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IMPROVING THE DESIGN OF PLASTIC ANCHORS FOR POLYSTYRENE

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Abstract: *The paper presents the redesign process of the plastic anchor used for polystyrene walls. This process is based on the information obtained within a focus group and an extended analysis of the products available on the Romanian market. After the redesign process was completed the design process of the mould required to produce the plastic anchor has been developed and analysed. The redesign anchor obtained using this mould has been validated using dimensional measurements and visual inspection.*
Key words: *redesign, polystyrene, plastic anchor, mould design*

1. INTRODUCTION

Extruded polystyrene insulation boards are used for thermal and acoustic insulation used in constructions, the insulation boards are fixed to the wall inside or outside with a special adhesive and using fasteners such as the plastic anchors illustrated in the figure below.

Fig. 1 Different types of plastic anchors available on the Romanian market

The polystyrene fixing plastic anchors present the following features:

- are longer than usual dowels;
- the fixing end is quite large, in comparison with the dowel body size;
- are mounted on the wall using a plastic pin;
- must have a very good thermal stability (typically between -35 °C and 80 °C) to ensure the mounting process can be done in any season.

Plastic anchors are manufactured only using moulding injection and the economic efficiency of this product is given mainly by the anchor`s design. If the essential properties are excluded (such as thermal stability, mechanical strength, standard length, etc.) the factors that can influence the production costs are the following:

- the injection machine used to produce the anchors;
- the injection type used, that can be either hot runner or cold runner;
- the injection process parameters that directly influence the productivity such as cooling time or total cycle time;
- the volume of injected material that is inserted into the feeding system and that needs to be reprocessed;
- the material type used to manufacture the anchors.

To design a competitive plastic anchor model for the Romanian market the authors have conducted a market study in order to analyse the products and the competitors on the market in order to identify the innovation and design directions that can lead to improved products. The research results have been further analysed within a focus group involving both those that mount this types of anchors and those who sell them in order to establish a set of technical features. These features were used in the redesign process for the anchor and its mould injection. The design process has been done using Catia V5 and Moldflow software solutions.

2. MARKET ANALISYS

In the Romanian market there are several companies that manufacture plastic anchors, companies such as: TALTEDOM SRL, ARTHUR GROUP ROMANIA, THERMOSYSTEM CONSTRUCT CORPORATION S.R.L, BADCOR SRL, EUROCLASS SERV S.R.L.

The study includes the anchors presented in Figure 1 for which the producers will not be explicitly indicated. The main conclusions regarding this local market analysis are presented below. Multi-cavity moulds are being used to mass produce the plastic anchors using both hot runner system and cold runner. Figure 2 presents the feed system used by three different moulds. As it can be seen in the case of eight injection dowels done within the same injection the amount of plastic that is lost at each injection is lower than the amount lost when more than eight elements are joined together within the same injection process.

There are two methods that are appealing to the manufactures regarding the plastic pin manufacturing: either together with the anchor or separately. Figure 3 presents some models for which the pins are injected together with the anchor. This type of manufacturing solution can be adopted only if a cold runner system is being used. This solution has some advantages regarding the packaging process for the product.

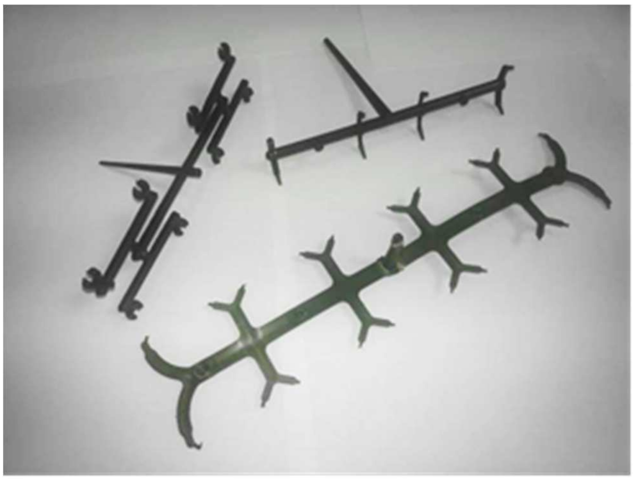

Fig. 2 Spure and runner elements from different manufactures of plastic anchor

The manufacturing processes that involve a cold runner system are using a fibre reinforced plastic for the plastic pin to enhance its resistance.

