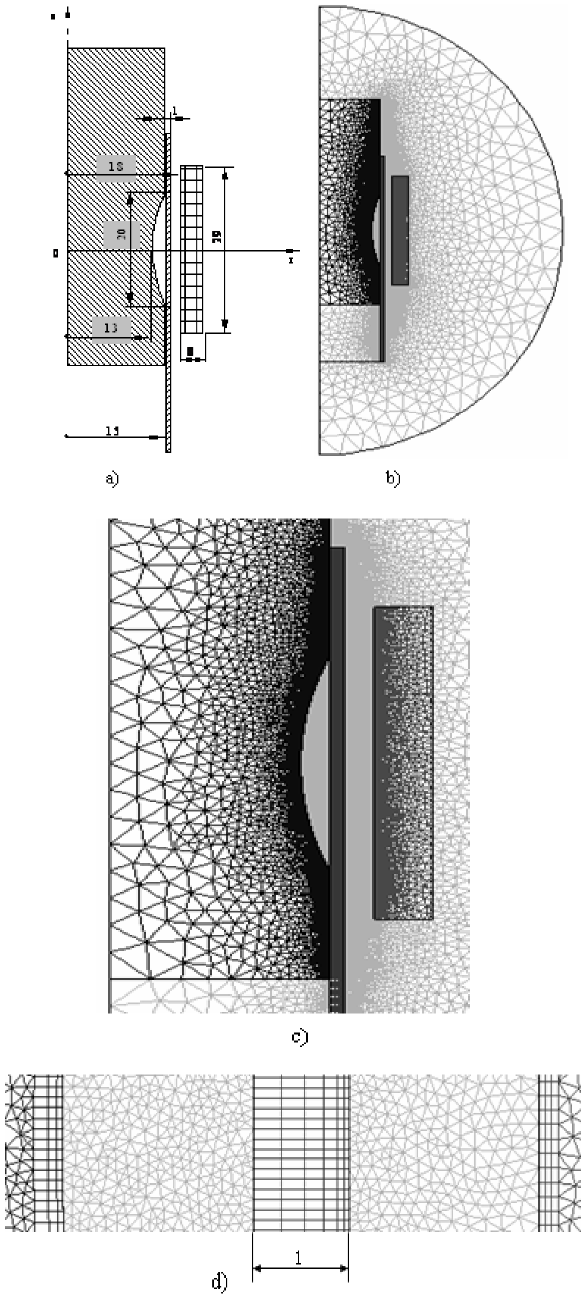


Fig. 5. The geometry (a) and the mesh for one turn solid conductor coil (b), (c), (d).

## III. NUMERICAL SIMULATION OF ELECTROMAGNETIC FORMING

The numerical simulation of transients in an electromagnetic forming installation using PSPICE software.is present in Fig.6.

