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FACULTAD DE INGENIERÍA EN CIENCIAS APLICADAS

CARRERA DE INGENIERÍA EN MECATRÓNICA

DISEÑO Y CONSTRUCCIÓN DE UNA MÁQUINA SELLADORA SEMIAUTOMÁTICA DE VASOS PARA MEJORAR EL PROCESO DE ENVASADO DE YOGUR.

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DESIGN AND CONSTRUCTION OF A SEMI-AUTOMATIC SEALING MACHINE OF VESSELS TO IMPROVE THE PROCESS YOGURT PACKAGING.

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Summary. This work focuses mainly the artisanal sector that is dedicated to the development and marketing of dairy such as yogurt. This project contributes to improving the packaging process yogurt so will increase production and competitiveness of small companies.

The main objective of this project is based on the design and construction of a semi-automatic sealing machine yogurt cups that will optimize both the production process and the conditions to which is subject the worker. In addition to reducing waste aluminum foil, packaging and content.

1. INTRODUCTION

Yogur since its appearance in the Ecuadorian market for 30 years has had a wide acceptance and accelerated growth; he is currently in a variety of presentations, sizes, textures, flavors, colors and trademarks.

In Cayambe there are several craft enterprises engaged in the processing and marketing of dairy such as yogurt, these companies have the need to increase their productivity and competitiveness through innovation of production processes.

Today most of these artisan companies have a line of packaging and sealing of yogurt that is done manually causing losses of product, production time, sealing defective and both physical discomfort and ergonomic; besides the worker is exposed to constant burns.

That is why we have seen the need for the implementation of a semiautomatic sealing machine for yogurt cups that will improve both the production process and working conditions to which is subject the worker repetitive tasks it performs; in addition to reducing waste aluminum foil, packaging and content.

2. CONTENT

2.1 MECHANICAL DESIGN OF THE MACHINE

Design of the gyratory plate. The turntable is one of the most important elements. It aims to go through four stages to meet the whole process of sealing the package.

The design requirements for the dish are:

- • The dish consists of four cavities in which they will be housed and packaging is in direct contact with food must be constructed of stainless steel AISI -304.
- • In addition to moving the container to the different stations, whose function withstand the force exerted by the rammer during the sealing step.

An analysis plate with different thicknesses is performed to determine the deformation occurring to exert the sealing force and the filled package. The following table shows the results obtained are shown according to Von Mises criterion.

Table 1: **Result thickness analysis**

Thickness	Safety Factor	Deformation
6	5,40	0,0000966
8	9,49	0,0000575

Source: Software Simulation SolidWorks 2012

There is chosen the thickness of 8mm since a maximum displacement of 0,1 is had.

For the static analysis of the gyratory plate SolidWorks is in use. The load that exercises the system of sealed and the full packing is distributed in an alone point like can be observed in the following figure.

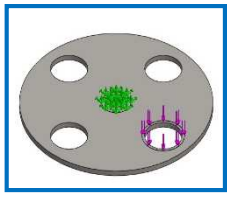


Figure 1: Load applied in a point of the gyratory plate

In the following table the results of the safety factor are observed by relation to Von Mises's tension being a minimal value of 9, this criterion is in the habit of being in use for verifying failures of elastic limit of ductile materials.

Table 1: **Result of the Safety factor**

Name	Type	Minimal	Maximum
Safety factor 1	Tension of von maximum Mises	9.48784	99321.3

Source: Software Simulation SolidWorks 2012

In the table 2 there appears the result of the minimal tension and maxim applied to the gyratory plate.

Table 2: **Result of the tension distribution**

Name	Type	Minimal	Maximum
Tensiones 1	Tension of Von Mises	2082.2 N/m^2	2.17971e+007 N/m^2

Source: Software Simulation SolidWorks 2012

In the figure 2 is observed clearly that the maximum tension that experiences the plate is of 2.17971e+007 N/m^2 and is minor to his elastic limit reason for which the element will not present a considerable deformation during his stage of work.

The displacements of the material produced in the plate are detailed in the following table.

Table 3: **Result of the distribution of displacements**

Name	Minimal	Maximum
Displacements	0 mm	0.100136 mm

Source: Software Simulation SolidWorks 2012

The deformations produced in the gyratory plate:

Table 4: **Result of the deformation**

Name	Minimal	Maximum
Deformations unitarias1	3.27115e-008	5.75172e-005

Source: Software Simulation SolidWorks 2012

With the analysis of convergence realized in the software SolidWork, it comes near to the conclusion that while the mesh is making to him the tension effort of Von Mises thinner it is increasing to a maximum value of 54360160 N/m^2 as appearing in following figure.

