ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XX [2022] | Fascicule 3 [August]

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CONTRIBUTIONS REGARDING THE REALIZATION OF A DRIVE SYSTEM FOR WINDING THIN RUBBER BANDS

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Abstract: The authors' original contributions can be found both in the general solution as well as in the realization of the specialized regulator for the driving system of the installation for thin rubber bands. The modernization of the existent installations by keeping the electromechanics parts and the attachment of some new command equipment, which includes also software, represents an economically efficient solution applied in many production companies in Romania, but also in Europe. Although the problem of driving the machine with a variable static couple is classical and it has had different solutions in time, the solution we propose contains many original elements, especially in the mechanical adaption process of the installations.
Keywords: thin rubber bands, drive systems, economically efficient solution

1. INTRODUCTION

The drive system was designed at the request of SC ARTEGO Tg. Jiu, one of the companies the Centre of Innovation and Technological Transfer CITT Craiova has signed contracts with for more than 10 years [4].

SC ARTEGO Tg. Jiu, founded in 1973, represents a good example of company which adapted well to the market economy due to a correct strategy regarding human resources (75 % of shares belongs to the employees) and due to a realistic policy regarding the equipment upgrade. Currently, ARTEGO is leader in Romania in transport bands, and also a competitive compony on international market.

The collaboration between SC ARTEGO Tg. Jiu and University of Craiova – CITT started in 2011 with the upgrade of the installation used for checking the transport of tubes from the rubber bands produced by this company.

2. ANALYSIS OF THE PROBLEM SIGNALLED BY THE BENEFICIARY

During 2018 SC ARTEGO diversified its products by manufacturing rubber–coated metal drums (Figure 1). We have to say that the engineers from ARTEGO Tg.Jiu were very creative in designing the installation, using the electromechanics of some equipment which they had and which was in good condition. However, although they carried out a lot of tests and they made several adaptations of the mechanical part, they weren't able to correlate the rotation speed of the drum with the extrusion speed. For this reason, the thin band either broke, or elongated or made a bigger looping arrow.

Figure 1. Initial phase of the project of diversifying the products

In this context, the beneficiary formulated a research theme and signed a contract with CITT Craiova. [5]. From the analysis of the technological process (Figure 2) it resulted that the beneficiary wanted to use the electromechanics part of some equipment which he owned and which were in a very good state. He also wanted that the research contract stipulated only the design and the carrying out of the automatization of the equipment.

Figure 2. The metallic drum on which the thin rubber band is wrapped – manual winding stage

For the rotation movement, the metallic drum must be fixed on a lathe driven by an asynchronous motor. The general expression of the static couple is [2]:

$$M_s = K\Omega^{\alpha} = K\Omega_N^{\alpha}\left(\frac{\Omega}{\Omega_N}\right)^{\alpha} = M_{sN}\left(\frac{\Omega}{\Omega_N}\right)^{\alpha}$$

the exponent having values $\alpha = -1 \dots 6$ according to the equipment used.

For α= – 1 the equation of the static characteristic is:

$$M_s = M_{sN}\left(\frac{\Omega}{\Omega_N}\right)^{-1} = M_{sN}\frac{\Omega_N}{\Omega}$$

The corresponding static power:

$$P_s = M_s\,\Omega = M_{sN}\,\Omega_N = P_{sN}$$

It results that for static couples inversely proportional to the speed, the static power required by the machine remains constant.

These types of characteristics are specific to the machine used for winding wires, tin, threads, paper where the pulling force and the linear force of the product must remain constant so the wrapped product wouldn't break or make looping arrows (Figure 3).

