Decreasing the Functioning Consumptions of Plastics Injection Moulding Machines

V Vasilache¹, M Vasilache¹ and A Vasilache¹
¹ S. C. VASILACHE s.n.c., 25/2 Măgurei street, Târgu-Mureş, Romania

E-mail: themannextdoor2007@yahoo.com

Abstract. A share of about 75% in the cost of a plastic moulded part is held by the energy consumption of the injection machine. It is the heating system of the plasticising unit which is responsible for the energophague character of the process. The transfer rate from the heating elements to the plasticising cylinder depends hardly on the geometry of the system. A new heating system is designed, replacing the classical systems which are applied on the exterior of the cylinder with an “engrooved system”. Proposed heating system leads to decreasing of energy consumption up to 30 % and maintenance costs up to 10 %. A supplementary possibility to decrease the maintenance costs is to modify the geometry of the injection torpedo. The proposed geometry eliminates the possibility of any breaking or gripping related to the injection torpedo.

1. Introduction
The field of plastic parts production is targeted by all economical-industrial strategies. This sector is an energophague one and an important consumer of water resources. Decreasing of energetic resources consumption is one of the goals of the Romanian National Strategy for Sustainable Development. The output of the Project implementation consists of subassemblies designed to be put on the existing equipment for plastics transforming in our country, in order to decrease the energetic consumptions of them.

Both duration (over 3 years), and consistency of the activities by which the authors address the problem and propose a series of solutions make this set of works to be different by a certain simple work of engineering design.

Granting an invention patent involves for a technical solution: novelty on world scale, technical progress and industrial applicability. OSIM granting 2 invention patents [1], [2] to the technical solutions addressed in our Project certifies the technical – scientific priority of the solutions on a national and international scale, becoming a clear indicator of the performance level of the results.

Studies on experimental models, digital simulations were performed, experimental stands were erected, prototypes were fabricated and "in situ" determinations to different plastics transformers economical agents were performed in order to attain the results which allow technical - economical conclusions related to the stated theme. All lasted for more than three years.

Documentation of state of art had a very precise purpose, representing a solid argument in the authors orientation related to what is yet to be done and what is proposed to be developed as technical, scientific and with economic effects novelty.

The screw (the part which transmits mechanical solicitations to the polymer mass) geometry is very important upon injection phenomenon which (due to polymer chains breakings, apparition of micro-cracks with free radicals aside of them, re-shaping of molecular spheroids) is not only a mechanical process but a chemical one too, some certain properties having the possibility to totally change. A screw geometry which escaped from calculation rigors or was developed in the idea that the only
purpose of the rotating screw is to transport the plastic grains, may lead to completely unexpected 
secondary effects. The screw geometry must hence be adapted to the structure and properties of the 
respective polymer.

The injection head or torpedo is fixed on top of the screw. This component is one of the most 
solicited, working in condition like:
- temperature: up to 300°C
- pressure: up to abt. 2500 bar
- torsion stress
- maximal wear.

The polymer melt is injected through the injection nozzle after exiting through the torpedo orifices 
(the torpedo works like a one-way valve, blocking the backwards flow of the plasticized polymer 
stream).

Most of the torpedoes from the top of the screws have a part of „closing bushing” type and one of 
„Top” type, which, both, have a surface of „slope” type mated one to the other. The „top” is screwed 
on the frontal extremity of the feeding screw. The „closing bushing” type part has an abt. 2.5 ÷ 3 mm 
thick wall, mated in an adjustment of H7/f6 with the plasticising cylinder which has an abt. 32.5 ÷ 
42.5 mm thick wall. Heat is transmitted from exterior to interior of the cylinder. The wall of the 
“bushing” gets faster to a certain dimensional value than the interior of the cylinder. Thus, a small 
tight of the “bushing” appears. At a certain moment within the functioning cycle, the screw executes 
an axial retreat movement in the plasticising cylinder (altogether with the „top” which is screwed in 
the screw). The slope surface of the „Top” pushes on the corresponding surface (also a slope surface) 
of the „bushing” in order to put in axial movement the „bushing” too. The axial force decomposes, a 
radial component resulting too. This component emphasises the grip of the „bushing” and, at a certain 
moment, this grip becomes so strong that the rod of the conical top breaks. The solution proposed by 
the authors consists in replacing the constructive component „conical top – closing bushing” with 
another one, which eliminates the existence of the „slope” type surfaces.