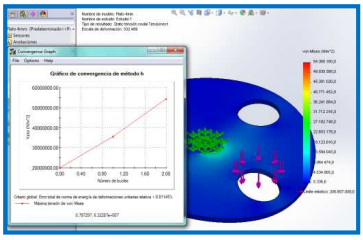


Figure 2: Analysis of convergence of the gyratory plate

The following equation is used to determine the safety factor of the element:

$$n = \frac{S_y}{\sigma_{max}} \qquad \text{Equation 1}$$

$$n = 5{,}7$$

Design of the axis. The axis of the sealer machine has as aim move to the plate. Across the axis the power of the servomotor is transmitted directly towards the gyratory plate.

- The axis will be constructed in Stainless Steel AISI 304.
- The axis is submitted to a load of compression and twist.

To realize the static design of the axis there is realized the graph of free body.

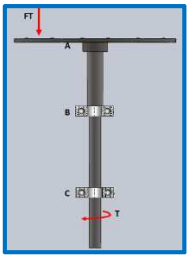


Figure 3: Diagrama de fuerzas del eje

In the figure is observed the graph of free body of the forces and reactions that take place in the axis.

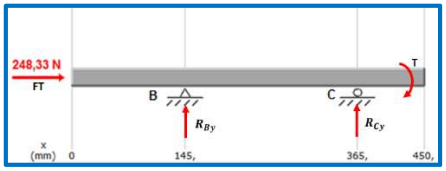


Figure 4: Graph of free body

In the following figure the graph is observed in the axis x of the axial force.

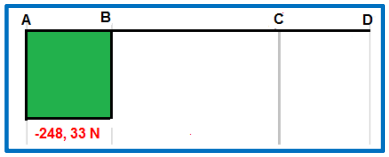


Figure 5: Graph of axial force

In the following figure there appears the graph of cutting force in the axis and.

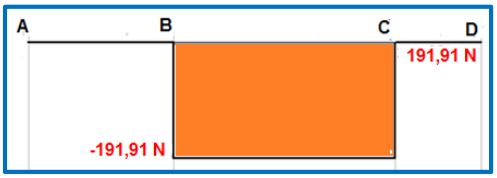


Figure 6: Graph of cutting force in and

The graph observes in the figure at the moment flector maximum that takes place in the axis.

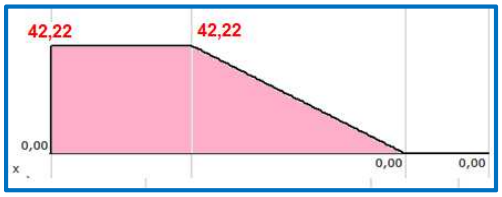


Figure 7: Graph at the moment flector xy.

In the figure the graph appears at the moment torsor:

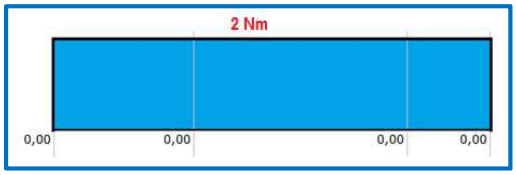


Figure 8: Graph at the moment torsor

Since the most loaded section is in the point B. For the design of the axis it controls the axial force, moment flector and torque Von Mises's equation is in use for the static analysis with the one that can decide the diameter.

$$\left(\frac{S_y \pi}{4N}\right)^2 d^6 - (F^2)d^2 - (16MF)d - (64M^2 + 48T^2) = 0 \qquad \text{Equation 2}$$

$$d = 16{,}2\ mm$$

The diameter of 1 is selected [in] is to say 25,4 [mm] for the facility of acquisition on the market.

Design of the support of the cupping glass. This system has as aim displace to the cupping glass so that it sucks in the top part the sheets of aluminum and places them in the full packing.

- The pipe goes to turn 90 ° being the manager of moving to the cupping glass of it arrives down.

The form of the piece appears in the following figure.

Figure 9: Form of the support of the cupping glass

Design pisadores for the sealed one. The pisadores for the sealed one are dependent on the form of the packing that is going to be sealed for what it is necessary to to bear in mind his dimensions. It has as principal aim seal the sheet with the packing and obtain a hermetic stamp.

