

# The design of a die with a vacuum thermal insulation

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**Abstract.** A new design of a die for the polymer underwater granulation plants has been developed. It differs from similar plants in the design of heat-insulating elements. Vacuum hollows are used as a heat insulator. A vacuumization process does not require a separate operation, and it is conducted simultaneously with connection of all the elements of the die by a brazing method.

## 1. Introduction

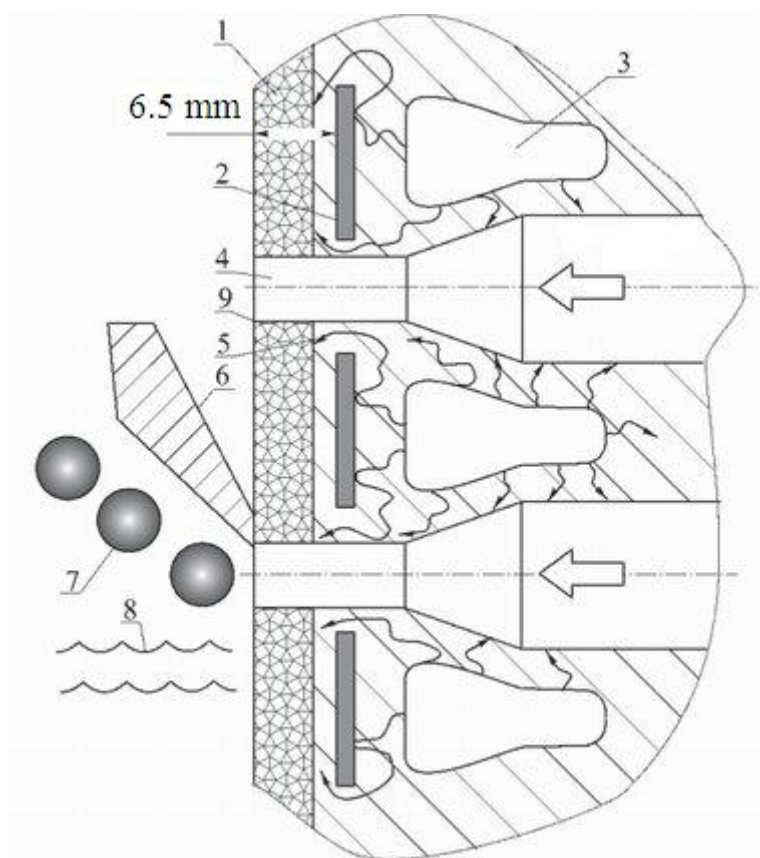
Modern production consumes a large amount of structural materials developed on a polymer base. An increased consumption of polymeric compositions requires a constant increase in production of polymer raw materials from manufacturers. The main product that manufacturing plants consume is a primary polymeric granulate. It is used as a material for product forming on automatic plastic machinery and as a raw material for a secondary granulation with addition of fillers and dyes.

The peak of production chains in the granulate manufacture is obtaining an extruder. The formation of the polymer granules is carried out due to the crushing of a polymer mass, passing through the holes in the die grid. Equipment manufacturers use various schemes of granulation: in the liquid state (underwater granulation), in the solid state (strang granulation). But at any scheme the quality of the product (size, shape, uniformity of granules) depends on many simultaneously affecting factors. They are: a wear degree of the die grid and granulating knives, temperatures of the polymer mass and dies, and etc. Therefore, in order to obtain a stable granulation process, the manufacturers use various technological solutions in the design of pelletizing heads of their machines both for maintaining a heat balance and for reduction of the wear and tear of the granulation unit.

## 2. Results and Discussion

The present paper is dedicated to the increase of the thermal stability of the die. Manufacturers use a variety of schemes of heating in order to control its thermal balance. SANDVIK Company applies oil or steam-heating (Figure 1) to maintain the heat balance of the granulation process. The heating channels (Figure 1, p.3) are maximally approximated to the surface of the die, and provide the warm-up of the granulation zone to avert the danger of melt 'sticking'. In order to concentrate the heat flux, exiting on the working surface of the die, an internal heat-insulating layer (Figure 1, p.2) is installed around the holes (Figure 1, p.4). That is, the energy capacity of the die heating elements after launching of the granulation process into the operation mode should provide a stable temperature of the die working surface, which is constantly cooled by the incoming polymer mass.





**Figure 1.** Draft of a working part of a die manufactured by SANDVIK Company: 1 – working surface, 2 – internal heat-insulating layer, 3 – heating channels (oil,  $T=200\text{ }^{\circ}\text{C}$ ), 4 – channels for polymer exit, 5 – heat fluxes, 6 – knife, 7 – polymer granules, 8 – water ring, 9 – cutting edge.

It is not always possible to solve this problem by a common increase of the power of the heaters (Figure 2, p.7–8) or the number and the flow cross section of oil channels (Figure 1, p.3) structurally because of the limited sizes of the die. Therefore, some manufacturers have taken a different road. For example, the manufacturers of TRUSIOMA Company, along with die array heating (Figure 2, p.7–8), simultaneously introduce additional structural elements into constructions. They isolate the channels, which form the polymer mass, from the die body, thus, protecting the die from undercooling. The working plane temperature is more than  $200\text{ }^{\circ}\text{C}$  and therefore the choice of materials for thermal insulators is limited.