As regarding the solutions for the heating system, it is found that all the existent solutions for the 
small machines, with max. 3 heating zones, consist from ceramic sleeves with resistive wire \cite{3}, from 
aluminium casted sleeves with tubular resistances introduced in some channels or from resistive wire 
which is coiled on a mica or mineral core \cite{4}. All these solutions have an interface zone between the 
resistive element and the housing and a second interface zone between the housing and the exterior of 
the plasticising cylinder. The fewer the interface zones are, the highest is the efficiency of conductive 
transmission of heat. The solution proposed by the authors consists in eliminating one of the two 
interface zones, by means of directly „grooving” some resistive elements in longitudinal channels 
which are milled on the exterior surface of the plasticising cylinder.

2. Experimental procedures

2.1 Work methods
The following methods, from point of view of research and/or design process, were used for running 
the Project:

- direct research, at natural scale (in situ);
- research by means of experimental proceedings, by means of laboratory studies on physical 
models;
- research by means of mathematical, numerical proceedings.

2.2 Constructive definition of the injection unit subject to simulation / experiments
An injection torpedo is always provided between the feeding screw and the injection nozzle, as a back- 
flow valve (in case of thermoplastic materials).

The newest solution, illustrated in figure 1, shows the final variant of the construction of the 
torpedo \cite{1}. The torpedo body (1) has a piston type zone (a) which mates an adjustment with the 
plasticising cylinder (not figured). Four equidistant inclined holes (A) related to the longitudinal axle 
of the body are provided between the piston zone and the threaded end of the torpedo. These holes 
communicate in an axial hole (B) where there is a ball (3) and a pin (4). When the screw rotates, the
melted material is pushed in the zone between the end of the thread helix and the piston zone. Here, the melted stream is divided in four streams through holes (A) and re-unifies in hole (B) where the ball is pushed until it tampons the pin. The melted stream is divided again, around the ball, and it is re-united after overpassing the ball. The screw advances with a great force in the moment of injection and, due to the piston zone, a corresponding pressure is created in front of him.

**Figure 1.** The injection TORPEDO proposed by the authors (final variant) [1,7].

It may be considered, simplifying, for our scope, that the plasticised fluid is a Newtonian fluid. The introduced errors do not influence significantly the problem. If we may consider, so, the pressure as being constant over all the fluid mass and, because the injection nozzle diameter is much smaller than the ball diameter, a force appears pushing the ball to the smaller diameter step. The melted polymer retreat is thus blocked and the melt is forced to evacuate through the only un-blocked orifice – the orifice of the injection nozzle. The new construction achieves a superior homogenization of the plasticised mass, does not introduce de-balancing and does not bring the danger of auto-grip.

Dimensional finalising of the injection torpedo geometry was done by means of Finite Element Method (FEM) and by means of photoelastometry method.

The injection unit is the most important part of the plastics injection moulding machine. This assembly is also the most energophague among all the assemblies of the machine, which is the reason for what it is the target of our actions to reduce the energetic consumptions of the plastics injection moulding machines. Our concerns on this direction were materialised in developing a new heating system for the injection unit, which system is subject of patenting procedure [5].

We gave up to the constructive solution of the well known heating sleeves and we have adopted a new system (figure 2, figure 3).

The injection cylinder (1) is provided with a number of longitudinal channels (A) on the circumference. An equal number of tubular rectilinear resistances (2) with the number of desired heating zones is introduced in each of the channels. The resistances of each zone are connected in derivation by means of some metallic parts (3), after they had been tightened by some colliers (4). Each zone is insulated with mineral insulation, an individual housing engulfing (5) the whole assembly; the interior surface of the housing is polished and behaves like a thermal reflector.

