THE ANNALS OF "DUNĂREA DE JOS" UNIVERSITY OF GALAȚI,
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING, ISSN 1221-4566
2003

Researches concerning the Influence of Transitory Processes and the Dependence Current - Torque in the Case of Gearboxes Electromagnetic Clutches

Constantin Stoian, Gabriel Frumușanu, Ștefan Mitu
University "Dunărea de Jos", Galați

ABSTRACT

In this paper, the influence of serial connected electromagnetic clutches characteristic on time delay between the electric command moment and the moment when spindle touches the nominal speed is analyzed. Experimental researches made by the authors, in order to reduce the load acceleration times and also, to obtain high working frequencies are included.
keywords: *electromagnetic clutches, transitory processes, machine-tools gearboxes.*

1. Theoretical Considerations

The actual tendency of automatising the technological processes supposes the use, on large scale, of friction electromagnetic clutches.

An important electromagnetic clutches characteristic is the time for the processes of clutch engagement - disengagement, that should be as short as possible and precisely known, in order to allow a precise positioning of machine tool working parts.

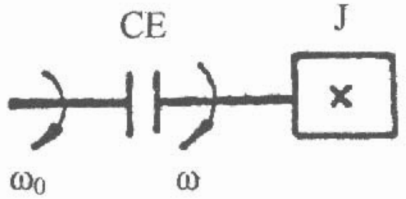

Fig. 1

The machine table (having the J inertia torque) starts by following the equation

$$M_1 = J \cdot \frac{d\omega}{dt} + M_2 \qquad (1)$$

where M_1 means the driving torque and M_2 - the resistant torque.

The M_1 torque, furnished by the clutch, depends on the intensity of the current through the clutch bobbin (as shown in Fig.2-a), but also on the relative speed between clutch discs (as we can see in Fig.2-b).

Up to this moment, the specialists in this problems admit the hypothesis that in the t_3 moment (Fig.2-a), corresponding to $i = 0.707I_n$, the clutch is able to transmit the nominal torque.

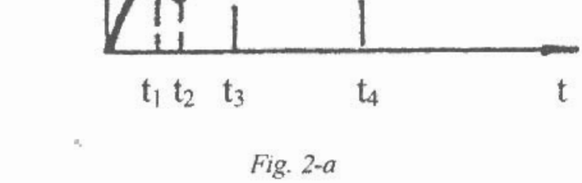

Fig. 2-a

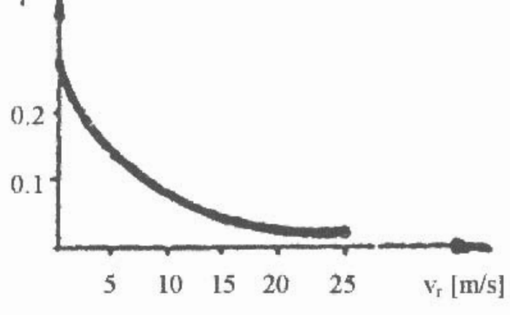

Fig. 2-b

2. The Influence of a Clutches Succession on a Spindle Start

By considering an electromagnetic clutches succession, the hypothesis upper mentioned (excessively simplifying) must be reconsidered. Thus, even if the evolution of the electric current through the clutches windings is always the same, the AF spindle (Fig.3) start takes place after a certain time delay; the length of this time delay depends on the structure of the kinematics chain corresponding to n_k spindle speed.

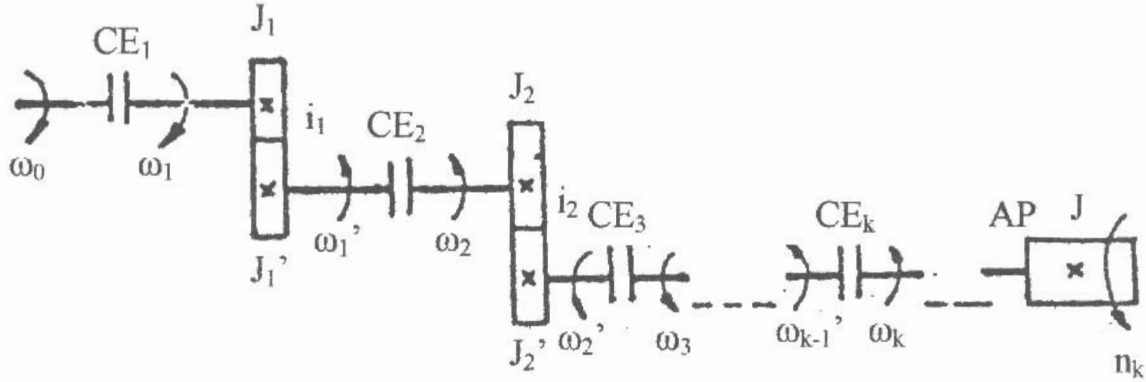

Fig. 3

It is possible to accept that, after the stabilization of the electric current through the bobbins, some of the clutches are still slipping and the spindle start cannot take place at the end of the time delay 0 - t_3.

