CONSTRUCTIVE AND DIMENSIONAL CONSIDERATIONS FOR THE CONSTRUCTION OF A VERTICAL TWO-PISTON INJECTION STAND

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ABSTRACT: This article discusses dimensional and thermal analysis and types of heat dissipation on the surface of linear and vertical piston injection system parts. The injection parts of the components and the conditions necessary for the implementation of the simulation model using heat transfer phenomena are presented. Specifically, in the current study we will only use convection and radiation and heat conduction. It is also desired to analyze the evolution of temperatures according to the power that the resistor applies to the entire assembly. In this case, the materials used for the individual parts of the assembly are also very important, as they play an important role in heat transfer in terms of thermal conductivity.
KEYWORDS: CAE part, thermal analysis, fabrication, simulation, thermal radiation

1. INTRODUCTION

Plastic injection technologies are of great interest today in many industries. Plastics are not natural resources which come from nature (such as ores, wood, clay, etc.), they were created by humans by combining chemicals. Thus in 1862, Alexander Parkes discovered a material made of cellulose that could be heated, moulded, and cooled. But to be produce it was quite expensive and had a low strength. The plastic injection industry exploded during World War II due to demand for low-cost and mass-produced products. So 1872, rubber injection moulding was successfully achieved. The injection process continued to evolve, so new types of resins were developed. The first injection machines that appeared worked based on compressed air, the system of opening and extracting the part from the mould was performed manually [1].

All plastic injection machines consist of two construction parts. So, we have the injection part and the closure part.

1.1 Two pistons build the solution

For this injection system, the first stage is like a conventional single-piston injection machine, the material granules are fed into the cylinder to be heated. The difference is that the material does not penetrate the mould, as in the case of the assembly without a plasticizing unit, the injection unit was improved by adding a plasticizing cylinder because it was desired to increase the amount of material injected in a single cycle. So, the injection machine works according to the following principle. The material granules are introduced inside the plasticizing cylinder, once optimal temperatures and pressures are reached, the material is then pushed with the help of a piston located inside the plasticizing cylinder into the injection cylinder, the piston in the plastification chamber does not change its initial position, thus ensuring the necessary pressure in the filling process of the injection cylinder and prevents the material from returning. When the filling has been achieved, but also when the pressures and temperatures necessary for the injection process have been reached, the material is pushed by the piston through a nozzle and then into the cavity of a mould [1-4].

What makes the difference between the two-piton solution and the piston-screw solution is that inside the plasticizing cylinder the piston is replaced by a screw. The screw is used only to melt plastic pellets. Without working in plastic injection into the mould, it keeps the temperature of the liquid plastic stable, allowing precise control of injection moulding and reducing shear forces, wear of various components, as well as excess heat while delivering plastics [3,4].

The constructive solution of the entire ensemble is found in both horizontal and vertical positioning. Horizontal solutions have the mounting axis but also the horizontal opening mode of the mould, facilitating the fall of the part from the mould simultaneously with its opening [1,3].

The advantages of cars that have two injection pistons are:

- Injection of products of increased gauge due to high quantities of injected material.
- Better control over pressure, but also temperature in the injection process.
- It requires lower pressures compared to a conventional machine.
- Mass productivity

And as disadvantages, they are:

- Compared to a machine with a piston and a screw, it shows a lower performance in terms of mixing and homogenizing the material.
- Higher material waste resulting from the injection process.
- A higher cost of maintaining the entire system.
- Higher energy consumption compared to a conventional injection system.
- High wear on the pipe through which the injection unit communicates with the plasticizing unit.

2. CONSTRUCTIVE CONSIDERATIONS ON THE REALIZATION OF THE TWO-PISTON INJECTION ASSEMBLY

The construction elements of the two-piston injection assembly and the vertical injection solution are further analysed.

2.1 Nozzle / injection head

One of the components of the injection unit is the nozzle, which is made of metal materials such as: bronze, stainless steel, carbon steel, brass Figure 1. As far as the constructive part is concerned, but also the function it performs in the system, it is like the one we have shown in the article [2].