The new construction, with smaller overall dimensions than the classical one, brings spectacular results related to energetic consumptions.

The tubular heating resistances are an important element of the new heating system (figure 4).

**Figure 2.** Transversal section through the injection unit which is equipped with the new solution [5].
2.3 Contributions to the conception of the new solutions

Two problems were followed within the study of the injection unit: geometry of the screw top (i.e. the injection torpedo) and the unit heating.

The experiments related the two assemblies: the injection torpedo and the heating system of the injection unit.

2.3.1. The injection Torpedo – proposed variant. MEF simulation was run for torpedoes with diameter Ø25, Ø30, Ø35, Ø40, Ø45.

Firstly, the parts and the assembly were 3D modelled. The torpedo material is: 38MoCrAl09 SR EN 10083 – 1 + A1 : 2002.

Structural analyse of the parts was then performed. Functioning conditions were as in table 1:

| Functioning conditions of the injection torpedoes. |
|---------------------------------------------------|
| Press. in front of hole ØA MPa | 163 | 155 | 214 | 164 | 130 |
| Press. behind holes ØF MPa    | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

Structural results obtained for each simulation are:
- equivalent stress (minimal value, maximal value, coloured contouring of value on part surface) [Mpa]
- maximal principal stress (minimal value, maximal value, coloured contouring of value on part surface) [Mpa]
- minimal principal stress (minimal value, maximal value, coloured contouring of value on part surface) [Mpa]
- deformation (minimal value, maximal value, coloured contouring of value on part surface) [mm]
- safety coefficient (minimal value, maximal value, coloured contouring of value on part surface)
Photoelastometry research was performed for Ø35 torpedo. The study was effectuated on models moulded from epoxy resin DINOX 010, with cold strengthening, using the method of « icing » the tensions. The method consists in stressing the model concomitant with its heating to the temperature of up to 100˚C and slow cooling, under stress [6]. In this way tensions are « iced » in the model and their configuration is not changed even if the model is cut.

Pressure application upon active model was realized by means of a hydraulic stand (figure 5) consisting of a metallic cylinder (1) into which the model (2) is introduced. A thermocouple (3) is introduced for monitoring the temperature during the model solicitation. Manometer (6) measures the pressure delivered by a gear pump (4) which is driven by an electric motor (5). A safety valve (7) limits the set pressure. The solicitation cylinder is installed in a thermostat oven (8). Pressure and temperature are kept constant during the test.

After stress application and cooling, the models are cut into slices that contain the zones of interest: central hole zone, inclined holes zone and joining area of the piston zone. The obtained slices were studied in a polariscope, obtaining the respective isochromates. The photo-elastic constant of the material is determined by means of calibration and then the value of the difference between the principal stresses alongside the isochromates is established. A report was issued at the end of the study, containing the isobars for $\sigma_2$ and the isobars for $\sigma_1$.

The stand for hydro-mechanical tests is a construction which allows testing the samples.

The stand (figure 5, figure 6) was intended to be multifunctional, in order to be used for some other ulterior tests. It consists of the following subassemblies: Chassis with protection covers; Hydraulic installation; Electric motor; Vertical device; Horizontal device; Electric driving box; Electric heating box.

Figure 5. Principle diagram of the installation for stressing the active model [8].

Figure 6. 3D view of the stand for hydro-mechanic tests [authors’ creation].

The stand for researching the mixing in the plasticised mass (figure 7) represents, mainly, a mould for injecting some calibration parts. The calibration parts are long type parts – in fact some cones with thin walls.

Figure 7. The stand for research the mixing (the mould) in open position [authors’ creation].
The research of the effect upon mixing of the melted plastic material by introducing the new torpedo was performed by mounting the classical solution at the end of the feeding screw and injecting a part from white or colourless virgin material, then injecting the same part from the same material but with some pigment added. It was counted the number of parts that were necessary to obtain a uniform coloured part, with no white stains.