Fig. 3 Different models of anchors injected together with the pins

Regarding the design process there are differences involved in the reinforcing method used for the anchor head. The anchor head represents the contact area that is being hammered when the anchors are mounted to the wall. This area uses two types of ribs and various combinations either transverse or circulars as presented in Figure 4.

Fig. 4 Various types to reinforce the anchor head

Some manufacturers choose to strengthen this area using different reinforcement's design patterns, some of the design patterns of some existing anchors are presented in Figure 5.

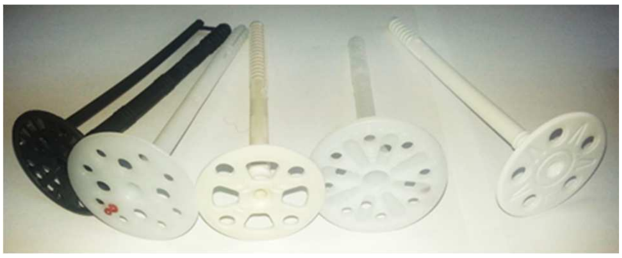

Fig. 5 Various reinforcement types for the anchor head

The design of the pin has also different forms (as presented in Figure 6) these shapes allow the pin to open the top of the anchor head and to absorb the force applied by the hammer when the anchor is mounted to the wall.

Fig. 6 Various types of pins

The anchor and pins weight varies from one model to another. Figure 7 presents the weight values of nine anchor sets with the length of 160 mm.

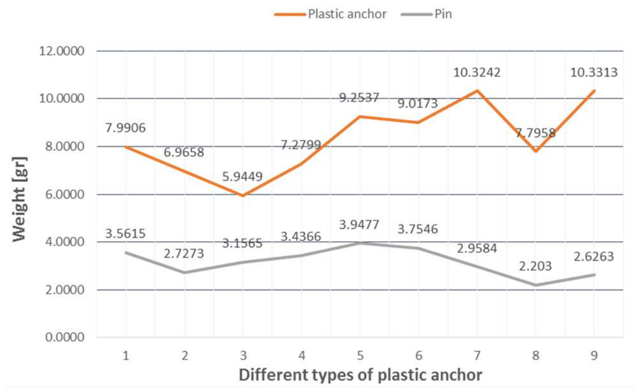

Fig. 7 Comparative weight of anchors and pins

The average weight of the anchor is around 8 g while the average weight of a pin is around 3 g.

In terms of packaging used for the plastic anchors, there are two different solutions, either in a plastic bag or a cardboard box. The amount of anchors within a single pack ranges from 50 pieces up to 1000 pieces.

3. FOCUS GRUP

To identify the technical characteristics for the redesigned plastic anchor a focus group has been assembled. This group was attended by workers who install thermal insulation systems with plastic anchors, people involved in the process of covering the plastic dowels and polystyrene blocks and people involved in sales for this type of product.

The conclusions of this focus group have been addressed and taken into consideration for the redesign process of the plastic dowels, these are the following:

- for some models the two half of the anchor head are too rigid and when the pin is introduced they don't open enough;
- for the models for which the dowel and the pin are injected together, the pins are harder to detach on some models;
- for the pins injected together with the dowel there are models that have to be forced within the dowel because of the injection gates that remain at the top of the pin;
- the material colour is not relevant;

- the workers that are covering the polystyrene panels with decorative mortars and dowels would like an anchor head that is flat so that the trowel won't get stuck within anchor head;
- The dowel holes within the head should not exceed 50% of the total anchor head surface.

Based on these consideration and conclusions of the analysis process of the existing products, a new redesigned dowel element has been created. The design has been validated using different simulation methods after which the injection mould has been designed and produced.

4. THE NEW DESIGN OF THE PLASTIC ANCHOR

In the design stage two new constraints have been introduced by the manufacturer, these are the following:

- The injection mould should be used with both regranulated material as well as recycled material that result from the injection process;
- To reduce the overall volume of the filling paths.