- There is born in mind the diameter of the cavity of the packing being equal to 74mm.
- The resistances that are used for the warming of the pisadores are of tubular type.

The form of the pisador of sealed appears in the following figure.

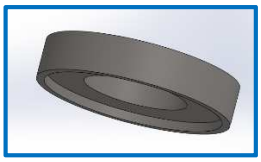


Figure 10: Form of the pisador of sealed

Time, force and temperature of sealed. The time, force and temperature are decisive factors in the stage of sealed since on these parameters it depends to obtain a hermetic stamp and of good quality.

- To major applied force it is needed less time of contact between the pisador of sealed and the packing of plastic, the temperature is kept constant. It is to say if one of three parameters changes necessarily it must change other one. In conclusion the factors are dependent one of other one for what if it wants to come near to a good stamp it is necessary to to analyze them as a whole.

The ideal values and that generate the best results are:

$$F_s = 245\ [N]$$
$$t_s = 4\ [s]$$

With a range of temperature of sealed of 135°C to 150°C.

Calculation of the electrical power. In the system there is necessary an element that controls the power supply towards the pisador of sealed. To obtain a good stamp there are born in mind all the variables that intervene and as these they relate.

- Energy of (supplied) entry.
- Temperature of sealed.
- Temperature of the environment at which the machine is going to be employed.
- Time of warming of the pisador.
- Temperature in the pisadores in every instant of time.

For the analysis there is in use the equation of the conservation of the energy, taking the pisador of sealed as a volume of control.

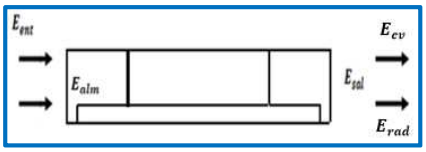


Figure 11: Volume of Control. Pisador of sealed

Then:

$$E_{ent} + E_g - E_{sal} = E_{alm} \quad \text{Equation 3}$$

$$E_{ent} = E_{alm} + E_{cv} + E_{rad} \quad \text{Equation 4}$$

Realizing all the calculations it is had:

$$t = \frac{0{,}040\ ln\frac{T_s - T_\infty}{T_i - T_\infty}}{\left(\frac{E_{ent}}{T_s - T_\infty} - 0{,}107\right)}$$

To replace values in the previous equation the maximum temperature is born in mind of sealed $T_s = 140\ ^\circ C$, the temperature sets of work $T_\infty = 20\ ^\circ C$ y and the initial difference of temperature between the environment and the pisador of sealed $T_i - T_\infty = 1\ ^\circ C$.

Table 5: *Energía suministrada al pisador y tiempo de calentamiento*

E_{ent}[watios]	θ(h)	θ(min)
200	0,122	7,32
300	0,080	4,80
400	0,059	3,54

Considering a time of reasonable warming from 1 to 5 min and the quantity of energy consumption, there takes a value of energy of entry of 300 watts with a time of warming according to the showed table 4, 8 minutes.

Design of carries packing of expulsion. It is the manager of pushing the packing up of the gyratory plate then to be displaced out of the sealer machine by a pneumatic actuator.

- This element has the function to support the force exercised by the weight of the full packing that is approximately of 1,96 N.

Analyzing the criteria before mentioned, the form of the element appears in the following figure.

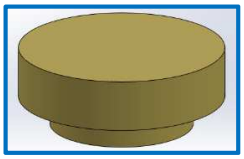


Figure 12: Form of porta packing

Another analysis is not done due to the fact that the load that the element supports during the stage of expulsion is low and is not affected by another type of loads.

Design of the structure of the machine. For the construction of the structure one of the most important factors is the selection of the material that is going to be in use since it is where they will hold themselves all the components of the sealer machine of glasses of yogurt.

To calculate the thickness of the pipe that will be in use for the construction of the machine the most awkward girders are born in mind links AB and CD as are observed in the figure. The girders are analyzed as perfectly fixed.