The pigmented material was cleaned out from the injection unit, the new torpedo replaced the classical torpedo at the front end of the feeding screw and the same injections were repeated, using a different coloured pigment. The injections related to both torpedoes were performed on the same machine, with the same mould, attention being given to maintaining the same settings of the injection machine and to use material from the same bag. A report was issued at the end of the tests, containing the necessary number of injections for obtaining a uniform coloured sample, with no colour stains.

2.3.2. The Heating System – proposed variant. Experimental research was performed for plasticising units with feeding screw diameter of 30 mm, 40 mm and 45 mm, in classical variant and in new variant, the experimental models being executed at 1:1 scale. The method consisted in mounting on the injection moulding machine the experimental model of the plasticising unit and measuring the consumption of electrical energy. The cylinder material is: 38MoCrAl09 SR EN 10083 – 1 + A1 : 2002. Functioning conditions: 300°C. Three different size machines were used, covering the domain of the small capacity injection machines: 250 kN, 500 kN and 800 kN.

Measurements were performed by means of an installation comprising a cylinder of the plasticising unit, three heating sleeves R (both classical variant, and new variant), three thermocouples of the machine (one for each heating sleeve), three temperature regulators of the machine (one for each heating sleeve), three electrical energy metering devices, three current metering instruments A and three voltage metering instruments V (one for each heating sleeve). The electrical energy metering devices were mounted in a stand aside the injection machine, while the other components were mounted on the injection moulding machine.

A report was issued at the end of the tests, containing among other registrations, the effective electricity consumption on the heating sleeve during each coupling of the thermoregulator.

3. Results and discussions

3.1. Project approach

The tests Protocol was issued within Activity 7 “Issuing tests Protocols” and it was internally advised.

As to the Project, two categories of tests are envisaged:
- digital experiments, by means of FEM simulation (research of mechanical behaviour), effectuated within Activity 4 “FEM simulation”
- experiments on the stand (testing mechanical behaviour and evaluation of the effect of introducing the new torpedo on mixing of the melt plastic material), effectuated within Activity 11 “Testing the prototypes on stands and comparison of experimental results to the numerical ones”

The purpose of the experiments was to establish a data base with behaviour results which can allow, then, the establishing of the final geometry of the two subassemblies. Experiments were performed for the injection Torpedo in order to determinate the mechanical behaviour of the new solution and to determinate the effect of introducing the new solution upon the mixing of the plasticised material.

Experiments were performed for the heating system of the injection unit, in order to determinate the effect of introducing the new solution upon the electrical energy consumption.

The photos were taken by the authors, using the following equipment:
1. Digital photographic camera SONY MAVICA FD91 – 1 pcs.
2. Photographical reflector 1000 W – 2 pcs.
3. Photographical tripod – 3 pcs.
4. Feeding cable with 3 sockets – 1 pcs.
3.2. Experiments upon the injection torpedo

3.2.1. Digital experiments. A specialised software was used, dedicated to mechanical engineers: INVENTOR 2009.

Hardware used in performing the tasks:
- Graphic station DELL M6400 Covette:
- processor INTEL Core 2 Duo (2.8 GHz, 6MB L2 Cache, 1066 MHz FSB)
- memory RAM 2048 MB (2x1024), 1066 MHz DDR3 Dual Channel Memory
- video 512 MB NVIDIA Quadro FX2700M (dedicated memory 512 MB)
- Hard disc 2x500 GB, 7200 rpm
- 8x DVD+/-RW
- monitor LCD 17 inch, 1920x1200 resolution
- printer XEROX 7500 Phaser: A3, colour, laser.

The Ø25 (figure 8), Ø30, Ø35, Ø40, Ø45 torpedoes were 3D modelled.

FEM simulations of charge functioning were performed for 36 variants for each of these 5 dimensions for the part Torpedo Body. Discretization was done using triangular elements. An example of discretization network appears in figure 9.

The 180 digital simulations (36 variants for each of the 5 dimensions of torpedoes) have generated 180 Reports.

Figure 8. 3D Model of Ø25 Torpedo [8].

Figure 9. Discretization of the part Body [8].

