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Application of energy-efficient systems in a processing line

Abstract. *Modern energy-efficient automatic processing lines are adapted to the required efficiency and character of the processed raw material. In this article, the authors presented a processing line in production of the foils that is used for lamination of PET foils in the hot extrusion cycle. The proposed production technology has not been applied in Poland yet, because extruders did not cooperate in one process line. In such concept, it is possible to produce heat shrink film using PE extruder and continue production on a PET extruder. Moreover, the application of energy-efficient IRD, FREE COOLING systems in a processing line was presented, because sector of plastics is a large electric energy consumer. The proposed solution makes the offer more attractive on the market, adjusting to the expectations of modern energy-efficient industry.*

Streszczenie. *Nowoczesne energooszczędne automatyczne linie technologiczne dostosowane są do wymaganej wydajności oraz charakteru obrabianego surowca. Autorzy w artykule zaprezentowali linie technologiczną w celu produkcji folii, która jest używana do laminowania folii PET w cyklu wytłaczania na gorąco. Proponowana technologia produkcji nie była wykorzystywana do tej pory w Polsce, gdyż wytłaczarki nie współpracowały w jednym ciągu technologicznym. Przy tak przyjętej koncepcji istnieje możliwość produkowania foli termokurczliwej przy kontynuowaniu produkcji na wytłaczarce PET. Ponadto przedstawiono zastosowanie energooszczędnych systemów IRD, FREE COOLING w linii technologicznej, ponieważ sektor tworzyw sztucznych należy do dużych odbiorców energii elektrycznej. Zaproponowane rozwiązanie zwiększa atrakcyjność oferty na rynku, dostosowując się do oczekiwań nowoczesnego energooszczędnego przemysłu.* ***Linia technologiczna do produkcji folii, która jest używana do laminowania folii PET***

Keywords: Energy-efficient systems, processing line,
Słowa kluczowe: Energooszczędne systemy, linia technologiczna.

Introduction

Dynamically developing automation of manufacturing processes is looking for new technological solutions enabling to raise energy-efficient, qualitative, efficiency and economic requirements [5, 6, 8, 9].

During co-extrusion, a few layers is extruded at once [7]. These layers may differ in, for example, structure (foamed and solid) and colour. Many extruders are applied for co-extrusion of the plastics. 3 PE extruders extruding 3 layers separately (A/B/C) are currently available on the market. A and B extruders can be one machine, which extrudes these layers in a proposed concept. Whereas, PET extruder consists of two extruders extruding 3 A/B/A layers. For example, worse raw material from the recycling can be added to a central layer. During co-extrusion, two extruders provide specific plastic to a common extruding head. Layered foils may also be extruded to get better mechanical properties of finished foils thanks to higher number of the layers. The advantage of such layered foils is better mechanical properties of the foils, and the fact that they are less thicker. It results in large savings in materials for a company. During extrusion of stretch foils, we can apply, for example, regranulate to a central layer, and glue only to external layers and one of the layers does not have neither glue, nor recycled raw material.

The extruders consist of three systems:

- power transmission system,
- control system,
- plasticizing system.

Technology of co-extrusion line of production of PET sheets and products from these sheets

Extrusion is a continuous process. (Fig. 1) The plastics, usually granulates, are added to a heated cylinder, which is subjected to plasticization and homogenization, through extruding head, and then through the calibrators forming a finished product [4]. A pressing is cooled down and then cut into segments of desired size or rolled up on the drums (Fig. 2).

PE extruder works with a PET extruder in production of foil that is used for lamination of PET foils using hot extrusion technology. (Fig. 1) Proposed production technology has not been applied in Poland yet, because extruders did not cooperate in one process line. In such concept, it is possible to produce heat shrink film using a PE extruder and continue production on a PET extruder.