The 3D redesigned model of the dowel and pin are illustrated in Figure 8. These have been designed within Catia V5 Molded Part module. The holes in the dowel head (1) represent 20% of the surface area and the reinforcement of the head was done using four vertical ribs (2) and three (3) horizontal ribs in order to absorb the hammer shocks within the mounting process. Within the focus group it was revealed that the workers mounting the dowels in the first phase are inserting the dowel at least halfway into the hole and they then hit it with a hammer and insert the pin, thus further reinforcement for the rod has been eliminated.

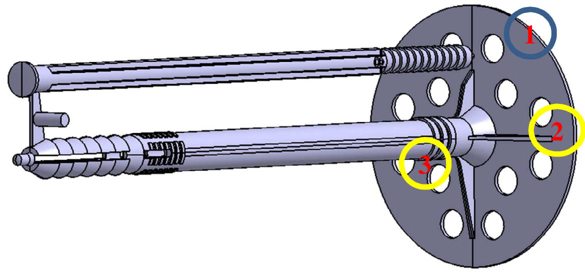

Fig. 8 The designed anchor and pin

The model validation in terms of manufacturing opportunities has been done using Moldflow software solution. Figure 9 illustrates an analysis regarding the wall thickness. The connecting radii have been reviewed so that their values are not less than 0.6 of their corresponding wall thickness as it is recommended by [4] and [5].

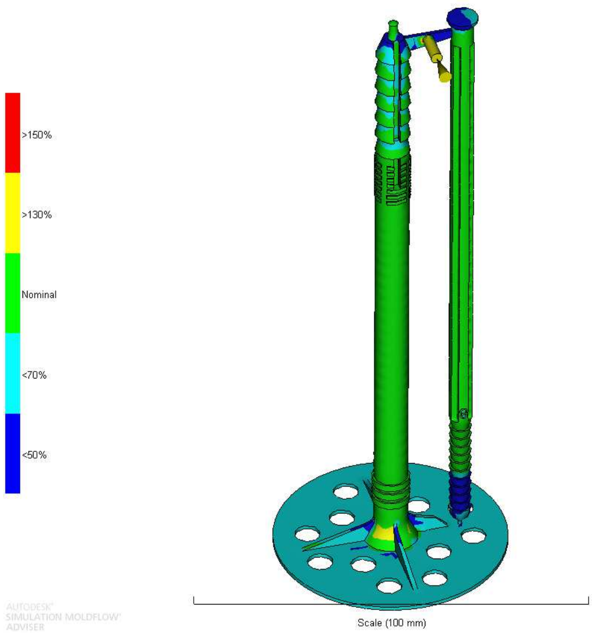

Fig. 9 Analysis of the wall thickness of the plastic anchor

After the 3D model has been validated, the next step is focused on identifying the optimal position of the injection point. Because the mould will have multiple injection parts the injection point will be located in the link between the dowel and the pin. This position is illustrated in Figure 10.

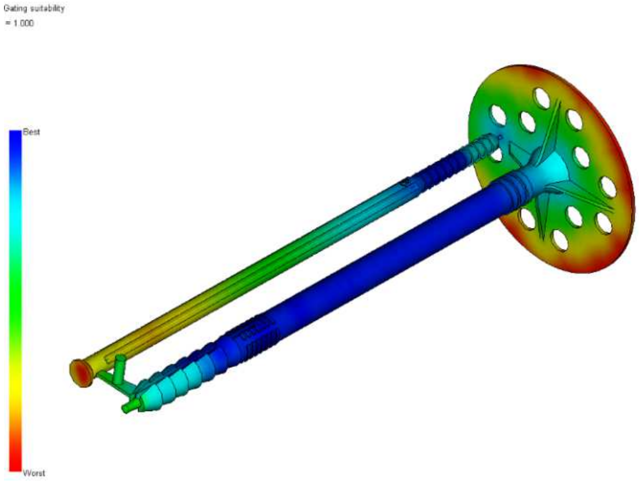

Fig. 10 Injection point

After all the production parameters have been checked for the dowel-pin assembly the next step of the mould design process is to estimate the optimal number of dowel-pin assembly elements within a single mould.