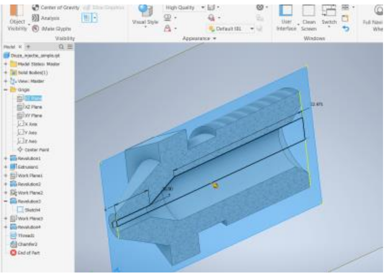

Figure 1. Figure 1. Injection nozzle

2.2 Plasticization cylinder

The plasticization cylinder is made of carbon or alloy steel and is in the form of a long tube Figure 2. Thermoplastics are not good conductors of heat and therefore the larger the diameter of the cylinder, the greater the temperature gradient will be. The optimal temperature distribution is achieved in plasticization cylinders with smaller diameters. He consists of two concentric parts, the outer cylinder has thick walls to be able to withstand the pressure during the injection and compression stages and to ensure a uniform distribution of temperature, the inner cylinder which is made of corrosion-resistant steels. Its inner surface is rectified because it meets the polymer and the piston.

2.3 Injection Cylinder

The injection cylinder is made of materials such as carbon or alloy steel, it is in the form of a long tube Figure 3. For the constructive part, it is the same as the one I presented in the article [2]. Unlike the classic construction solution, the introduction of material pellets has been removed from its attributions.

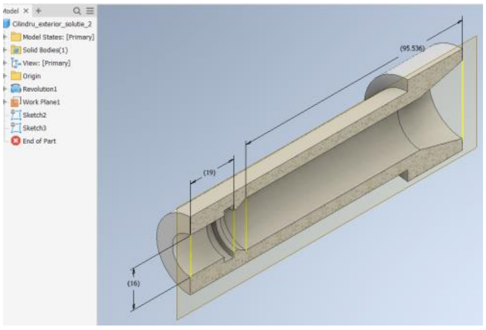

Figure 2. Plasticization cylinder

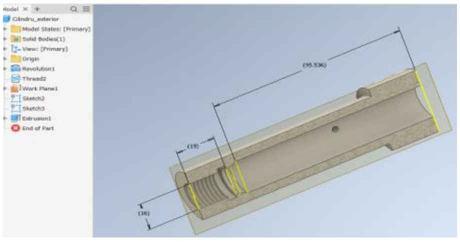

Figure 3. Injection Cylinder

2.4 Plasticization piston

The route that the piston must follow in this process is to inject the molten material when the optimal level of material inside the injection cylinder is reached. Its operation is done hydraulically or pneumatically by pressing on its upper part. It comes in the form of a rod made of carbon steel Figure 4.

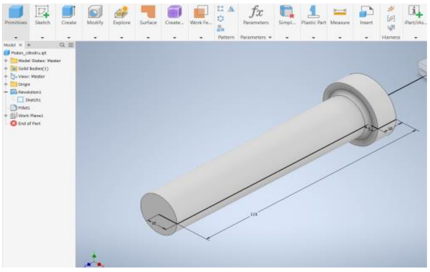

Figure 4. Plasticization piston

2.5 Injection Piston

The role of the piston it performs in the injection process is to push the material that has previously melted into the plasticizing chamber. Pressure is controlled by the speed with which the piston moves. As a construction, it is like the one presented in the work [2] Figure 5. It is operated manually, hydraulically, or pneumatically by pressing it on the top.

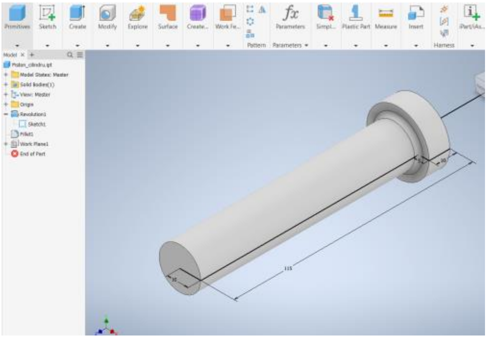

Figure 5. Injection piston

2.6 Heater bands

The heater bands strips are positioned along the entire length of the cylinder, with minimal space between them Figure 6.