Most often the porous ceramics (manufactured by ‘TRUSIOMA’) is used as heat-reflecting bushes. This material has a good thermal conductivity coefficient, but is not very convenient technologically in manufacture and installation as it has high hardness and brittleness. The most serious disadvantage of ceramics is a small linear expansion coefficient compared to steel. Therefore, coupling sizes of the heat insulator and conjugated metal parts of the die during assembly and operation differ significantly, what adversely affects the durability and reliable performance of the entire structure.

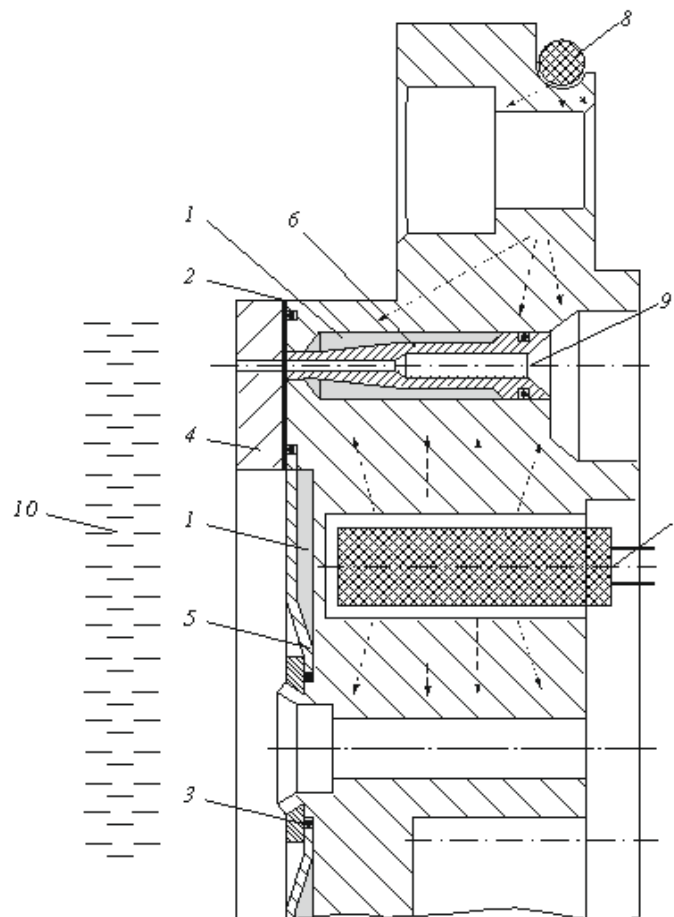
After the analysis of the existing constructions of dies and disadvantages identified in the process of the pelletizer operation, at the MTM Department in TPU a modernized die has been designed for the TRUSIOMA pelletizer.

Earlier the department has already carried out repair works on worn-out dies. The technology of repair of their work surface was developed [1]. A highly wear-resistant cast-alloy was used as a new working surface based on high-speed steel, which is additionally alloyed with chromium and vanadium. The favorable influence of these elements on the morphology of carbides in the alloys with

the cast structure and a significant increase in wear-resistance of the material with the same a chemical composition was shown in papers [3] and [4].

The same material was used for manufacture of a working granulating surface of new dies.

The proposed design has a working surface in the form of a solid ring made of a highly wear-resistant alloy. To fix the ring a soldering technology in the high-temperature vacuum, which is developed at the Department (patent № RU 2297307 C1) is used [2]. It provides obtainment of a solid weld seam (Figure 2, p.2) that has high strength. Since vacuumization is one of the most effective ways to reduce the heat transfer coefficient, this opportunity was used to replace the ceramic heat insulators with vacuum hollows. Bushes feeding the polymer (Figure 2, p.6) are separated from the body of the die by air space. To maintain the vacuum, which is created in the hollows when the die is in the furnace, at the top of each bush an annular groove is provided, in which copper solder is laid during the die assemblage. The conjugation of the bush with the body at the outlet from the die is sealed with a layer of solder (Figure 2, p.2) and a retaining ring (Figure 2, p.1).



**Figure 2.** Draft of a die with a vacuum thermal insulation: 1 – vacuum heat insulating chambers, 2 – main solder layer, 3 – ring insertions of solder for sealing the vacuum chambers, 4 – working ring, 5 – vacuum chamber cover, 6 – bush guides, 7, 8 – electrical heaters, 9 – polymer channels, 10 – process water.

For more efficient operation of heaters (Figure 2, p.7), a protecting cover (Figure 2, p.5) has been introduced into the die configuration. During heating the cover is also sealed with the solder (Figure 2, p.3), positioned in the form of two rings laid along the perimeter of the cover, to create an efficient vacuum layer. To prevent deformation of the cover under atmospheric pressure it is implemented in

the form of a non-flat concave profile. The solder, which is put into every connections of the die, has the same melting point (about 1200 °C); therefore, during formation of the main seam, the simultaneous meltdown and sealing of all the cover guides occur. The die cooling after completion of the soldering process occurs under vacuum, thus, exhaustion (about  $0.0193 \cdot 10^{-2} \dots 0.0193 \cdot 10^{-3}$  psi) at all sealed hollows is securely preserved. This was confirmed by control unsealing of several vacuum hollows under the water layer.

### 3. Conclusion

The tested design of the die has showed good results while at operation. It can be quickly heated to the operating temperature. Besides, this design has a sufficient range of temperature adjustment of the die working plane during the setting-up of the granulation process for various polymer compositions.

The production tests were held on the basis of Angarsk polymer plant. After successful completion of the tests, a batch of dies with vacuum heat insulation has been manufactured and shipped to the enterprise.

### References

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