Figure 10. Solicitation diagrams: a – equivalent stress; b - Maximum Principal Stress; c - Minimum Principal Stress, d- Deformation, e – Safety Factor [10].
3.2.2. Experiments using the photoelastometry method. The model (figure 11) was moulded in a mould especially made for this experiment. The mould has 4 retractable cores (for the 4 holes Ø9), and for the zone Ø31 of the model it has two dismountable half-rings.

The model volume is of 43800 mm³.

Necessary materials and equipment for manufacturing the model appear in table 2:

| Material | Properties |
|----------|------------|
| Epoxy Resin DINOX 010 - P | Density $\rho_R = 1,18\pm1,25$ [g/cm³] 
| TETA | triethylenetetramine |
| Demoulding agent | (oil wax in CCl₄) |
| Balloon 250 ml | Provided with agitating system and thermostat |
| Mould |

In figure 12 appears the hydro-mechanic stand dedicated to stressing the models.

![Figure 11](image1.png) ![Figure 12](image2.png)

**Figure 11.** Model of Ø 35 torpedo before solicitation [8].  **Figure 12.** The hydro-mechanic stand [8].

After solicitation and cooling, the models were cut by using a diamond disk and slices were obtained which contained the interest zones of the model: the central hole zone, the zone of inclined holes and of joining of the piston zone. The slices were studied in a polariscope in yellow sodium light, obtaining the related isochromates. The photo-elastic constant of the material was determined by means of calibration and then the value of the difference of the principal stresses alongside the isochromates was determined.

Figure 13 and figure 14 catch aspects of the models after solicitation.

![Figure 13](image3.png)

**Figure 13.** Model of Ø 35 torpedo before solicitation (a) and after solicitation (b and c) [8].
3.2.3. Experiments in real functioning conditions. Testing the mechanical behaviour and evaluation of effect of new Torpedo upon mixing of the plasticised material in the plasticising cylinder were the goals of the experiment.

An especially designed and manufactured stand (a special injection mould) was used, manufactured within Activity 10 „Acquisition of research services (Outsourced manufacturing of stands for tests).

Tests were performed on an 80 tf thermoplastic plastic injection moulding machine (ARBURG Allrounder 420M/800-225) and on a 160 tf one (NEGRI BOSSI V160-610).

The machine is equipped, firstly, with the classical torpedo (figure 15).

Secondly, the machine is equipped with the new injection torpedo (figure 15). Details relating the technical solution of the new injection torpedo may be found in [1].

The testing sample must be the longest possible (the ratio between the length and the maximum diameter of the sample must be at least 3), in order to better observe the pigment traces and to analyse the mixing of the plasticised material that passed through the torpedo. The conical shape facilitates visualisation of the possible colour traces. Consequently, the sample had a conical shape, with thin walls of abt. 2 mm (for fast cooling and reducing the possibility that in the interior of the material mass to be residual traces of colour). Reinforcements on the inner and outer face of the sample were designed in order also to facilitate the visualisation of the colour traces. A smooth area was designed on the inner face, with no reinforcement, of abt. 50x40 mm for applying after injecting the sample, a self-adhesive label for identification of the sample.

A witness sample had been moulded, white coloured, from low density polyethylene (figure 16). The material had been dried, before moulding, during 1 hour at 65°C.

Blue pigment had been then added in the feeding hopper and so many samples were moulded using the classical torpedo until the sample became uniformly coloured (figure 16).

The feeding hopper was then emptied and the blue pigment was very well cleaned. The plasticising/injecting unit was emptied. White material was fed in the hopper and it was circulated through the plasticising/injecting unit until all the blue traces disappeared.

Red pigment had been then added in the feeding hopper and so many samples were moulded using the new torpedo until the sample became uniformly coloured (figure 16).

Moulding with both technical solutions of torpedo were performed on the same machine, with the same mould, attention being paid to keeping the same settings of the machine and to using material from the same bag. The time interval between the two sets of testing was not longer than the necessary
period for cleaning the pigmented material from the unit and the hopper and feeding with new material. A report was issued at end of each set of testing containing the results of the experiment.