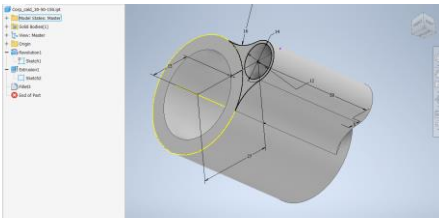

Figure 6. Heater band

The principle of operation is the same as that presented in the article [2]. In the side hole in the construction of the heating strip figure7 there is an electrical resistance that has a resistance of 220 volts.

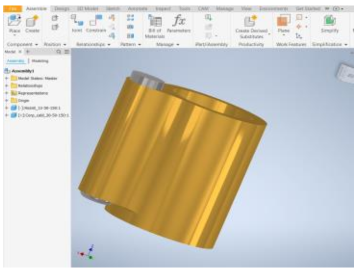

Figure 7. Heater bands with built-in resistance

2.7 Clamping brackets to prevent backflow of material

To form the connection between the mixing cylinder and the injection cylinder, we chose an aluminum bracket, Figure 8. This connection not only has the role of transporting the molten material into the injection chamber but also of preventing the backflow of the material in the injection process.

2.8 Bracket support for the two - piston injection machine

For this stand I also used the support in Figure.9 that was also used in the article [2].

2.9 Support metal structure stand of the whole assembly

The metal structure supporting for the entire assembly Figure10 is built using the INVENTOR 2024 program educational version, on the same principle that we mentioned in the article [2]. To arrange the aluminum bars at an angle of 45 degrees, a lockable connection for ITEM aluminum profile was used, to be able to carry out the assembly at an adjustable and non-rotating angle.

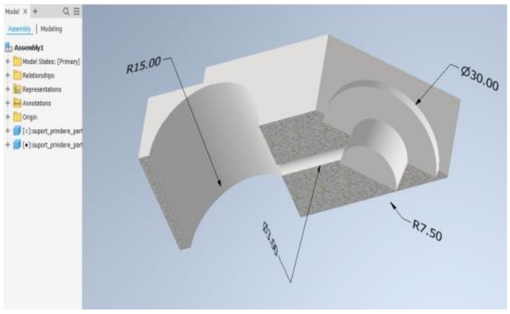

Figure 8. Support for the prevention of material backflow

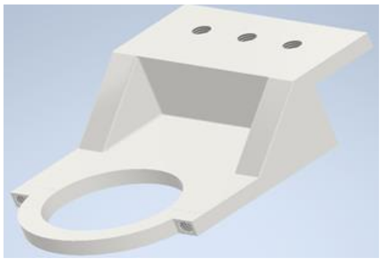

Figure 9. Bracket support

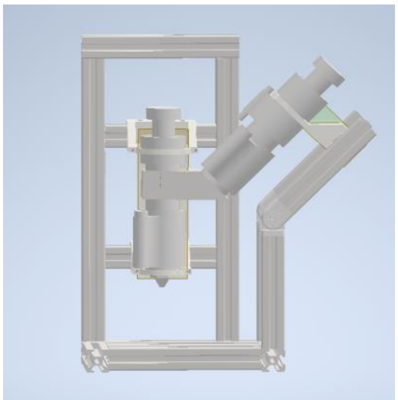

Figure 10. Metal structure with injection system

3. THERMAL CONSIDERATIONS REGARDING THE INFLUENCE OF TEMPERS IN THE INJECTION PROCESS

Therefore, in order to find out what is the real operating temperature of a resistor with a power of 50W and another of 220 W that we want to use in the composition of the injection assembly, we use Stefan Boltzmann's calculation formula, and then with the help of the FUSION 360 educational version and the finite element thermal simulation module, For the entire assembly, the loads were simulated, and thus the temperatures that occur in the injection process were determined.

For the following calculation, two thermal resistances are used:

- The first has a power of 50[W], having as constructive parameters:
  - radius of 3 mm.

- height of 40 mm.
- The second has a power of 220[W], has a radius of 6mm with a height of 50mm.