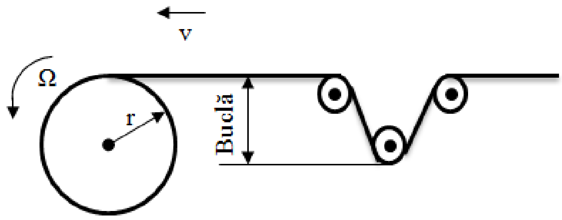

Figure 3. Explanation regarding the calculus of static couple

It is known that:

$$M_s = T\,r\,;\; v = \Omega\,r$$

It results:

$$M_s = \frac{Tv}{\Omega} = \frac{K}{\Omega}.$$

Thus, the research subject refers to the realization of a drive system of a working machine which develops a static couple inversely proportional to the speed that must be tuned while the diameter increases so that the pulling force remains constant, the band loop has values within a controlled range, respectively.

3. THE ANALYSIS OF THE MECHANICAL STRUCTURE OF THE INSTALLATION

The installation (Figure 4) is made up of an extruder with the help of which the thin rubber band is obtained, and a lathe which carries out the rotation movement of the drum and the translation movement of the wagon that is rigidly attached to the extruder. The extruder, rigidly attached to wagon of the lathe, moves on a groove parallel to the lathe groove. In other words, the extruder and lathe grooves are parallel, so that the thin rubber band, during the winding process, to be perpendicular on the drum.

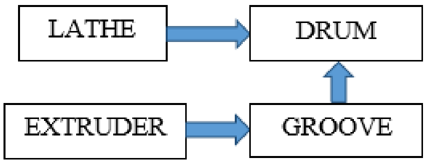

Figure 4. Functional block diagram of the winding installation for thin rubber bands

Figure 5. Solution for sustaining the band and the loop control

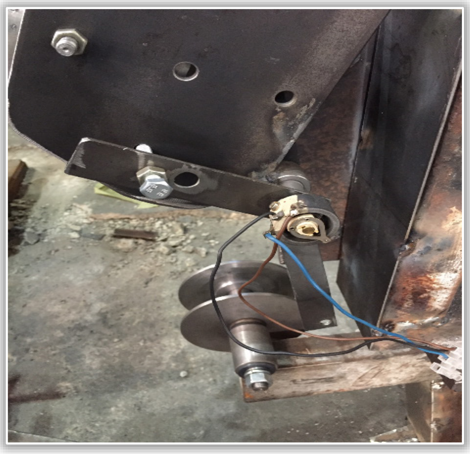

Figure 6 Transducer for the arrow loop

The linear speed needed for getting the thin rubber band is variable, depending on the consistency of the extruded material and on the temperature of the winding machine.

Taking into account the fact that the rubber band is soft, it was mounted a sustaining system (Figure 5), made up of several rolls with free rotating movement. One of them is mounted on a swivelling bracket that gives the information regarding the arrow made by the thin band (Figure 6) from a slide–wire potentiometer.

4. PROPOSALS REGARDING THE DRIVING SYSTEM OF THE WINDING INSTALLATION FOR THIN RUBBER BANDS

The driving system [3] (Figure 7) of the winding part is made up of the electric engine of the lathe, on which the drum is fixed, supplied with variable voltage and frequency from static convertor that was mounted during the research. The convertor receives at input a command from the numeric regulator, carried out during the research. At regulator input it is applied a value of analogic reaction for the control of the arrow made by the band winding on the drum which is obtained from o potentiometer whose shaft is fixed on the swivelling bracket (Figure 8).

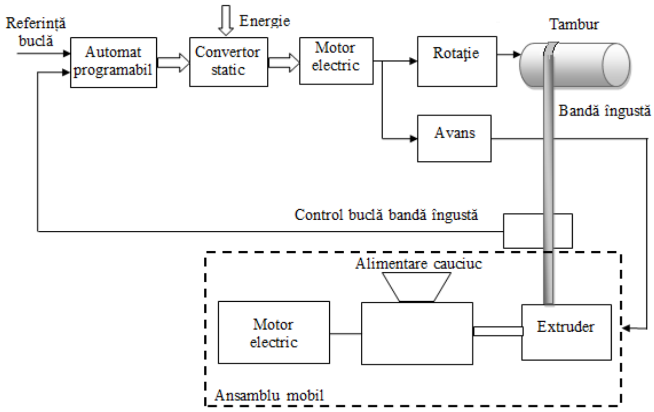

Figure 7. Structure of the driving system of the winding installation for thin rubber band