Figure 13: Structure of the sealer machine of glasses

$$F = m \times g \qquad \text{Equation 5}$$

$$F = 50 \times 9{,}81 = 490{,}5\ N$$

For this analysis there is in use the software MDSolid in the one that locates the static force of 490,5 N as a punctual load in the center of the girder and the following graph of forces is obtained:

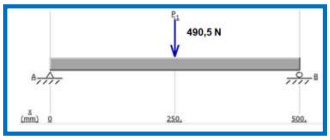
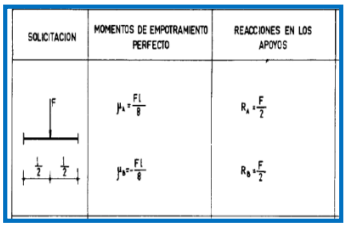


Figure 14: Graph of forces of the girder.

To calculate the moment flector maximum is in use:

Table 6: *Perfectly fixed girders*



Source: Form of girders. http://www.slideshare.net/marggot696/formulario-de-vigas

$$M_{max} = \frac{F \times L}{8}$$ Equation 6

$$M_{max} = \frac{490{,}5\ N \times 0{,}5m}{8} = 30{,}66\ N.m$$

To calculate the thickness there is born in mind the maximum effort of flexion that supports the girder and the following equation is used:

$$Z = \frac{M}{R}$$ Equation 7

$$Z = 0{,}0000000495\ m^3 = 0{,}0495\ cm^3$$

There chooses a structural square pipe AISI 304 of an inch for being the most common on the market.

Table 7*: General specifications square pipe AISI 304*

in	A[cm^2]	I[cm^4]	Sy[MPa]	Su[MPa]
1	1,35	1,21	310	620

Source: DIPAC Manta S.A. (2012).

2.2 DESCRIPTION OF THE SYSTEM OF CONTROL

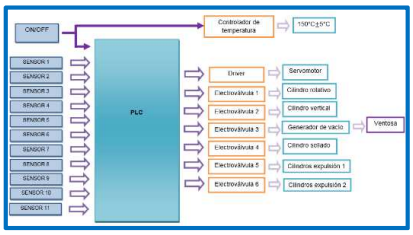


Figure 15: Process of the sealer machine

For the control of the system of displacement of the gyratory plate, system of placement of the sheets of aluminum, system of sealed and system of expulsion is in use a PLC by means of which the sensors are controlled and actuators that intervene in the process of the sealer machine of glasses.

The SIMATIC S7-200. is certainly a mike PLC to the maximum level: it is compact and powerful, particularly in what concerns real time response. (SIEMENS, SIMATIC S7-200. Tecnología de control al máximo nivel)**.**

Servomotor and driver. The servomotor is the manager of making turn to the plate and position it in every working station.

To find the suitable servomotor, this one must conquer the quantity of inertia produced by the axis, the gyratory plate and the packings full of yogur.

$$\Sigma M = \Sigma I \times \alpha$$ Equation 8

$$M = 0{,}0881 \times 10{,}47$$

$$M = 0{,}92\ N.m$$

Due to external loads already be voluntary or involuntary and amicable with the environment there re-is in use the servomotor that is detailed later:

Table 8: *Technical information servomotor*

Type		Characteristics
Tension		220 VAC
Range of power		750 W
Current		3,9 A
Speed range		3000 rpm
Torque	**Nominal**	2,39 Nm

Source: User's manual servo (KINCO, 2013)

Magnetic sensor of proximity. Some magnetic sensors have in his interior switches of sheet or called network switch.

One uses these sensors in the sealer cylinder, cylinder of expulsion and cylinders of positioning of the cupping glass since they are processes of supreme importance for the good functioning of the sealer machine.

Table 9: *Characteristic technical sensor*

Voltage of operation	10 a 30 VDC
Time of connection	≤1 ms

Time of disconnection	≤1 ms
Protection degree	IP 68

Source: Technical characteristics of the magnetic sensor of proximity (SICK, Sensor MZT8)

Inductive sensor of proximity. The sensors of proximity, they are sensors that detect the presence without contact of ferrous metals turning a sign of movement or presence of an object into an electrical sign.

Table 10*: Characteristic technical sensor of proximity*

Voltage of operation	12 a 24 VDC
Nominal distance of operation	10mm
Retard of response	0,3 ms
Protection degree	IP 69

Source: Technical characteristics XS1 N18PA349D. (Schneider Electric)

Photoelectric sensor of proximity. This type of sensor is in use for the detection of the plastic packing and to initiate the process of placement of the sheets of aluminum and sealed.

