STUDIES AND RESEARCH ON THE DESIGN AND CONSTRUCTION OF A MACHINE FOR TENDERIZE MEAT WITH THE PNEUMATIC ACTION AND AUTOMATION MODULES.

Prof.Silviu Macuta.PhD[1] , Aurel Simion.PhD[2]
"Dunarea de Jos" University of Galati,Romania[1], University of Craiova, Romania[2]
silviu.macuta@ugal.ro

Abstract: *The mechanical tenderization , during meat processing, can be the advantageous solution for rapid maturation of the product. This method represents the possibility to modulate the working process on optimal variants of applying the impact force, the pressing time and the relaxation time of the product.*

In this paper there is presented an experimental model of machine of our own conception for the optimization of the tenderization process of the meat.

The paper, presents the adequate system of pneumatic action and the automation elements of the working parameters which were made as our own conception for construction of a machine for meat tenderization. Within the elaborated pneumatic scheme of driving there are identified the elements that can be electrically driven and the basis established scheme includes the programmable controller of the process.

Keywords: TENDERIZATION, PRESSING FORCE, PNEUMATIC, AUTOMATION, OPTIMIZATION PROCESS, MICROCONTROLLER.

1. Introduction

The mechanical tenderization methods, most used have been the ones that involve pins or blades that do not have possibilities of changing the working parameters. The method proposed by us for meat tenderization is made by beating and it allows adjusting the working parameters of the machine to different types of processed meat.

In this paper the authors present a machine for meat tenderization by mechanical method. The authors present a pneumatic machine for meat tenderization with elements of automation of the entire working process of tenderization.[9],10].

By own conception of the pneumatic action scheme and automatic system which endow the machine, the authors create the possibility to modulate the working process (of tenderization) in diverse variants of applying the impact force, the pressing time and the release time of the product after each working cycle [1][3]. The entire process is controlled by a microcontroller which has programing possibilities after a cyclograme which was established by the operator.

2. The mechanical structure of the machine. Design and description of scheme kinematical

In figure 1 there is presented the design of this machine, with the following components [9] :

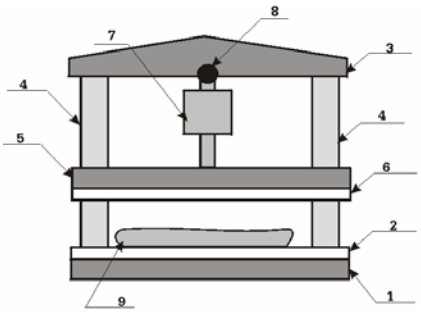

Fig. 1. *The machine for meat tenderization with mechanical operation*

1. Frame
2. Meat placement place – (PTFE)
3. Upper securing cross part
4. Guiding colons
5. Pressing mobile plate
6. Pressing element (PTFE)
7. Pneumatic driving cylinder
8. Coupling ball
9. Product for processing (meat)

The construction and the role of elements are given by their features needed for function. This way, the two guiding colons (4) are jointed with the machine frame (1) and with the upper securing cross part (3). On the two colons (4) slides the pressing plate (5). The movement of the pressing plate (5) is ensured by the driving pneumatic cylinder (7). In turn, the driving pneumatic cylinder (7) is fixed on the upper securing cross part (3) by coupling ball (8) that has the role of taking possible coaxial deviations. The rod of the driving pneumatic piston (7) is jointed with the pressing plate (5) determining its movement.

The functioning of the machine consists of pressing the product (9) between the placement element (2) that is fixed on the machine frame (1) and the pressing element (6) that is jointed with the pressing plate (5). The elements (2) and (6) are made of PFTE (Polytetrafluoroethylene, teflon) in order to meet the requirements of the machine that processes food.

During the function the machine has the following states:

1. Repose – the pressing plate is located in the upper part, the space between the placement element and pressing element is maximal. In this position the product can be put into the machine.
2. The movement of the pressing plate until the product is caught between the two elements. This movement is produced by the pneumatic cylinder.
3. The effective pressing, when the product is caught between the two elements, it is pressed with a force that is proportional with the air pressure from the pneumatic cylinder.
4. Upward movement of the pressing plate done by the pneumatic cylinder until repose position. This state shows the finishing of the processing.[8],[9],[10].