Figure 8. Rolls for sustaining the band and loop control

5. CONTRIBUTIONS REGARDING THE REALIZATION OF THE NUMERIC REGULATOR SPECIALIZED FOR THE DRIVING SYSTEM OF THE INSTALLATION FOR THIN RUBBER BANDS

The authors' original contributions can be found both in the general solution as well as in the realization of the specialized regulator for the driving system of the installation for thin rubber bands. The numeric regulator [1], [3], created for this application, is made of (Figure 9) a microcontroller, an analogic adaptor for processing the arrow made by thin rubber band, an alpha numeric display and a keyboard for setting the functional parameters, a communication module with the convertor which supplies the driving engine, a numeric input/output module for the interface with the winding installation and a communication module with an extern computer, useful especially in the designing and checking stages of the system.

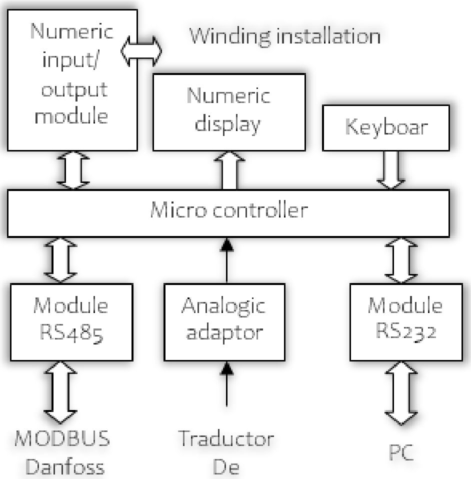

Figure 9. Diagram of the regulator for the driving system command

It was implemented a proportional–integrator regulator (Figure 10). Because the controlled process is slow, it was chosen a sampling timespan of 0,1s. The imposed value corresponds to the horizontal position of the swiveling bracket (the available voltage at the potentiometer cursor is equal with half of the maximum range, 5 V respectively). At any other position of the bracket, the error is different from zero and it has as effect, at last, the voltage change of the static convertor frequency and of the speed of the metallic drum.

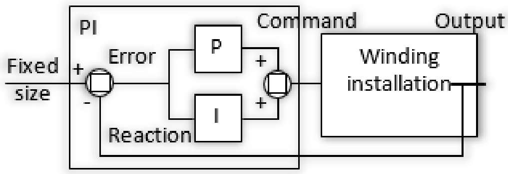

Figure 10. Structural diagram of the regulator

The program for the controller contains routines for the serial communication with the invertor and frequency (MODBUS RTU protocol), for the introduction, display and memorization of the scalar values, the scanning of the analogic channel associated the position of the swiveling bracket, as well as the sequence in which the PI regulator is implemented. Thus, with a periodicity of 0,1, the following mathematical evaluation are carried out:

$$Eroare=CanalAnalogic-511$$

$$BufferIntegrare=BufferIntegrare+Ki*Eroare$$

$$Comanda=BufferIntegrare+Kp*Eroare$$

The Command range is then serially transmitted to the inverter. This has values within the range between 0…4000h, namely 0…16 384 in decimal, which means a command between 0,0% and 100,0% from the maximum programmed frequency.

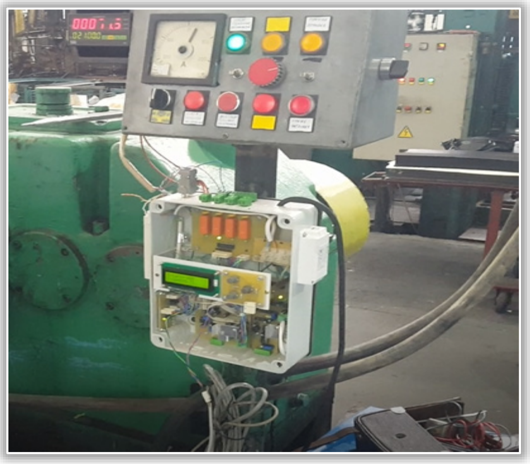

Figure 11. Regulator and the control panel

The Analogic Channel range is between 0 and 1 023 (analogic–numeric inverter is configured on 10 bits). The 511 value corresponds to the horizontal position of the swiveling bracket, and it represents the range imposed on the PI regulator.