Table 11: *Technical characteristics sensor*

Voltage of operation	10 a 30 VDC
Nominal distance of operation	45mm
Retard of response	≤2 ms
Protection degree	IP 67

Source: Technical characteristics sensor V18. (SICK, Catalogo sensores SICK, 2006)

Controller of temperature. It is the manager of supporting a stable temperature in the pisador. This controller is detailed later.

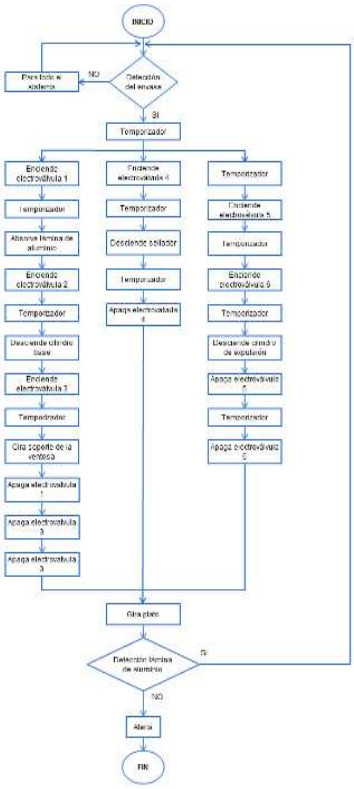
Table 12: *Characteristic technical controller of temperature*

Voltage of operation	**85/264 VAC**
Type of control	ON/OFF
Accuracy of measurement	±0.1%

Source: User's manual (WATLOW)

Due to the fact that the range of work is of 140 and 150 there is in use a control ON-OFF since it is a reliable system, easy to control. Beside being used commonly in the industries.

2.3 FLOW CHART OF THE PROGRAM OF CONTROL



2.4 SELECTION OF THE PNEUMATIC ELEMENTS

System of placement of the sheets of aluminium.

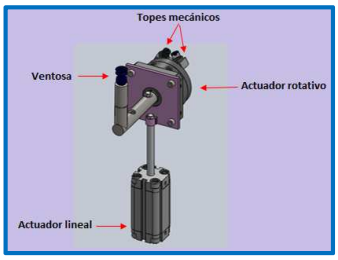


***Figure 16**:* System of placement of the sheets

There is in use a rotary actuador of the following characteristics:

Table 13: *Technical information rotary actuador DMS*

Angle of draft	270°
Pressure of functioning	1,8-10 bar
Torque to 6 bar	2,5 Nm

Source: Rotating Actuadores DSM (FESTO, 2015)

Generator of emptiness. The diameter of the cupping glass is a fundamental factor since on this one there depends the force of retention of the same one. Besides the number of cupping glasses that intervene in the system and the properties of the object to displacing.

With the following equation it is possible to calculate the diameter needed for the cupping glass: (SCHMALZ, 2014)

$$d = 1{,}12 \times \sqrt{\frac{m \times S}{P_u \times n \times \mu}} \qquad \text{Equation 9}$$

$$d = 1{,}12 \times \sqrt{\frac{0{,}0012\ Kg \times 2}{0{,}6\ bar \times 1 \times 0{,}5}}$$

$$d = 1{,}12 \times \sqrt{0{,}008} = 0{,}10\ cm = 1\ mm$$

There is chosen an element that is ideal for thin sheets and paper, besides the fact that it does not produce wrinkles on having aspired. The cupping glass SGPN the mentioned specifications assemble and his minimal existing diameter on the market is 20 mm, his characteristics appear in the following table:

Table 14*: Technical windy characteristics page SGPN*

Model	**Force of aspiration [N]**	**Volume $[cm^3]$**
SGPN 20	8,5	0,31

Source: (SCHMALZ, 2014, p. 218)

To define the generator of emptiness that is going to be in use it is necessary to to determine the capacity of aspiration of the same one and goes in agreement to the diameter of the cupping glass.

Table 15*: Capacity of aspiration of a generator of emptiness*

Ø ventosa	Capacidad de aspiración V_s	
Hasta 20 [mm]	0,17 $[m^3/h]$	2,83 $[l/min]$

Source: (Acosta Jaramillo, 2014, p. 76)

With this one value calculates the capacity of aspiration that must have the generator of emptiness. (SCHMALZ, 2014)

$$V = n \times V_s \qquad \text{Equation 10}$$

$$V = 1 \times 2{,}83 = 2{,}83\ \frac{l}{min}$$

In agreement to the result of the capacity of aspiration and the pressure to which the system works 7 bars. There is selected the generator of emptiness VAD-M5 FESTO.