The operator places the product on the surface of the placement element when the machine is at repose state. Then there is given a command of descending of the pressing plate until the effective pressing is made. In this state the product stays a time established by the technology of processing a certain type of meat. When this time ends there is given the command for lifting the pressing plate until the repose state. During the pressing state of the machine the operator can either modify the time of pressing or the pressing force in function of the technology of a specific meat (see below).

The function of the machine is determined by a series of constructive and technological factors. They have been determined in function of the necessities of product processing.

The result of processing is mainly determined by the following factors:

- The processing degree – this refers to the ratio between the initial and final states of the product.
- The quality of processing – it refers to the range of maintaining the product features at the end of processing.

It is obvious that the higher the processing degree, the lower its quality. By determining and choosing the best technological parameters we try to reduce this tendency.

The mechanical construction of machine assumes the knowing of the kinematical scheme so that the operation condition to be fulfilled. On the basis of its design and working principle that have been already presented the kinematical scheme is presented in the figure 2.

1. Placement plate
2. Mobile pressing plate.
3. Guiding colons – jointed with the placement plate.
4. Sliding bearings; they are jointed with the mobile plate for pressing and they glide on the guiding colons.
5. Upper securing cross part – it is jointed with the guiding colons.
6. Coupling ball – for correcting eventual coaxial deviations.
7. Driving pneumatic cylinder.

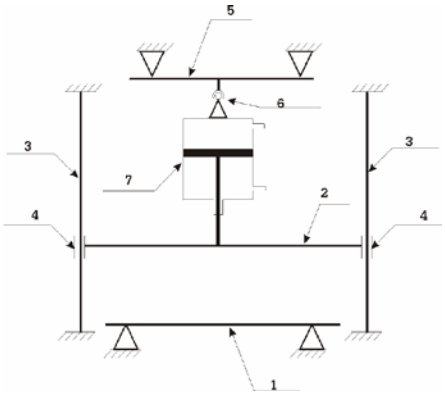

Fig. 2. *The kinematical scheme of the machine*

3. The pneumatic installation for action.

The machine is driven by mean of a pneumatic cylinder. In order to adjust the working parameters in a wide range and to achieve the automation goal of machine there was adopted a pneumatic scheme of operating which is presented in the figure 3.

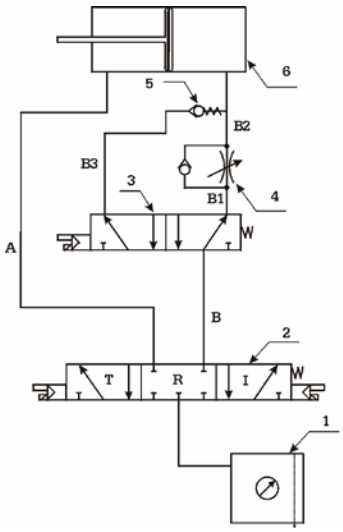

Fig. 3. *Pneumatic operating scheme.*

In figure 3 is presented pneumatic scheme with the following components :

1. Air pressuring unit – compressor.
2. Distributor with electrical command 5 HP/3 positions – it determines the working status (direction).
3. Distributor with electrical command 5 HP/2 positions – it determines the working way.
4. One-way switch of flow – drosel.
5. Anti – back flap.
6. Pneumatic cylinder.

The functioning of the pneumatic installation is characterized by three states:

- Release state – distributor (1) position R.
- Operating – piston pushing – distributor (1), position I
- Operating withdrawal of piston – distributor (1), position T.

In function of the distributor state (2) there are possible two working ways:

- With operation – controlled piston pushing (adjusting the speed at pressing) – distributor (2) not operating.
- No control at piston pushing (maximal speed) – distributor (2) operating.