The programming language is "C". This is the sequence that corresponds to the PI regulator.

```
//––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––
if (ContorEsantionare==0)
{     ContorEsantionare=10;            //10*10ms=100ms.
      //––––––––––– Calculare eroare –––––––––––––––––––––––––––––––––––––––––––
      if(CanalAnalogic>511)     //Semn=1 pt. „+"; Semn=0 pt. „–".
      {Eroare=CanalAnalogic–511;Semn=0;}
      else{Eroare=511–CanalAnalogic;Semn=1;}
      //––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––
      if (In1)  //Se testeaza daca regulatorul este activat.
      {        //––––––––––– Calculare Kp_F ––––––––––––––––––––––––––––––––––––
               Kp_F=Kp*Eroare/100;     //Scalare: /100.
               //––––––––––– Calculare Kp_F –––––––––––    ––––––––––––––––––––––––––––––          Ki_F=Ki*Eroare/100;       //Scalare: /100.
               //––––––––––– Calculare BufferIntegrare–––––––––––––––––––––––––
               if(Semn==0)               //Eroarea este pozitiva.
               {    BufferIntegrare +=Ki_F;
                    if (BufferIntegrare>0x4000)
                    BufferIntegrare=0x4000;
               }
               else                      //Eroarea este negativa.
               {    if(BufferIntegrare>Ki_F)
                      {BufferIntegrare –=Ki_F;}
                 else{BufferIntegrare=0;}
               }
               //––––––––––– Calculare Comanda –––––––––––
               if(Semn==0)
               {    Comanda=BufferIntegrare + Kp_F;
                    if (Comanda>0x4000)Comanda=0x4000;
               }
               else
               {    if(BufferIntegrare>Kp_F)
                    {Comanda=BufferIntegrare – Kp_F;}
                 else{Comanda=0;}
               }
      }
      else //S–a comandat oprirea; se reseteaza variabilele regulatorului.
      {BufferIntegrare=Comanda=0;}
}
//––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––––
```

6. CHECKING THE SOLUTION AT THE BENEFICIARY

In order to get an important set of values of the specific ranges from the winding installation, necessary for getting the specialized numeric regulator, a communication program between the regulator and the PC was designed, and the values are displayed in a graphic interface (Figure 12) as graphs (Figure 13) which presents their evolution during the checks (Figure 14).