Table 16*: Characteristics of the generator of emptiness*

Type	VAD
Nominal diameter of the tewel	0,5 mm

Pressure of functioning	1,5-10 bar

Source: Catalogue Generators of emptiness VAD/VAK (FESTO, 2014, p. 6)

System of sealed. The pisador of sealed moves for the action of a pneumatic cylinder placed in the structure of this system. The approximate force in order that it is realized sealed hermetically is of 245 N. The following pneumatic cylinder is used:

Table 17*: Technical characteristics cylinder*

Diameter of the piston	32 mm
Pressure of functioning	1-10 bar
Theoretical force with 6 bar in advance	483 N

Source: (FESTO, 2015)

System of expulsion. It takes charge expelling in packing out of the gyratory plate.

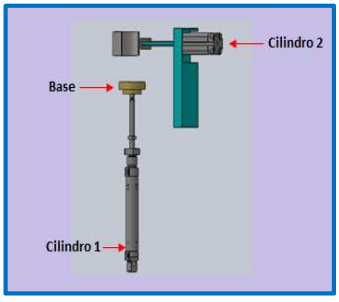


Figure 17: System of expulsion

The following pneumatic cylinder is in use.

Table 18: *Technical characteristics cylinder*

Diameter of the piston	10 mm
Pressure of functioning	1-10 bar
Theoretical force with 6 bar in advance	47 N

Source: (FESTO, 2015)

3. CONCLUSIONS

- The sealer semiautomatic machine of packings of yogurt was constructed by existing elements on the local and national market hereby his maintenance and replacement of components will be facilitated in case of suffering some deterioration or hurt.

- To determine the dimensions and the materials that shape the sealer machine of glasses of yogurt the design and selection of elements was realized before as sensors, actuadores having in it counts the function that every component is going to fulfill.

- In the tests realized in the system of sealed there is had that to major pressure applied to the sealer cylinder 7 bars it is necessary to to reduce the time of contact between the packing and the pisador being the second 4, the temperature is kept in a range of 145 ºC to 155 ºC. With these values the awaited results were obtained it is to say the stamp of the packing is completely hermetic.

- · In agreement to the tests of functioning of the machine realized it was found that the pressure of the generator of emptiness is 7 bars and a regulation is 100 % in order that they absorb the cupping glass only a sheet. In addition do not cause hurts to the delicate surface of the same one; on having increased the value of the pressure the depression is major causing several problems as: it absorbs major quantity of sheets, damages the surface for ende one is going to produce a defective stamp and losses in the product.

4. RECOMMENDATIONS

- There should be implemented a dispenser of packings and a system of dosed of yogurt in order that the machine could work automatically without need of the intervention of the operator in the process of packaging yogur.

- If there is replaced any of the elements that agree each of the systems to realize it for one of equal or similar characteristics to prevent the machine from suffering some alteration in his functioning.

- To check that the air quantity supplied with the this compressor of agreement the specifications of functioning of the equipment

5. BIBLIOGRAPHICAL REFERENCES

Acosta Jaramillo, C. A. (2014). Diseño y construcción de una máquina automática sembradora de semillas de tomate y pimiento en bandejas de 50x28.2 cm en el proceso de producción de plántulaS. Ibarra.

Alimentariaonline. (Marzo de 2007). Obtenido de http://alimentariaonline.com/media/MA017_LLENA2SELLA_F.pdf

Budinas R., N. J. (2008). Diseño en Ingeniería Mecánica de Shigley (Octava ed.).

Calapaqui, G., & Durán, B. (Noviembre de 2012). Dimensionamiento y construcción de una máquina para el dosificado y sellado de envases de yogurt semi industrial con el uso de un mini plc para la empresa INFAIME. Quito, Pichincha, Ecuador.

Cruz, J., & Villamarín, E. (Julio de 2011). Diseño y construcción de un sistema para corte y sellado de envases plásticos de hasta 500cc para la empresa Chemequil industrias CIA.LTDA. Quito, Pichincha, Ecuador.

Incropera, F. (s.f.). Fundamentos de Transferencia de Calor (Cuarta ed.). Prentice Hall.

INEN. (1996). ELABORACIÓN DE YOGURT NORMA 710. Quito, Ecuador.

6. REFERENCES OF THE AUTHOR

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