![Sample images](image)

**Figure 16.** Photograph of the obtained samples: a - Witness sample, white coloured, b - Sample moulded with classical torpedo, c - Sample moulded with new torpedo [authors’ creation].

### 3.3. Experiments upon the Heating System

As related from the testing protocol, a single category of experiments were performed:

- experiments in conditions of real functioning

The equipment:

- three plastics injection moulding machines, of 25 tf, of 50 tf and of 80 tf, covering thus the domain of the small capacity machines. The machines were endowed from manufacturer with thermocouples for measuring the temperatures of the heating zones and with thermoregulators for thermostating these zones.
- a measuring stand, comprising three electricity metering instruments, three ampermeters and three voltmeters
- a digital display clock

Temperature was set for each zone at 300°C.

The times that the thermoregulators were connected to the heating sleeves and the related electricity consumptions were recorded in the test report.

Each measurement lasted for minimum five hours.

Sets of measures were performed on the three already named machines, on each machine with both the classical (ceramic sleeves) and the new heating system.

### 4. Discussions

#### 4.1. Injection Torpedo

**4.1.1. Results and interpretations related to the digital experiments.** We have digitally simulated 180 constructive variants of injection Torpedoes, for diameters Ø25, Ø30, Ø35, Ø40, Ø45 (36 variants for each dimension). The maximum value and its localisation for equivalent stress, for maximum principal stress, for minimum principal stress, for deformation, for safety coefficient were the purpose for each simulated variant.

It comes out from the Analyse Reports that the equivalent stress has its maximum value in the area of intersecting of the inclined orifices from the torpedo body, as it can be seen in figure 17 (the red coloured area).
The Analyse Reports reveal that the minimum value for the safety coefficient is located in the area of intersecting of the inclined orifices from the torpedo body, as it can be seen in figure 17 (the red coloured area).

OBSERVATION: most of the safety coefficients are less than 1.

INTERMEDIARY CONCLUSION: The geometries had to be modified for the Ø 30 mm, Ø 35 mm, Ø 40 mm and Ø 45 mm torpedoes. Solutions had to be found for solving the stresses in the area of intersecting of the inclined orifices and the axial hole from the torpedo body (most of the graphical representations indicated this zone to be the critical zone).

The visualization of the variation trend for the studied solicitations (equivalent stress, maximum principal stress, minimum principal stress, deformation and safety coefficient) was necessary in order to make a right decision related to how the torpedo geometry could be modified for obtaining an optimization of its behaviour under load relating it to the variable elements of the geometry (d, B, R_t and R_s).

The respective variation diagrams were obtained by studying the variation of the maximum value for the equivalent stress, for the maximum principal stress, for the minimum principal stress, for the deformation and for the safety coefficient as a function of d and B for $R_t \in \{0,1,2,5,5\}$ and $R_s \in \{0,1.5,2\}$. Such a diagram is illustrated in figure 18.
The variation function of deformation related to dimension B of the torpedo body reaches a maximum point for the Ø35 mm torpedo and a minimum one for the Ø40 mm torpedo for the same dimension B = 17 mm.

The value of the function is greater for dimension 20 mm than for dimension 15 mm for all diameters. The variation is extremely small only for diameter Ø30 mm.

INTERMEDIARY CONCLUZION: Dimensions d and B do not have an important influence on the variation of the maximal value of the maximum principal stress.

Some other dimensions than B, Rs, RT must be modified in order to obtain safety coefficients greater than 1 at all the torpedoes. The angle between the inclined holes had been modified from 60° to 50°, as well as dimension E, dimension F and only for torpedoes Ø40 and Ø45.

4.1.2. Results and interpretations of photoelastometry experiments. The variation diagram had been drawn related to the principal stresses which were obtained by means of photoelastometry and FEM (Figure 19).

The experimental results show, as a rule, greater values for stresses than the FEM values.

The photoelastometry method was used in order to check the work hypothesis that had been used in our numeric calculations and for a fast highlight of the areas with stress concentrators.