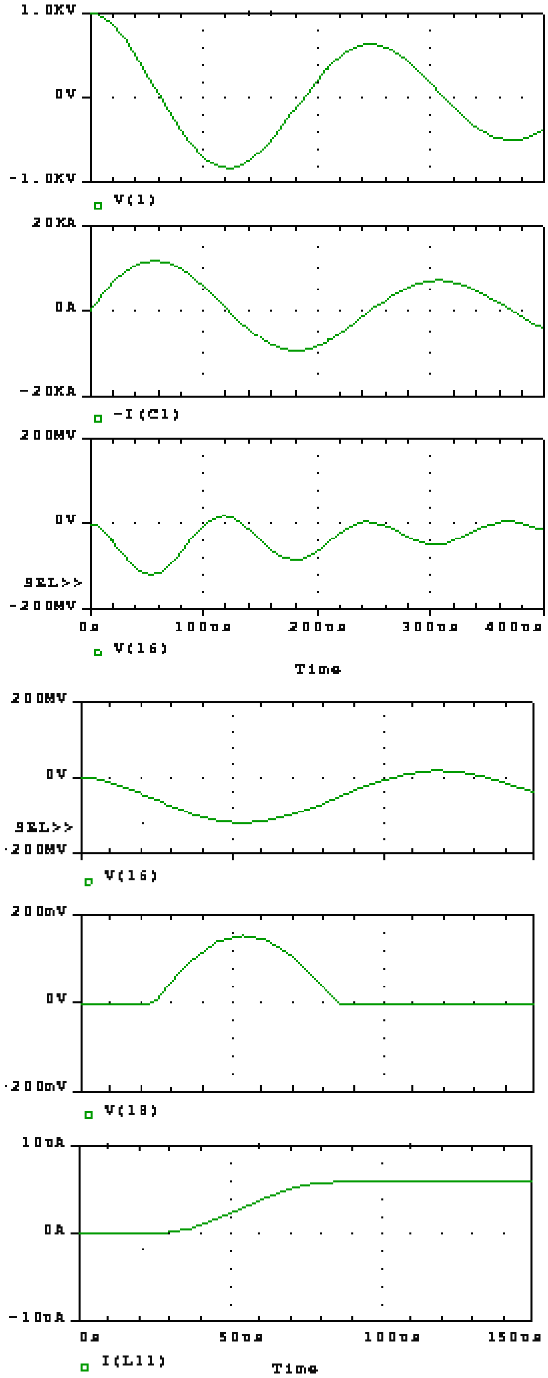


Fig. 6. The numerical simulation of electromagnetic forming instalation using PSPICE.

The numerical simulation of transients in an electromagnetic forming installation using FLUX2D software.is present in Fig.7. Differences between results presents in Fig.6 and Fig.7 is relative big, because the numerical model from FLUX2D neglecting the induction effects due to the motion pf the work pieces.

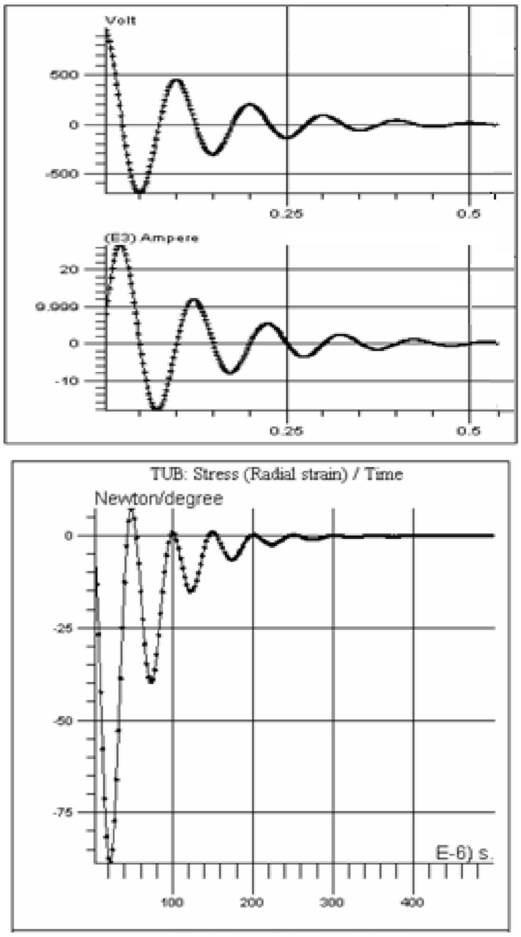


Fig. 7. The numerical simulation of electromagnetic forming instalation using FLUX2D.

## IV. CONCLUSIONS

In this paper we present comparison betwen results of numerical simulation of electromagnetic forming applied to compression of tubular conductor using PSPICE and FLUX2D software.
Differences between results obtained with PSPICE and FLUX2D is is relative big, because the numerical model in FLUX2D neglecting the induction effects due to the motion pf the work pieces.


## ACKOWLEDGMENTS

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