The proposed method is to multiply the dowel-pin assembly on a total area equal to the opencast backing plate. The machine chosen for the injection of the plastic anchor assembly is the Haitian Mars II 2500 machine and the back plate dimensions are illustrated in the figure below.

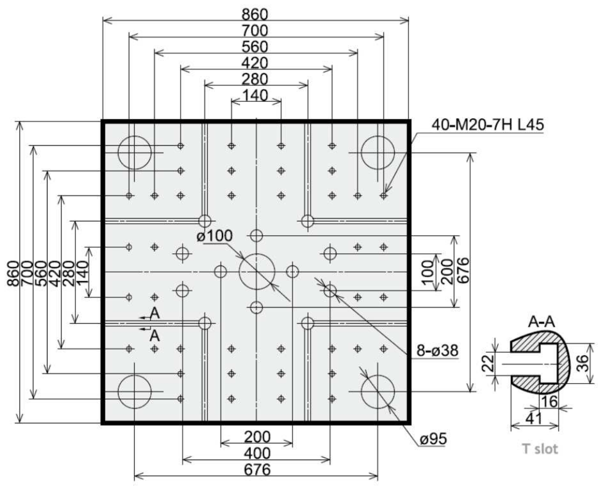

Fig. 11 The platen dimensions for the Haitian Mars II 2500

The estimated number of injection dowel-pins assemblies is eight. The injection network for eight anchor assemblies has been designed using computer aided design in order to determine the volume of the injection network.

Sizing the distribution channels with circular section is done using the formula provided by [1] for an injection system with a dot antechamber type:

$$D = s\_max + 1.5 \text{ mm} \qquad (1)$$

Using this formula the diameter of the distribution channel should be 8 mm.

The number of dowel-pin assemblies has been verified using the following relationship:

$$N_1 = 0.8 \frac{S_s}{V_p + V_r} \qquad (2)$$

Where, S_s represents the shot size, V_p represents the injected part volume and V_r represents the injection network volume. The Haitian Mars II – 2500 machine has a theoretic shot size of 471 cm^3 [2], which provide the necessary material to inject within a single cycle eight pairs of the dowel-pin element.

To design the mould tempering system a simplified pre dimensioning calculation has been done after which the system results have been simulated in Moldflow software solution.

To determine the amount of heat ceded to the mould by the eight dowel-pin assemblies injected within a cycle the following relationship has been used [3]:

$$Q = \frac{3600}{F_t} \cdot m \cdot \Delta_i \qquad (3)$$

Where F_t represents the Fill time (sec), m represents the weight of the eight dowel-pin assemblies in Kg, while Δ_i represents the plastic material enthalpy that is being calculated using the following formula [3]:

$$\Delta_i = i_2 - i_1 = c_P(T_{Mp} - T_D) \qquad (4)$$

Where the presented values are the following:

- i_2 – the enthalpy of the plastic material at the entry into the mould;
- i_1 – the enthalpy of the plastic material at the mould release;
- c_p – the specific heat of the plastic material (kcal/kg °C);
- T_{Mp} – the temperature of the material within the mould;
- T_D – mould-release temperature;

Within the formula (3) all the elements are known and based on the material injected the Δ_i value is calculated and then the amount of heat. In order to calculate the surfaces of the cooling channels the mould convection and radiation losses are neglected therefore the heat is considered to be discharged using the cooling circuit. In order to determine the length of the cooling channel the following relationship is used [3]:

$$l = Q \cdot \frac{\frac{1}{19.37+0.2\cdot T_i\cdot(10^{-4}\cdot w\cdot\rho)^{0.95}}+\frac{\delta}{\lambda})}{\pi\cdot D_c(T_2-T_1)} \qquad (5)$$

where,:

- T_i – the coolant temperature at the entrance of the circuit in K°
- w - the velocity of the fluid in the cooling channels
- ρ – the density of the coolant fluid in kg/m^3
- δ – the average distance between the cavity and the cooling channel in m;
- λ – the thermal conductivity coefficient in W/mK°
- D_c – the cooling channel diameter in m
- T_2 – the temperature of the plastic material at injection, in K°
- T_1 – the cooling fluid temperature in K°

The cooling channel diameter of 8 mm results in a length of at least 1.6 m required for each active plate. Given the dimensions of the plates the total length is 1.8 m for each plate. With these preliminary data within the Moldflow software the cooling process can be simulated. The data obtained are presented in the Figure 12.