The photoelastometry (red colour) versus FEM (blue colour) difference $\sigma_1 - \sigma_2$ was put on the horizontal axis in figure 19, since the radial distance of the determination points (green colour) was put on the vertical axis. The graphic representation is overlapped on the axial section of the torpedo body (the same scale was used for the axial section and the vertical axis) in order to illustrate the most suggestive possible the stress localization in the torpedo body.

It is noticeable that stress increase quasi-exponential in the area of intersection between the axial hole and the inclined orifices. The same thing is illustrated in figure 10, where the red coloured areas are located in the same zones.

![Figure 19. Comparison between the values $\sigma_1 - \sigma_2$ which were obtained by means of photoelastometry and by FEM [11].](image-url)
The great number of isochromates (which are the geometric place of the points with an equal difference of principal stresses) in the holes zone is a result of the existence of an only one compression stress on longitudinal direction. The principal stresses within the figure plane at the top of the part are sensitively close as magnitude and of the same sign – so, their difference being very small. (figure 14).

![Figure 14](image)

**Figure 20.** Zones with dimensional modifications [11].

### 4.1.3. Results and interpretations after experiments in real functioning conditions

Results of the tests are illustrated in table 3:

| Nr. of experiment | Torpedo type | Pigment | Necessary number of injections for obtaining an uniform colour |
|-------------------|--------------|---------|-------------------------------------------------------------|
| 1                 | classical    | -       | 1                                                            |
| 2                 | classical    | blue    | 9                                                            |
| 3                 | new          | -       | 1                                                            |
| 4                 | new          | red     | 6                                                            |

It may be observed that fewer injections are necessary with the new torpedo than with the classical one in order to obtain a uniform colour of the moulded part. This thing reveals a better mixing of the plastic melt by using the new torpedo than the classical one.

### 4.2. The Heating System

#### 4.2.1. Results and interpretations after experiments in real functioning conditions

Tests were performed using three plastic injection moulding machines: of 25 tf, of 50 tf and of 80 tf. Both the classical and the new heating system were tested on each machine.

By analysing consumptions of the 25 tf, 50 tf and 80 tf machines that were equipped with the classical heating system, we have noticed that temperature allocation on each heating sleeve corresponds to the allocation of consumption.

It is easy to compare for each machine dimension the consumption of the classical heating system versus the new one, by studying the diagrams which we have issued within the Project. The result of the comparison, illustrated in table 4, is clearly favourable to equip the machines with the new heating system.
Table 4. Synthesis of electricity consumption.

| Measuring conditions | Classical system | New system |
|----------------------|-----------------|------------|
| 1. Machine type      | 25 tons Moulding machine (MI63/25TP) |         |
| Consumption after one hour [W] | 3654 | 2267 |
| Consumption after two hours [W] | 5489 | 2808 |
| Consumption after three hours [W] | 7062 | 3286 |
| Consumption after five hours [W] | 9439 | 4359 |
| Difference after five hours kW | 5.080 | 53.819 |
| 1. Machine type      | 50 tons Moulding machine (MI100/50TP) |         |
| Consumption after one hour [W] | 3051 | 2463 |
| Consumption after two hours [W] | 4347 | 3133 |
| Consumption after three hours [W] | 5601 | 3736 |
| Consumption after five hours [W] | 8148 | 5405 |
| Difference after five hours kW | 2.743 | 33.665 |
| 1. Machine type      | 80 tons Moulding machine (MI250/80TP) |         |
| Consumption after one hour [W] | 3797 | 3684 |
| Consumption after two hours [W] | 5497 | 4481 |
| Consumption after three hours [W] | 7600 | 5471 |
| Consumption after five hours [W] | 10903 | 7545 |
| Difference after five hours kW | 3.358 | 30.799 |

It is to be noticed, for all the studied machines, that the difference classic/new is smallest for the heating sleeve No. 2. This situation is complying to reality behaviour, since heating sleeve No. 2 is located between sleeve No. 1 and sleeve No. 3, borrowing lateral heating from both sides.