With the first working way the impact force will equal the pressing force. With the second one the impact force will be given by the following formula (.1.):

$$Fi = \frac{Ep}{d} = \frac{\frac{m_p \times v_p^2}{2}}{Gi - Gp} = \frac{m_p \times v_p^2}{2 \times (Gi - Gp)} \quad (1)$$

where:

Fi = the impact force
Ep – the energy of pressing plate
d – the distance of pressing action
mp – the mass of the pressing plate plus the mass of the pressing element
vp – the speed of the pressing plate at the impact moment
Gi – the initial thickness of the product
Gp – the thickness of the pressed product

With the controlled speed working way the functioning is as follows:

- Distributor (3) not in action
- Distributor (1) is brought in position I
- The air from the preparing unit follows the way branch B – branch B1 – flow flap – branch B2 – pneumatic cylinder. The air from cylinder will be evacuated on A way into the atmosphere. Due to flow flap (4), the speed of the piston will be determined by the flap adjustment. It is important that on the B3 way air will not circulate due to anti back flap (5).
- In order to withdraw the piston, the distributor (2) is brought to T position where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made as follows: piston – B2 branch – flow flap – B1 branch – B branch – atmosphere. In this case, the flow flap will have no effect because of the direction sense of the air circulation. As for the previous case, on the B3 branch there will not be any air circulation due to the anti back flap.[6].

For the working way with maximal speed, the functioning will be as follows:

- Distributor (3) in action
- Distributor (2) brought in I position
- The air from the preparing unit follows the following path: branch B3 – flap (5) – branch B2 – pneumatic cylinder. The air from the cylinder will be evacuated on the A path into the atmosphere.
- For piston withdrawal, the distributor (2) is brought in position T, where the air circulation will be: preparing unit – A branch – head of the piston. The evacuation of the air will be made through the following path: piston – branch B2 – flow flap – branch B1 – branch B – atmosphere. In this case the flow flap will have no effect due to the direction sense of the air circulation. On the B3 branch will be no air circulation due to the anti back flap.

4.The electrical installation for operation and the automation modules.

For the achievement of the operating and automation electrical scheme are needed the operation conditions for each state of machine as described above. In parallel, the operating must comply with the technological conditions of the process. Besides that the operating should follow the requirements imposed by the functioning parameters.[8],[10].

4.1 Operating principles and conditions

The operating principles result from the technological requirements as well as from the researching methods that are desired to be applied. The establishing of the working pressure that influence both moving speed of the mobile plate will be made exclusivelly by hand through adjusting the pressure at the air preparation unit as well as by adjusting the one way flow flap.

Firstly, there will be adopted two operation ways:

- Manual operation – where the operator controls manually the movement of the mobile plate;
- Automation operation – where the operator establishes the functioning parameters and the cycle if automation driven by automation component.

On the contrary with the manual operation, the automatic operation makes an entire functioning cycle. This cycle can be described as having the following states:

1. Descending the mobile plate until the pressing of the product is done.
2. Keeping the product under pressure for a certain time called **pressing time**.
3. The release of the pressing by removing the pressure and lifting the mobile plate on a reduced distance enough for removing pressure on the product.
4. Keeping the release state for a certain time called **release time.**
5. Return to the pressure state (# 2).
6. Repeating points 2 and 3 by a number of times called **number of subcycles**.
7. Withdrawal of the mobile plate in the upper part, finishing a cycle.

The operating conditions are determined by a series of factors as follows:

- Machine architecture
- Technological parameters
- Flexibility in changing the value of the functioning parameters
- Ensuring operation protection
- Ensuring the functioning within the limits of the working parameters.

4.2 The block operating scheme

From the pneumatic operation scheme result the elements that can be electrically driven; they are:

- Distributor of machine states (sense of direction) – this has two driving coils by which the distributor is brought to one of the three states: R, I and T (see above).
- Distributor of the working way – by which there will be established the way the piston will be driven, the controlled speed or the maximal speed.