Technology of production of co-extrusion line for extrusion of PET sheets and products from these sheets in a proposed concept will take place in accordance with the following stages (Fig. 2):

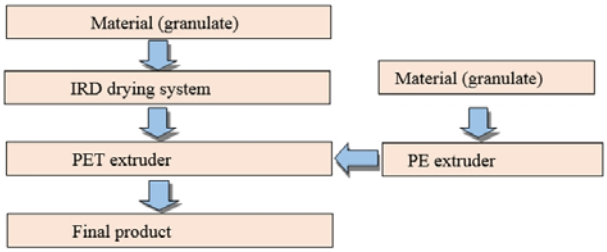

Fig.1. The concept of co-extrusion line for extruding PET sheets and products from these sheets

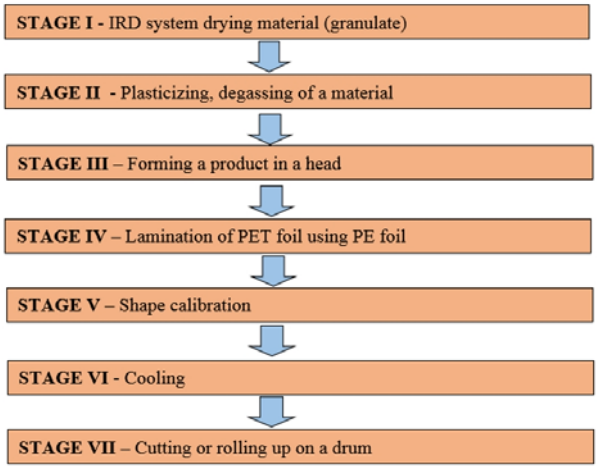

Fig.2. The stages of co-extrusion technological line for extruding PET sheets and products from these sheets

During movement of the plastics in an extruder cylinder, its pressure and temperature increase, which leads to releasing volatile compounds from the plastics (Stage II). Therefore, we applied special degassing systems that carry,

from a compression zone through special holes, gases through their outflow, or through additional vacuum system, which prevents outflow of the plastics through vent holes. The depth of the coils of a worm and distances between them increase in the vent holes. It causes that on the short segment under degassing hole, the pressure of molten plastic drops to zero and does not show inclination to outflow through this hole, whereas, gaseous parts do not penetrate through this hole outside.

The problem of degassing of the plastics is very important, because compressed gas particles cause:

- uneven outflow of the plastics from a head
- decreasing quality of finished products (forming of space filled with gas in the plastics).

If the plastic gets through the hole in a cylinder between compression and dosage zones (and not only compression), the cause may be:

- excessive gassing of the plastics, (wet or inclusions of other plastics);
- bad settings of temperature on the cylinder;
- bad rotational speed of a worm;
- wear and tear of a worm and cylinder and reverse motion of a raw material.

The concept based on innovative technology of co-extrusion line for extrusion of PET sheets and products from these sheets uses latest production technologies within the scope of production of plastics and it is innovative both on the national and global scale. Implementing and launching of the planned concept will be the use of technical knowledge from the period shorter than 5 years. The proposed solution makes the offer more attractive on the market, adjusting to the expectations of modern industry.

IRD system in the process of drying material of technology of extrusion of PET sheets

In the case of the plastics, particularly constructional plastics, application of appropriate method of drying and maintaining specific plastic parameters of drying are important. (Stage I) Non-fulfilment of these conditions makes it impossible to get high-quality final product.

In the event that material is not dried enough before adding to the cylinder of an extruder, then, reaction with water takes place while plasticizing of the plastics. Hydrolysis reaction leads to the changes in molecular structure of the plastics. The products manufactured under such conditions often have completely different, much worse physical properties, mainly decreased impact resistance and tensile strength.

Therefore, innovative IRD system (Infrared Rotary Drum) was applied in sheet extrusion technology, in the process of drying material, in which infrared radiation causes oscillation of heat affecting directly the core of the particles from the inside to the outside to make humidity inside particle quickly heating and evaporating to the air in the environment (Fig. 3).

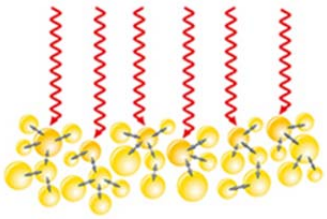

Fig.3. Sheet extrusion technology with application of IRD in the process of drying material [10]

The proposed method of drying ensures continuous processing of PET scraps, reducing humidity from over 4000 ppm to below 50 ppm in several dozen minutes, in comparison with 5-6 hours in traditional systems. It is a considerable benefit for PET material in the process of drying and crystallization of IRD (Fig. 4) in comparison with conventional drying Fig. 5.