Starting from here, if a clutch characteristic $M_1 = f(i, \omega_{rel})$ is known, its start time delay can be found from the equation (1), where J and M_2 are torques referred to the clutch axis.

For example, if the clutch CE_2 is closed, within the other clutches are still slipping, the inertia torque referred to CE_1 clutch axis is

$$J_{1red} = J_1 + \left(J_1' + J_2 + J_2' \cdot i_2^2\right) \cdot i_1^2 \qquad (2)$$

If the CE_3 clutch would, also, close then the relation (2) becomes

$$J_{1red} = J_1 + \left[J_1' + J_2 + \left(J_2' + J_3 + J_3' \cdot i_3^2\right) \cdot i_2^2\right] \cdot i_1^2 \qquad (3)$$

By generalizing, the following expressions result:

a) if CE_{k+1} - open

$$\left(J_k\right)_{red} = J_k + J_k' \cdot i_k^2; \qquad (4)$$

$$\left(M_2\right)_k = M_{fr} + i_k \cdot \left(M_1\right)_{k+1}; \qquad (5)$$

$$\left(M_1\right)_k = f\left(i, \omega_k - \omega_{k-1}'\right) = \\ = \left(J_k\right)_{red} \cdot \frac{d\omega_k}{dt} + i_k \cdot i_{k+1} \cdot \left(M_1\right)_{k-1} \qquad (6)$$

b) if CE_{k+1} - closed

$$\left(J_k\right)_{red} = J_k + \left(J_k' + J_{k+1} + J_{k+1}' \cdot i_{k+1}^2\right) \cdot i_k^2 \qquad (7)$$

$$\left(M_1\right)_{red} = \left(J_k\right)_{red} \cdot \frac{d\omega_k}{dt} + M_{fr} + i_k \cdot i_{k+1}\left(M_1\right)_{k+2} \qquad (8)$$

3. Experimental Research

To find the real time of getting a rotation speed at the spindle, in conditions of a driving kinematics chain commended by electromagnetic clutches, it is necessary to draw, in the case of each clutch, the curve

$$M = f(I, \omega_{rel}), \qquad (9)$$

where M means the friction torque developed by the clutch, I - the electric current intensity and ω_{rel} - the relative rotation speed between the clutch discs in friction, measured in rad/s.

Dedicated publications suggest, in the case of electromagnetic clutches, graphic representations of the functions

$$I = f(t), \tag{10}$$

$$M = g(t), \tag{11}$$

and

$$\omega = h(t), \tag{12}$$

in transitory working regime.

If the function I = f(t) is correct, the other two can be corrected, because they are not having in view the existence of a $\mu = f(\omega_{rel})$ dependence relation.

In order to avoid the upper mentioned errors, a special experimental stand was conceived; its principle scheme is exposed in the Fig.4.

To draw function (9) graphic, an polytropic kind of expression

$$M = a \cdot I^b \cdot n^c \tag{13}$$

was used.

By logaritming, to make linear the relation (13), results

$$lg(M) = lg(a) + b \cdot lg(I) + c \cdot lg(n). \tag{14}$$

By denominating with M_{exp} the function (9) values, experimentally obtained, their medium square deviation is

$$D = \sqrt{\frac{1}{n} \cdot \left[\sum_{i=1}^{n} (lg\, M_{exp,i} - lg\, M_i)^2 \right]} = \sqrt{\frac{S^2}{n}}, \tag{15}$$

where

$$lg\, M_i = k + b \cdot lg\, I + c \cdot lg\, n_i. \tag{16}$$

The minimum condition applied to the function (15) can be obtained by making equal to zero the partial derivates of the function S = f(k, b, c) respect to k, b and c.