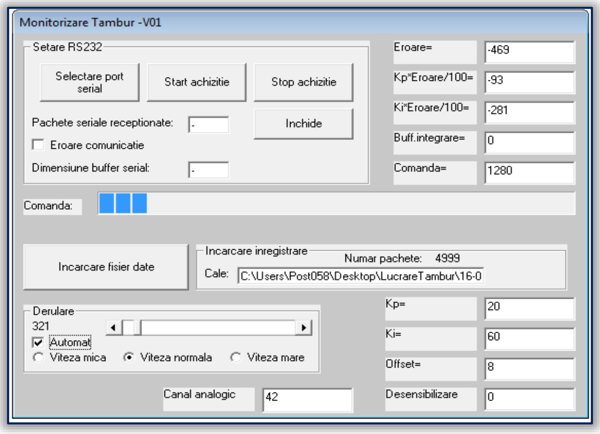

Figure 12. Graphic interface

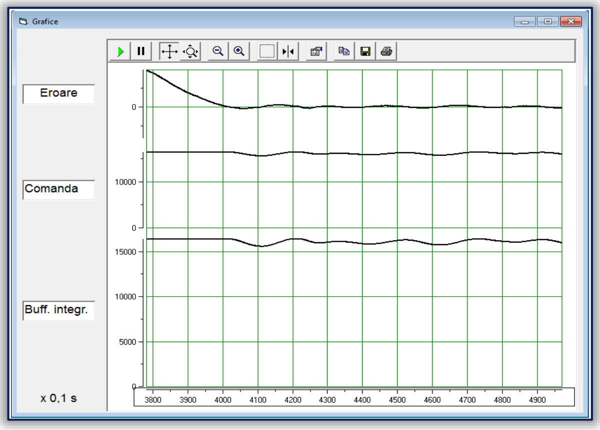

Figure 13. Time evolution of the variable of the winding installation

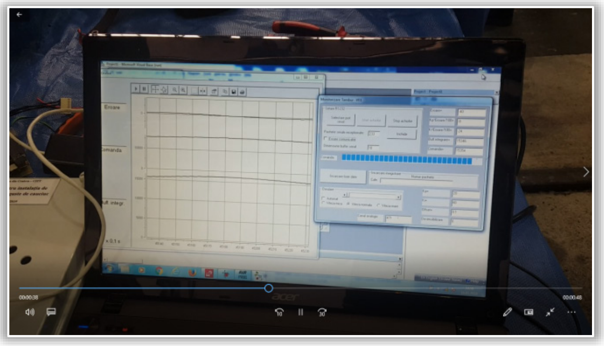

Figure 14. Explication regarding the variable evolution

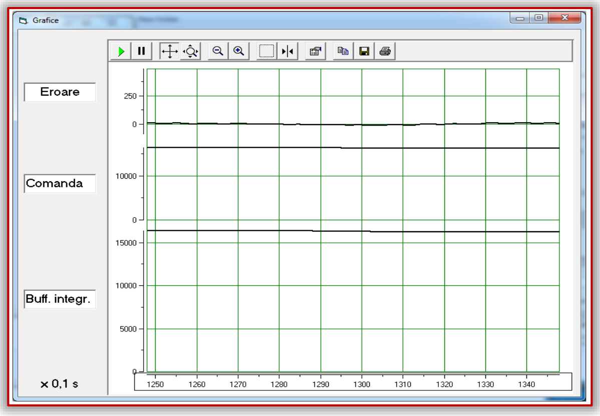

Figure 15. Function during the PI regulator saturation – the command reached the maximum value

Figure 13 shows the moment of passing from a rubber band speed superior to the charging capacity of the mechanical drum to a value when the regulator leaves the saturation regime (at saturation the command range is maximum). The interface displays the information only graphically or numerically or both at the same time (Figure 14). Reaching the equilibrium state is shown by reduced oscillations of the error and of the command.

The optimum functioning regime is obtained when the speed of the metallic drum is very close to the extruder speed. In this way, the productivity can reach very high values. The matching of these two speeds is signalled by turning on a lamp, the operator being warned on the danger a PI regulator saturation (Figure 15).

7. CONCLUSIONS

Although the problem of driving the machine with a variable static couple is classical and it has had different solutions in time, the solution we propose contains many original elements, especially in the mechanical adaption process of the installations.

The authors' original contributions can be found both in the general solution as well as in the realization of the specialized regulator for the driving system of the installation for thin rubber bands.

The modernization of the existent installations by keeping the electromechanics parts and the attachment of some new command equipment, which includes also software, represents an economically efficient solution applied in many production companies in Romania, but also in Europe.

The Romanian companies want a collaboration with the universities for applied research if this collaboration can solve a certain problem in a short period of time.

The academic applied research is taking place slowly because of the law provisions regarding public acquisitions, being a cause of the few contracts with companies.

The academic research teams' interests in researches with companies is reduced because of the academic promotion criteria for the engineering domain which does not recognize the importance of such research.

This paper can be considered a good example of putting together a research team made up of academic people, teachers and production engineers.

Note: This paper was presented at CNAE 2022 – XXth National Conference of Electric Drives, organized by University POLITEHNICA Timisoara, Faculty of Faculty of Electrotechnics and Electroenergetics (ROMANIA), in Timisoara, ROMANIA, in 12–13 May, 2022.

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