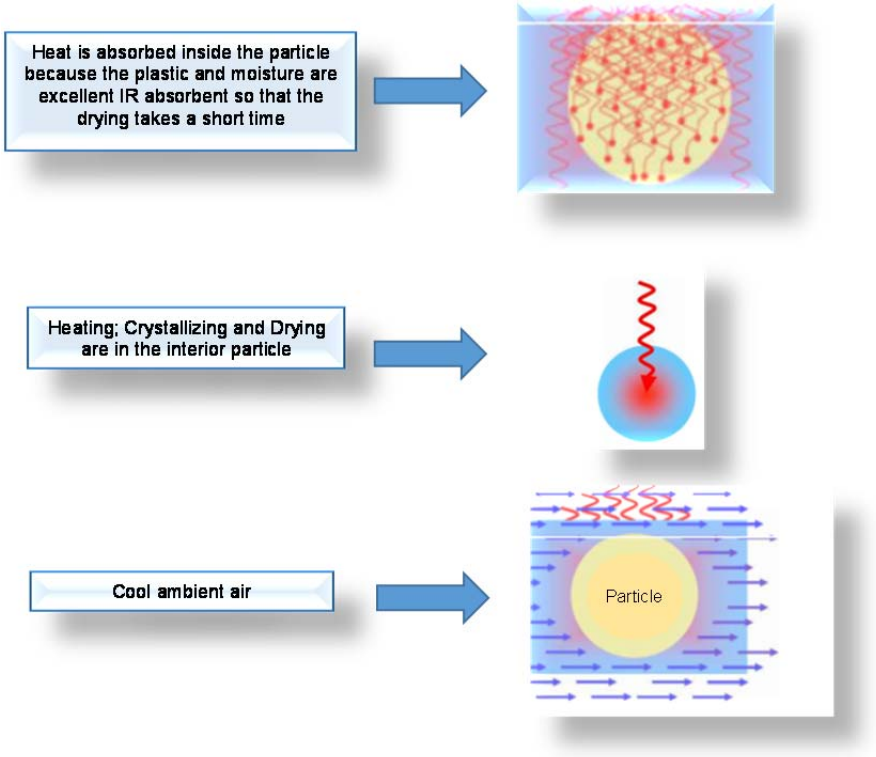

Fig.4. Process of drying material – IRD

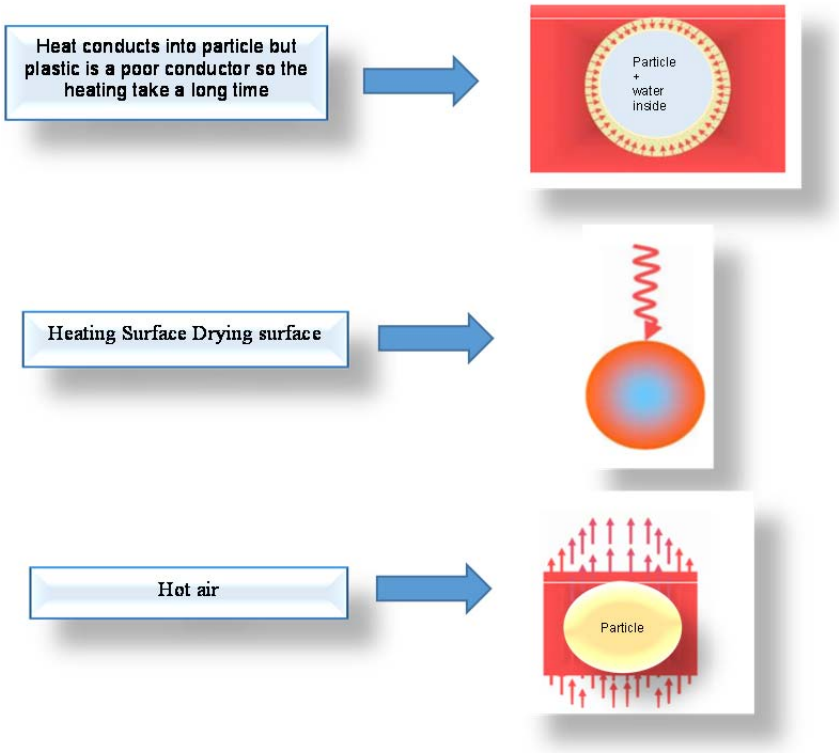

Fig.5. Process of conventional drying [10]

The advantages in comparison with traditional drying systems and IRD:

- **up to 60% lower energy consumption** in comparison with conventional drying systems,
- time-saving,
- continuous process,
- accurate material processing,
- high efficiency.