5. Conclusions
We have studied within our Project aspects related to the „heart“ of the plastics injection moulding machine: the plasticising/injection unit. The studied aspects refer to increase the reliability of the plasticising/injection unit and to decrease the electrical energy consumption.

The Project approached the practical problem of issuing some new constructive solutions for the plasticising/injection unit, solutions which had been patented by the authors (RO-99019, RO-99128 and patent request 00641), relating respectively to a dozing – injecting Torpedo and to a Heating System for the plasticising/injection units for thermoplastics. The following objectives were aimed by the Project:

- Study of mechanical behaviour of a new dozing – injecting Torpedo
- Study of mixing of the plasticised material, through the new torpedo as well as through the classical one
- Study of electrical energy consumption, with the new heating system as well as with the classical one

These objectives were fulfilled by means of performing digital simulations, photoelastometry experiments, experiments with some prototypes on different specially created stands, experiments and measurements performed on machines in functioning condition.

A starting point consisted in the great number of defections of the existing dozing – injecting Torpedoes. Repairing of such a defection consumes a working shift time (8 hours), counting the cooling time, emptying the unit, the effective repair, re-heating and re-filling the unit.

The second starting point consisted in the great consumption of electrical energy of the plastics injection moulding machine, the energetic consumption sharing abt. 75% in the cost price calculation for the moulded parts.
We have theoretically and practically demonstrated within the Project that adopting of some other geometry for the dozing – injecting Torpedo leads to eliminating the reliability problems of the classical torpedo, as well as that adopting of some other conception for the Heating System leads to a significant decrease of the electrical energy consumption.

We may state, finally, that the desired objective was attained: we have found new geometries for some essential sub-assemblies of the plastics injection moulding machines, their adopting leading to increasing the reliability of the machine and to decreasing its energetic consumption.

References

[1] Vasilache V and Vasilache M 1990 *Torpila pentru dozat - injectat* Patent No. 99019/ Romania

[2] Vasilache V and Vasilache M 1990 *Sistem de încălzire pentru unităţile de injectat mase plastic termoplastr*, Patent No. 99128/ Romania

[3] Vasilache V, Grama L and Vasilache M 2009 Decreasing the Energetic Consumption at the Plastics Injection Molding Machines *Nonconventional Technologies Review* 1

[4] Vasilache V, Vasilache M and Vasilache A 2013 *Maşini de injectat material plastic* Ed. Universităţii Petru Maior Tg-Mureş ISBN978-606-581-066-2

[5] Vasilache V, Vasilache M and Vasilache A 2015 *Sistem de încălzire Buletinul Oficial de Proprietate Industrială – secţiunea Brevete de Invenţie* 3

[6] Theocaris P S, Boleanțu L, Buga M ș.a. 1977 *Analiza experimentală a tensiunilor*, ET, București

[7] Grama L and Vasilache V 2009 *Optimization of the Plasticizing Unit Construction*

[8] Vasilache V – *Contributions to constructive improvement of the small capacity plastics injection moulding machines for thermoplastics*

[9] Şoaită D, Vasilache V, ș. a. 2015 Referat de testări pentru prototipuri: Torpila pentru injectare, Sistem de încălzire “Reducerea Consumurilor de Funcţionare la Maşinile de Injectat Materiale Plastice” Proiect de cercetare finanțat de UE în cadrul POSCCE Tg-Mureş

[10] Şoaită D, Vasilache V, ș. a. 2014 Referat privind simularea prin metoda elementului finit “Reducerea Consumurilor de Funcţionare la Maşinile de Injectat Materiale Plastice” Proiect de cercetare finanțat de UE în cadrul POSCCE, Tg-Mureş

[11] Grama L and Vasilache V 2009 Improvements of the geometry of the injection torpedo *XXIII MicroCAD International Scientific Conference*

Acknowledgements

This Project was supported by a grant of the Romanian National Authority for Scientific Research, project RECOPLAS (POS-CCE, O.2.3.3., ID 1292, SMIS 38814, ctr. No 405/01.08.2012).