The ejection system within the mould is dimensioned starting with the required force that is necessary using the following equation:

$$F_a = n\cdot(\mu\cdot p\cdot A)+\sum F_R \qquad (6)$$

where:

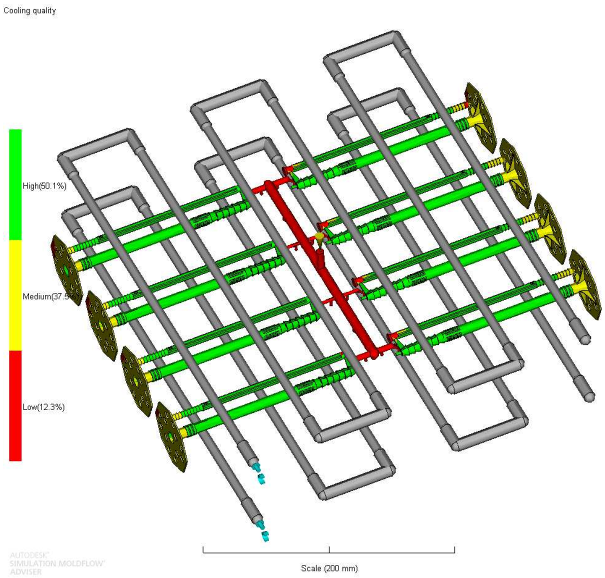

Fig. 12 Simulation of the cooling process

- n – number of injection areas;
- μ – the friction coefficient between the surface of the injection area and the injected parts;
- p – the contact pressure between the part and the injection area, N/m²;
- A – the contact surface between the part and the injection area, m²;
- F_R – The friction forces in the die.

The mould design has been done in Catia V5 software. Figure 13 presents an exploded view of the mould.

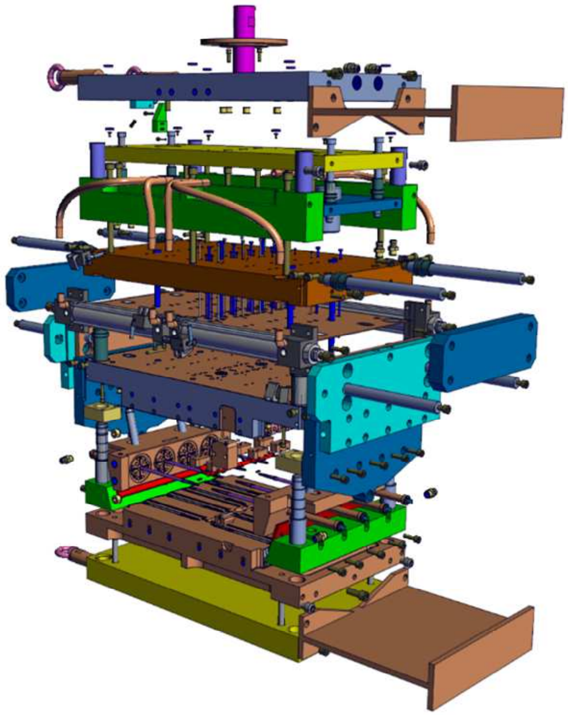

Fig. 13 Exploded view of the mould

The mould has a total of 432 components, of which 62 are unique parts. The active plates are presented in Figure 13, they have core backing plate in order to allow a better cooling for the head of the anchor.