The block scheme is presented in figure 4.:

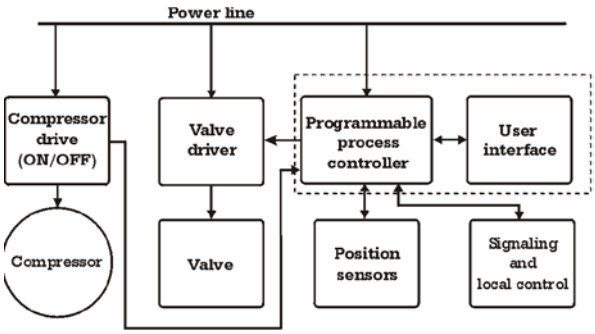

Fig. 4 *The operating block scheme*

The block scheme with the following components :

- Power line – electricity supply line
- Compressor drive – on/off switch of the compressor
- Valve drive – air valve operating block
- Position sensors – position sensors and state; they are:
  - Superior course cut-off
  - UP position of mobile plate transmitter
  - DOWN position of mobile plate transmitter
  - Cut – off protection flap – the machine is endowed with a flap that limits the working space of the machine in order to ensure operator protection [5].
  - Sensor of compressor state – it signals the state of the compressor ON/OFF
  - Programmable process controller, User interface.
- Signaling and local control – through these features the operator can make functioning commands; they are:
  - Signaling of UP movement of the mobile plate
  - Signaling of DOWN movement of the mobile plate
  - Signaling the working way – manual/automatic
  - Signaling the driving mode – normal speed/maximal speed
  - Command of DOWN movement of the mobile plate
  - Command of UP movement of the mobile plate
  - Command START automatic cycle
  - Command STOP automatic cycle

4.2.1. Scheme electric drive

Pneumatic scheme resulting from items that can be electrically operated. These are:

• Distributor machine states (sense) - it has two coils is operated by the retailer brought in one of three states, R, I, T (see above)

• Distributive approach - that will determine how to drive the piston, controlled speed or full speed.

Compressor drive circuitry is shown in the figure below. Also in this scheme it is and transformer that provides the necessary voltage supply 24V DC-dispensers shareholders. In figure.5 is presented electric drive compressor scheme.

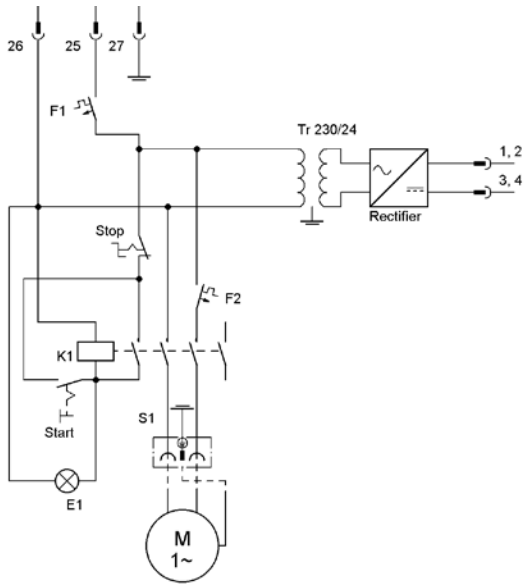

Fig.5 *Electric drive compressor scheme*

Notations in the figure represent:

- 1, 2, 3, 4, 25, 26, 27 - is generally placed in positions of connector switchboard
- F1 - Breaker - general
- F2 - breaker / thermal - compressor motor protection
- K1 - power contactor compressor
- S1 - connecting compressor outlet
- Start - start button compressor
- Stop - stop button compressor
- E1 - compressor status signaling lamp
- Tr 230/24 - the processed 230V / 24V
- Rectifier - 24V DC voltage rectifier + filtering shareholder distribution

Scheme of electric drive pneumatic distributor is shown in Figure 6. Also in this scheme are summarized these elements:

- Adapters level position sensors
- Local signaling Power
- Power Position Sensor