We use Stefan Boltzmann's law which is the following according to the source [6] equation (1).

$$P = \sigma * A * T^4 \quad (1)$$

Where:

- P - power;
- σ - the Boltzmann constant 5,6*10-8[$Wm^{-2}K^{-4}$];
- A - the surface of the resistance area expressed in [mm];
- T - temperature expressed in [°C];

The area is calculated according to the formula (2):

$$A = 2 * \pi * r * h \quad (2)$$

For resistance 1 we have: A=2∗π∗3∗40=753.9mm and resistance 2 we have: A=2∗π∗4∗50=1884.9mm

and so, for a resistor with a power of 50 [W] and an area value equal to 753.98 mm we have equation (3):

$$T_1 = \left(\frac{P}{\sigma * A}\right)^{\frac{1}{4}} = 770.02\ [°K] \quad (3)$$

And for the resistance with a power of 220 [W] and an area value equal to 1884.95 mm we have equation (4):

$$T_1 = \left(\frac{P}{\sigma * A}\right)^{\frac{1}{4}} = 928.37\ [°K] \quad (4)$$

Since the result of the calculation is expressed in Kelvin, it must be converted into degrees Celsius and thus we obtain:

- 1043.17°K-273.15°K=770.02°C (for a 50 W power resistance);
- 1201.928°K-273.15°K=928.37°C (for a resistance of 220 W power);

To see what the temperature evolution is depending on the strength of the applied resistance. We have performed the following calculation for the resistance with the values Table 1 (which has a radius of 3mm and a height of 40mm) and we obtain the following values, Figure 11.

For the resistance with the following values of the powers: Table 2 (which has a radius of 6mm and a height of 50mm) we have the following temperatures Figure 12.

The materials from which the components are made are assigned (brass for the nozzle, carbon steel for pistons and cylinders, brass for the heater bands, steel for the resistor coating) and then the application of loads on the surfaces of the elements analysed in Figure 11, (we encounter the thermal phenomenon of radiation). To be able to attribute the radiation phenomenon, we also need the value of the emissivity coefficient.

Table 1. Table 1. Temperature values by power

Number	Power [W]	Temperature [°C]
1	50	770.02
2	60	818.66
3	70	861.56
4	80	900.08
5	90	935.14
6	100	967.39

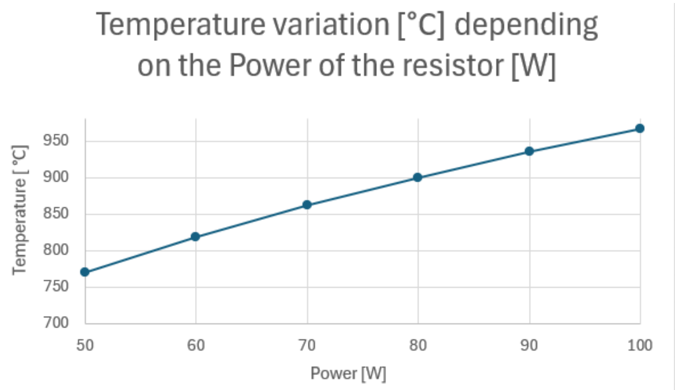

Figure 11. Temperature variation depending on the power of the resistance with an area equal to 753mm

Table 2. Table 1. Temperature values by power

Number	Power [W]	Temperature [°C]
1	220	928.37
2	210	914.48
3	200	900.08
4	190	885.13
5	180	869.58

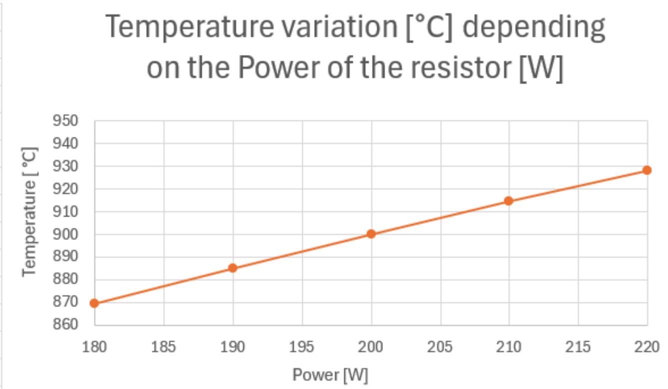

Figure 12. Temperature variation according to the power of the resistance with an area equal to 1884mm

According to the bibliographic source [5] we have an emissivity coefficient value for brass of 0.03 at a temperature of 25°C and for steel a value of 0.07, at a temperature of 25°C. Then the internal heat load of the thermal resistances of 50 W and 220 W is applied (the temperature value that was calculated in chapter 3 for the 2 resistances is added). The simulation takes place at an ambient temperature value of 25 degrees Celsius.