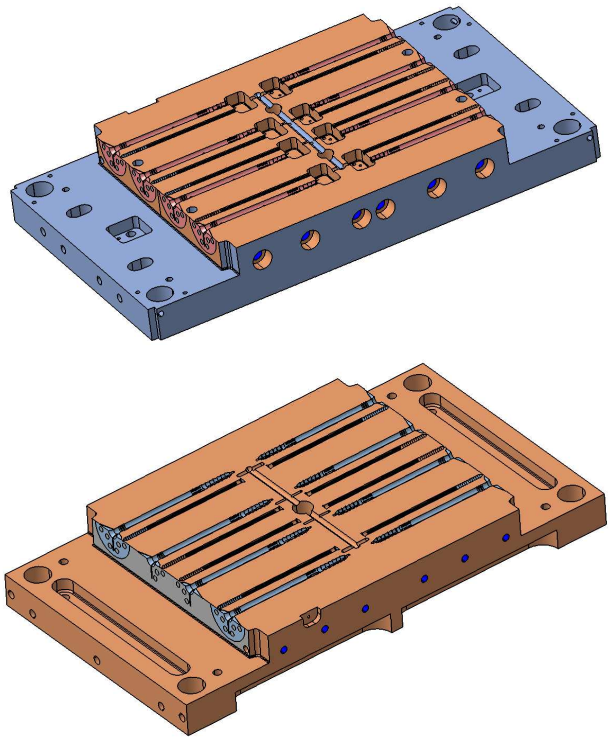

Fig. 14 Active plates of the mould

Having the mould parts manufactured they have been installed in order to carry out a series of tests regarding the injection system and the quality of the products. In the process of fine tuning and adjustment of the mould components the product has been validated and the next step involves the planning stage in order to commissioning the mass production of the plastic anchor.

5. CONCLUSIONS

Using different tools and software solutions have supported the identification of the technical characteristic set required to enable the redesign process of a plastic dowel for polystyrene. Using Autodesk Moldflow software solution a number of issues related to the injection and mould cooling techniques have been simulated and checked. Within the Catia V5 software the mould has been designed using elements from the available parts catalogue. The mould has been tested successfully with both re-granulated material as well as recycled material obtained using grinding operations. The products obtained are comparable to those of the competitors on the market. The review of the dimensional characteristics of the anchors ensures that their dimensions are according to the ones required by these types of parts.

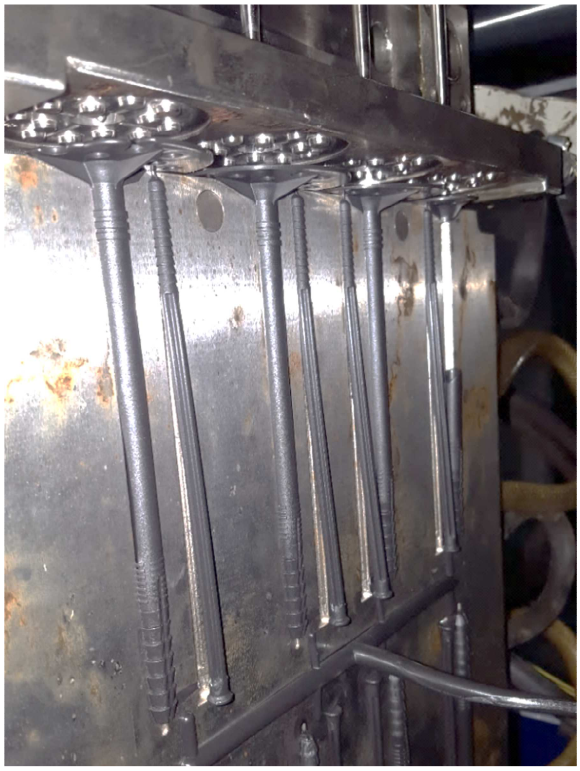

Fig. 15 Aspects during the injection

6. ACKNOWLEDGEMENT AND DISCLAIMER

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REPROIECTAREA REPERULUI DIBLU PENTRU POLISTIREN

Rezumat: Lucrarea prezintă procesul de reproiectare a diblului din plastic pentru pereți din polistiren. Reproiectarea are la bază informațiile obținute în urma realizării unui focus grup precum şi o analiză a produselor de pe piața românească. După reproiectarea reperului diblu pentru polistiren s-a proiectat, analizat și realizat matrița necesară pentru acest produs. Diblul obținut utilizând această matriță a fost validat prin măsurări dimensionale și inspecție vizuală.

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