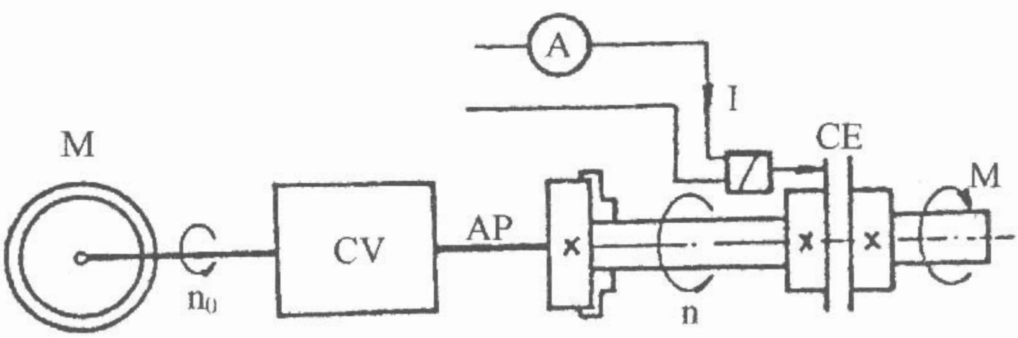

Fig.4

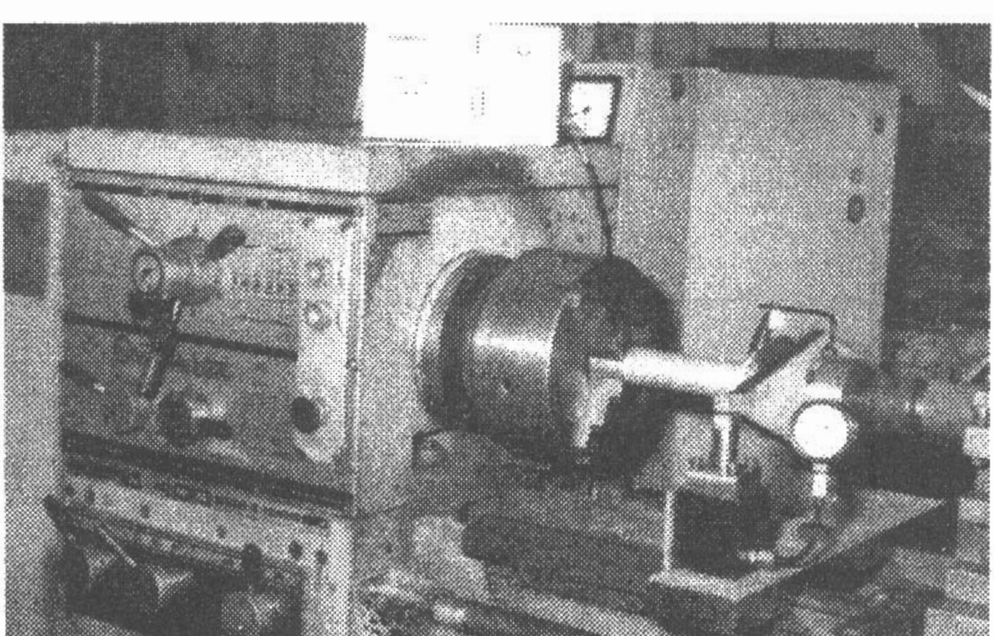

Fig.5

4. Results and Conclusions

Numerical integration of equations (7), (8) allows to calculate clutches rotation speeds at short time steps (Δt = 0.1 . . . 0.001 s), by testing their situation in order to draw clutches start curves $n_k = f(t)$ and to find the spindle time of start.

The experiments were made by using two clutches, having the nominal torques of 50 Nm and 100 Nm. The following formula resulted

$$M_1 = 6.66 \cdot \frac{I^{0.455}}{n^{0.125}}, \qquad (17)$$

respective

$$M_2 = 7.07 \cdot \frac{I^{3.14}}{n^{0.014}}. \qquad (18)$$

The medium square deviation resulted D_1 = 1.94, respective D_2 = 3.42.

References

[1] – **Fransua, Al.** ş.a., *Maşini şi sisteme de acţionări electrice* Ed. Tehnică, Bucureşti, 1978.
[2] – **Cooke, R., Wusow, J.**, *Clutches and Brakes*, Warner Electric Internal Literature, London, 1984.
[3] - **Boţan, N.** - *Bazele calculului acţionărilor electrice*, Ed. Tehnică, Bucureşti, 1970.
[4] - * * * - Cuplaje şi frâne electromagnetice. Prospect. Uzina Mecanică Cugir, Romania.

CERCETĂRI PRIVIND INFLUENŢA PROCESELOR TRANZITORII ŞI DEPENDENŢA CURENT-CUPLU ÎN CAZUL CUPLAJELOR DIN CUTIILE DE VITEZE

Rezumat

În cadrul lucrării este analizată influenţa pe care o au caracteristicile cuplajelor electromagnetice, legate în serie, asupra decalajului în timp dintre momentul comenzii electrice şi cel al obţinerii turaţiei nominale la arborele principal. De asemenea, sunt prezentate cercetările experimentale efectuate de către autori în vederea reducerii timpilor de accelerare a sarcinii şi obţinerea unei frecvenţe de lucru ridicate.

RECHERCHES CONCERNANT L'INFLUENCE DES PROCESSUS TRANSITOIRES ET LA DEPENDANCE COURANT ELECTRIQUE - COUPLE DANS LE CAS DES COUPLAGES DES BOITES DE VITESES

Résumé

Dans ce papier il s'agit d'analyser l'influence des caractéristiques des couplages electromagnetiques, liées en série, sur le décalage temporel entre le moment de la commande électrique et celui quand la vitesse de rotation nominale de l'arbre principal est atteinte. Recherches expérimentales effectuées par les auteurs pour réduire des temps d'accélération de la charge et pour obtenir une fréquence élevée du travail sont aussi exposées.