Rotating drum will be applied in the process of drying. This drum has an internal spiral pushing material forward while rotating; at the same time, material is affected by IRD rays. (Table 1) (Fig. 6) As a result, we get high-quality material, which is then automatically loaded from a dryer to an inlet of an extruder (Stage II).

Fig.6. Process of drying IRD material (granulate) [10]

Table 1. Rotating drum (drying and crystallizing)

Parameters	
Drum size (Dia. x L mm)	1500*3600
Feeder size (Dia. x L mm)	139*650
Output capacity (kgs/hr)	700
Infrared lights power (kW)	144
Feeding power (kW)	0.75
Drum turning power (kW)	2.2
Cooling Blower (kW)	0.75

To sum up, technology of sheet extrusion with application of IRD in the process of drying and crystallization of a material is one of the best in the world and its character is innovative.

Application of free cooling system in the process of cooling technology of extrusion of PET sheets

The following elements were applied in the cooling process: 602 kW fan cooling tower with supply and control cabinet and tank and pump module for oil cooling circuit, compression freezer with 84 kW tank and pump module for cooling circuit of dimensioning cylinders (Stage IV).

Industrial fan cooling tower is a water and air heat exchanger that cools down water with the use of a cooler air, of which flow is forced by cooling fans [3]. Cooling tower is built of a block of aluminium lamellas, copper pipes and axial flow fans [1]. Optimal geometry of arrangement of the tubes and distances between lamellas, special surface of the lamellas and **energy-efficient cooling fans** of high flow guarantee maximum heat exchange. Cooling capacity and level of acoustic noise conform to European norm ENV1048. 5 diameters of cooling fans are applied: 500, 630, 800, 900 and 1000 mm. In order to obtain desired efficiency, between 1 and 16 cooling fans in one or two rows in 8 noise levels are installed. Fan cooling tower is characterized by high efficiency at minimum electric energy consumption and unattended axial flow fans of low noise level. The whole cooling process is fully automatic and controlled by microprocessor controller with a display [2].

Industrial compression freezer in one compact casing contains cooling system, water cycle and electric controlling and supplying system. Normally, the devices work in ambient temperatures up to 50°C. Cooling system consists of evaporator, compressors, air condenser, expansion valve. Water cycle, of which main elements include tank, pump, evaporator, flow sensor is designed for a given load. Electric system in an integrated cabinet contains supplying components and microprocessor controller with a display.

Innovative free cooling system in a compression freezer, which reduces electric energy consumption was applied in technology of sheet extrusion**.**

Fan cooling tower will cooperate with a compression freezer in three modes selected automatically depending on ambient temperature:

- ***Mode 1- Air temperature outside above 20°C***

Cooling is performed with the use of a compression freezer of cooling efficiency 80 kW and installed electric power 20,8 kW.

- ***Mode 2- Air temperature outside between 20°C and 10°C***

Cooling is performed with the use of a 50% of a free cooling system of cooling efficiency 80 kW and installed electric power 4,3 kW, supported by 50% compression freezer of cooling efficiency 80kW and installed electric power 20,8 kW.

- ***Mode 3- Air temperature outside below 20°C***

Cooling is performed with the use of a free cooling system of cooling efficiency 80 kW and installed electric power 4,3 kW, decreasing with lowering ambient temperature.