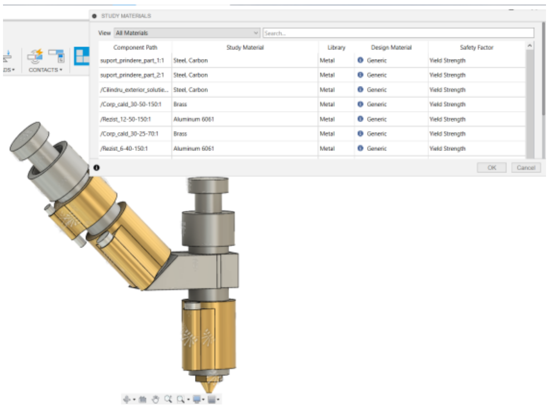

Figure 13. Injection assembly with assigned material and loads

After performing the previous step and applying the contacts between all the thermally charged elements but also checking the dimensions of the tetrahedron (a calculation accuracy as good as possible is recommended), the next step is to move on to running the temperature calculation program and otherwise we will obtain the temperature diagram Figure 14 and Figure 15.

A maximum temperature of 928 ° C is reached around the 220W resistor, the minimum temperature is reached at the top of the plasticizing piston, as the material which is introduced in machine does not must having a thermal shock that is too high once it has left the feed hopper.

Material pellets that are subjected to the melting process must have a progressive increase in temperature. Even if the material reaches the optimal temperature when it leaves the plasticization chamber, there is heat loss in the connecting pipe between the two chambers. Equipping the injection cylinder with additional resistance is intended to maintain the optimal temperature of the material during the injection process.

4. CONCLUSION

In the process of selecting the resistors that we want to use in the composition of the injection system, they must be chosen according to the temperature value that they can generate. A resistor of 100 W can have a greater influence in an assembly, compared to a resistor of 220W because the heat flux they can generate is also influenced by the size of the area that the resistor has.

In the injection process, it is very important to control the temperature of the areas controlled by the resistors, because too high a temperature inside the injection assembly can degrade the material before leaving the injection unit and thus material waste can occur. And too low a temperature can led to non-homogenization but also the risk of the material being solidified before leaving the nozzle hole.

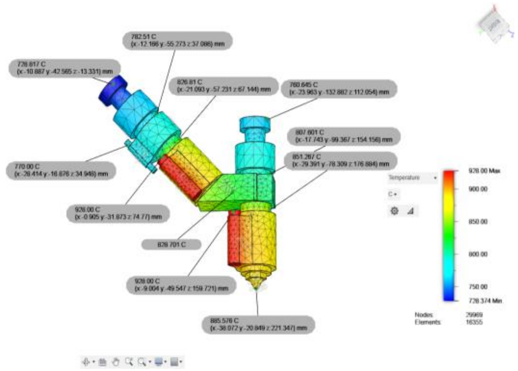

Figure 14. Injection assembly with temperature study

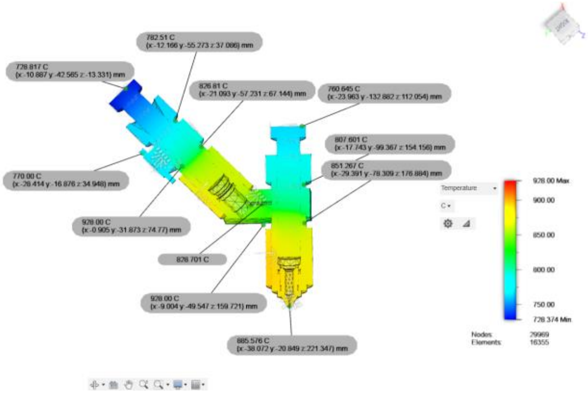

Figure 15. Study of heat transfer inside the injection assembly

To avoid the solidification of the material, the injection machine can be additionally equipped with 2 additional resistors for the nozzle zone, one being located on the right side and the other on the left side.

5. REFERENCES

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