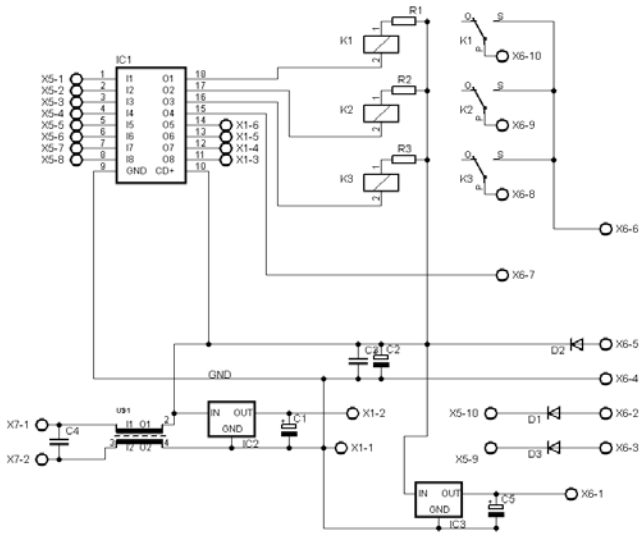

Fig. 6 *Scheme of electric drive pneumatic distributor.*

4.3 Elements of automation and possibilities to use

The block scheme of electrical operation is endowed with the programmable controller of the process that is the main element of machine commands [8],[9].

Programmable process controller is a real time programmable module with 8 digital entries and 8 digital exits. The implemented program into the controller has to comply with the functioning requirements of the machine. The controller is presented in the figure below.

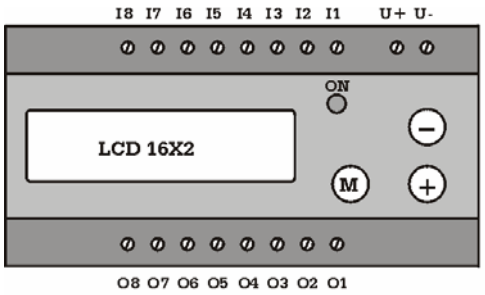

Fig. 7 *The programmable controller*

In the upper part there are 8 entries, from I1-I8. Also, here is mounted the power switch U+, U-. The exits O1-O8 are located in the bottom part. The connections to the controller are made by coupling the signal cables with the screw connectors according with the signal. The interface with the user is made of an alphanumeric screen of LCD type which has 2 rows and 16 characters on each row. Also, there is a small bulb signaling that the processor is ON. The user can change the parameters by operating one of three buttons:

M- menu

+ - plus – increase a value

- minus – decrease a value

The implemented program in the controller implies the approaching of some aspects related to the state of the machine, the working way and the working parameters. The controller having as signals of entry the position sensors, the state of the compressor starting connector, the state of the protection flap and the state of the switchers of working way and driving mode can operate separately each state of the machine.The states of the machine are given by the working way and the position of the mobile plate.

With manual mode, the state of the machine is not limited by the program but for the lifting of the mobile plate so that the pneumatic cylinder of driving should not reach at the end of the course (at the limit).

With automatic mode the machine states have been described below and they are:

- Repose
- Descending the plate
- Pressing
- Release
- Lifting the plate

Also, the programmer should allow the user to set values for the working parameters. The working parameters are:

- Pressing time
- Release time
- Number of subcycles
- Time of error for movement

The last one, the time of error for movement is a parameter that limits any movement in time. If this time is exceeded, it is assumed that a defect has occured and a system error is started. The error is removed by stopping and starting the air compressor. The program is structured in several sections:

- Initialization
- Detecting the state of the machine
- Manual working way – if selected
- Automatic working way – if selected
- Parameters setting mode
- Error into the machine

The two active machine working ways, automatic and manual, can be graphically represented.[5],[10]. With the same aspect there can be represented each of the working states of the machine: the working graph of the repose state, of the pressing state, of the release state, etc. For instance, for the automatic working way, the graph of the function is presented below:

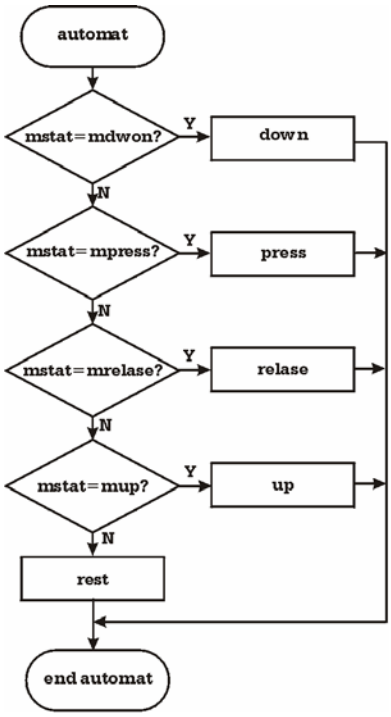

Fig. 8 *The working graph of the automatic working way*

In this working mode the states are tested and for every one it is executed the specific function. The states noted in the figure with their correspondents are:

- mrest – repose
- mdown – Down movement
- mpress – Pressing
- mrelase – Release
- mup – Up movement

If the system variable is not something that implies movement (mdown, mpress, mrelase or mup) it results that it is in mrest – repose.

5. Conclusions

- The mechanical tenderization is a modern technological component of the process of meat manufacture. It allows the worker to modulate the working state of the machine on different optimal variants of applying the impact force, the pressing time and release of the product. It permits the worker to adjust the working parameters to the type of the meat; this issue makes this paper original;

- The experimental model of the machine presented in the paper is of our own conception and it can solve the problem of meat tenderization within the meat processing technology;

- The authors have designed and constructed a pneumatic installation of operating the machine for mechanical tenderization where all working states of the process are automatic;

- The programmable controller of the process has his own software program that ensures a programming variant after a cyclograme that was established by the operator;

- The working graphs that are presented in the paper determine the recording of the functioning cyclograme that is needed for the performance of functioning.

- The present paper opens directions for researching in automation of different steps of technologies for meat processing.

References

1. Davis, K. A., D. L. Huffman, and J. C. Cordray - Effect of mechanical tenderization, aging, and pressing on beef quality. Journal of Food Science. Volume 40, Pages: 1222-1224, 1975.
2. Heller, C. E et all. - Decontamination of beef subprimal cuts intended for blade tenderization or moisture enhancement. Journal of Food Protection. Volume 70, Pages: 1174-1180, 2007.
3. Jeremiah L. E., L. L. Gibson, and B. Cunningham - The influence of mechanical tenderization on the palatability of certain bovine muscles. Food Research International. Volume 32, Pages: 585-591, 1999.
4. Loucks, L. J., et all., - Effect of mechanical tenderization and cooking treatments upon product attributes of pre-rigor and post-rigor beef roasts. Journal of Animal Science. Volume 58, Pages: 626-630, 1984.
5. Măcuţa S., - Elemente de mecanică fină şi servomecanisme. Editura Didactică şi Pedagogică Bucureşti, 2003.
6. Oprean A. şi al., - Acţionări şi automatizări hidraulice. Sisteme mecano-pneumo-electrohidraulice. Editura Tehnică Bucureşti, 1983.
7. Oprean A., - Hidraulica maşinilor unelte. Editura Didactică şi Pedagogică Bucureşti, 1978.
8. Aurel Simion,Thesis of PhD, University of Craiova , june 2015.
9. Simion Aurel, Badescu Mircea-Studies and researches on designing and constructing a machine for meat tenderization in order to obtain traditionally products.- Annals of "Dunarea de jos" University of Galati,Mathematics,Physics,Theoretical,Fascicle II,year V(XXXVI),2013.
10. Simion Aurel,Mircea Badescu, Silviu Macuta-Studies and researches on the pneumatic action of a machine used for meat tenderization and possibilities for automation of this operation- Annals of "Dunarea de jos" University of Galati,Mathematics,Physics,Theoretical,Fascicle II,year V(XXXVI),2013.