Air temperature distribution in an annual cycle (8760 h/year) (Fig. 7)

- air temperature outside above 20°C: 768 h/year*;
- air temperature outside between 20°C and 10°C: 2822 h/year*;
- air temperature outside below 10°C: 5170 h/year*;

(* statistical climatic data for Warsaw. Source: website of the Ministry of Infrastructure (http://www.mi.gov.pl))

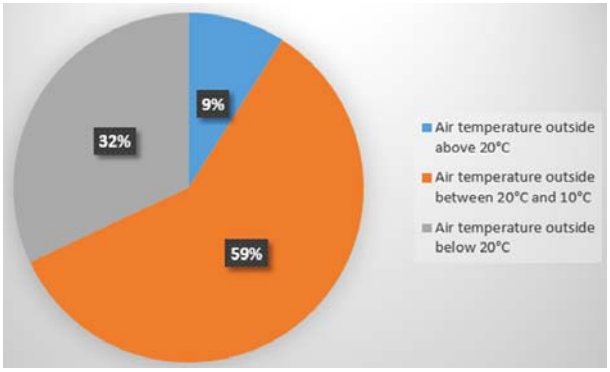

Fig.7. Air temperature distribution in an annual cycle (8760 h/year)

Economic analysis of energy saving.

The cost of energy [PLN/year] = Installed power [kW] * Number of hours per year [h/year] * The cost of kWh [PLN/kWh]

The costs of cooling electric energy in the case of full year work of a compression freezer:

20,8 kW * 8760 h/year * 0,45 [PLN/kWh] = 81 994 [PLN/year]

The costs of cooling electric energy in the case of work of a compression freezer with an innovative free cooling system (Fig. 8):

The costs of cooling electric energy for *Mode 1*:

20,8 kW * 768 h/year * 0,45 [PLN/kWh] = 7 188 [PLN/year]

The costs of cooling electric energy for *Mode 2*:

(50% * 4,3 + 50% * 20,8) kW * 2822 h/year * 0,45 [PLN/kWh] = 15 937 [PLN/year]

The costs of cooling electric energy for *Mode 3*:

4,3 kW * 5170 h/year * 0,45 [PLN/kWh] = 10 004 [PLN/year]

Total costs of cooling electric energy:

7 188 + 15 937 + 10 004 = 33 129 [PLN/year]

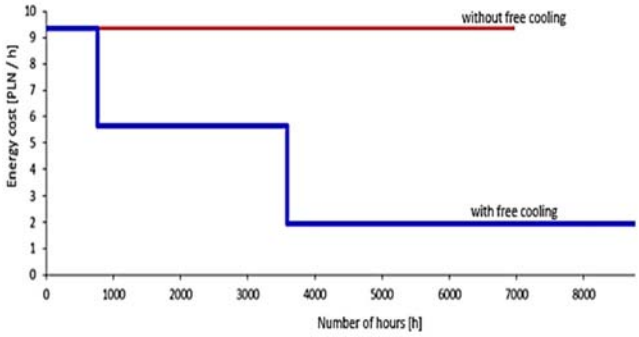

Fig.8. The unit costs of energy for particular periods

Savings (Fig. 9):

81 994 – 33 130 = 48 864 [PLN/year]

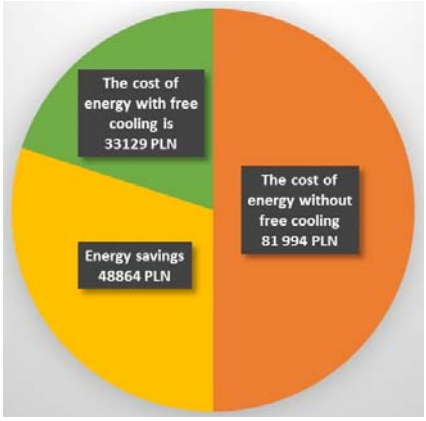

Fig.9. Annual costs and energy saving [PLN]

To sum up, sheet extrusion technology with applied free cooling system in the process of cooling considerably reduces electric energy consumption.

Conclusions

The proposed concept of innovative technology of line based on co-extrusion production of PET sheets and products from these sheets will result in:

- energy-saving process,
  - application of innovative method of IRD drying in production technology,
  - application of innovative free cooling system in the process of cooling, in technology of production of sheets, which reduces energy consumption (60%),
- low noise level,
- reduction of emission of harmful production substances,
- the possibility of full automation, computerization of the process,
- low labour consumption,
- manufacturing products in one technological operation,
- high quality and repeatability of the shape and size, aesthetic product,
- possibility of adding recyclate in large quantities,
- easily adjusted line for the recycling of the foils, belts, fibres,
- possibility of mass production.

The proposed concept of production of co-extrusion processing line for extrusion of PET sheets and products from these sheets is energy-efficient and has impact on quality of final products, which make products competitive on the market.

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