APLICATION OF CO_2 COOLING FOR BLOW MOULDING PROCESS

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ABSTRAKT: *The mould blowing process is the third most used technology for the production of plastic products on the world. These products are characterized by complex hollow shapes and are used for example in the packaging, transportation, pharmaceutical and automotive industries. With the ongoing growth of these industries, increasingly higher demands are being made on optimizing production. Hence, much work is being focused on these problems. The present article deals with optimizing the cooling systems. It is necessary to emphasize the importance of this part of the blow moulding process since cooling time in relation to the value, thickness, shape, material, etc. of the product can represent 80% of the time in the production cycle. The optimization was made cooperation conventional cooling system with system injection of liquid CO_2 into internal parts of product. It was explored and discussed variants of implementation, so optimal batching. A proper attention was given evaluation cooling ability of system. Results are showed that CO_2 system could increase cooling efficiency as products small volumes as products large volumes. The improve productivity examined group of product was got in range 17 % – 24 %. It was also proved that increase speed of cooling didn´t influence used behavior of products.*

INTRODUCTION:

The cooling process in blow moulding is a stationary, anizothermal, cyclic process in which heat is taken from the moulded plastic product. The heat reduction is ensured cooling system of mould and cooling from blowing medium [1]. The efficiency system of mould is obviously higher. It is because as the blowing medium is commonly used air by temperature 20°C.This condition is brought low thermal heating (low efficiency). It is opened large field for optimization with aim to shortening production time. Therefore many researchers are focused on this theme. The cooling internal parts are possible separate along method ensuring cooling medium. First method is used deep frozen air. The values of frozen air are depended on used system. For example systems FASTI and BEKOBLIZZ are able to supplied condition of air up to 16 bar (230 psi) pressure and temperature as low as -35°C [2], [3]. These values are got sequent passed through drying, cooling and filtering steps. Vortex tube is different system which is even able ensured supplies -46°C frozen air. The frozen air is got by passing trough stationary generator where the press gas is separate into hot (127°C) and cold flows [4]. Mixing frozen air with water is next interesting method how increase cooling efficiency [5]. Other access to enhance thermal reductive ability is injection inert gases into inter parts of product. The liquid CO_2, N_2 are reached temperature -78 °C or -210 °C which could bring expressively thermal reduction [6]. Therefore presented work is focused to explore applicability CO_2 as cooling medium. The accomplishment question of applicability was tested with equipment borrow from company Linde Gas (shown in fig. 1). It is equipment which make possible to injection liquid medium in a directed period. CO_2 is evaporated by influence degrease of pressure inside defined space. Change of state to gaseous is demanded energy. Necessary energy is taken from internal part of cooling space in form of heat.

Finding answers on several questions were necessary to proper evaluation of applicability. Consequently our attention was given at first to integration used cooling system into blowing machine. Exploring optimal batching of CO_2 was necessary to do in next step. Credibly judgments are possible only by testing group of products. Therefore the group was made up from products characterized by different shapes, volume and thickness. After that evaluating efficiency of system could be done. Problem influence fast cooling on behavior of product is discussed on the end of article.

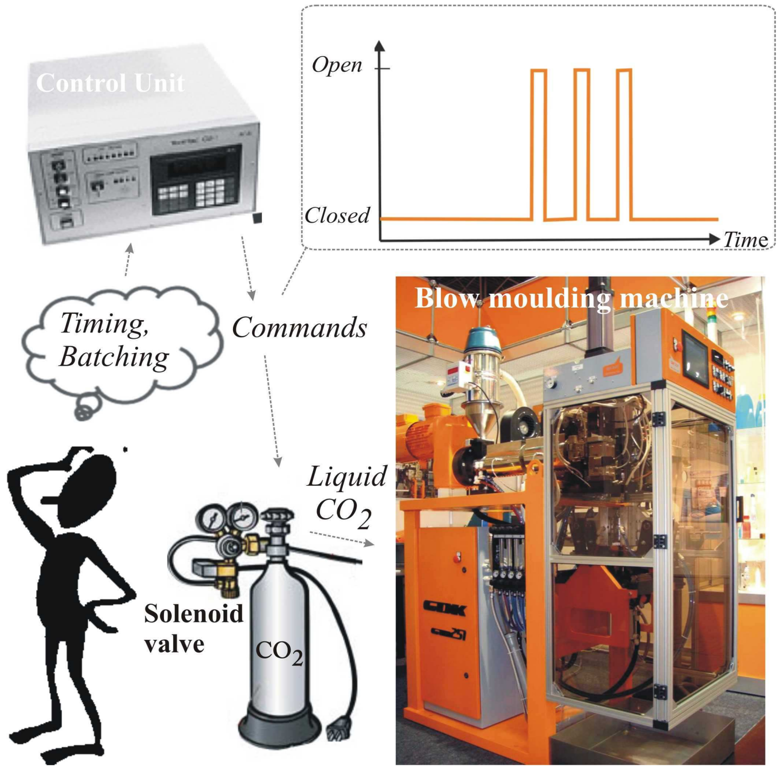

Fig. 1. *Connection cooling system of CO_2 to mould blowing process*

IMPLEMENTATION OF CO_2 SYSTEM:

The blow molding technology is produced complex enclosed hollow shape products or products open hollow shape. Enclosed products are most of all blows up with needles. Disadvantage application of blowing needle is needful to cut place of puncture. Also coordination of puncture process is demanding for optimal placing and setting of movement. For improve of cooling process a continual flow of medium is with advantage used. In this cooling variant it is necessary solved venting. The figure 2 is shown example sophisticate solve venting by cooling phase [7]. The presented blowing needle is integrated two needles (one for blowing, second for venting) into one complex. This substitution is saved using one more needle which is necessary to venting of circulated medium. There is also some application of needle for products characterized opened hollow shape. Our effort was focused different way with respect to presented restriction and wider spread blow up products trough blowing pin. It is integrated CO_2 cooling system directly to blowing machine, into blowing pin. There are several possibilities how to led cooling medium trough blowing pin. Variants are depended on used blowing technology (extrusion, injection blowing or stretch blowing). We were focused to integration examined CO_2 cooling system into extrusion blowing machine. The easiest integration is got capillary leading liquid CO_2 through core of blowing pin. Injection and next expansion (figure 3) is created inside flow (figure 4) which is took heat inside part of product. The venting is ensured by opened venting valve. Another possibility is created special blowing pin. This pin could have drilled channel bringing CO_2 into product. Venting it will be lead off inside core. It is turned about inside flow of medium. From presented variants it was chosen and connected variant one for simple and multiply applicable.

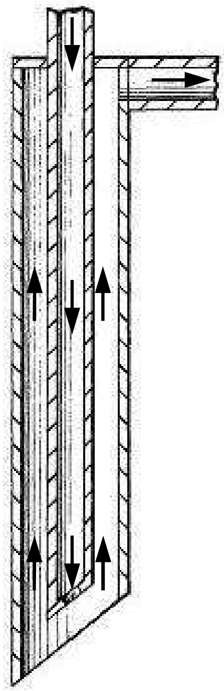

Fig. 2. *Especial Blowing Needle [7]*

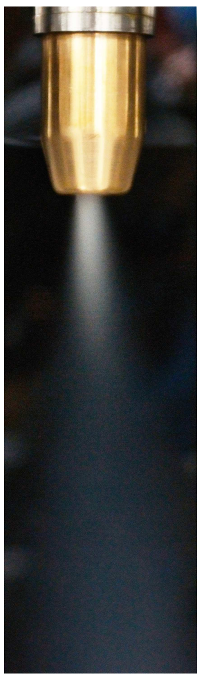

Fig.3. *Expansion of CO2*

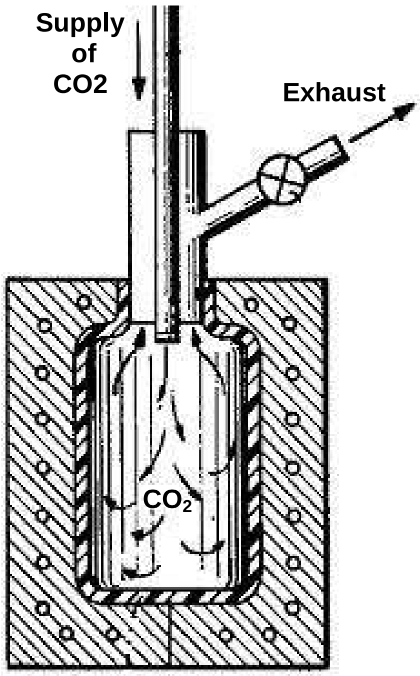

Fig.4. *Supply of CO2 to product and inside flow*

The optimal setting of system was next task. The maximal efficiency is got by employing system as long as possible. Consequently it was explored possibility using CO_2 as blow medium. The cooling reduce was really impressive but unfortunately the product contain defects. The producing of reject was evoked very fast expansion of CO_2. It was brought insufficient venting of mould and wrinkles emergence on product surface. Reduce effect of CO_2 was therefore timed after blow up product. The blow molding process is not different than common process at first steps. The air by standard condition (20°C and pressure 6 bars) blow up parison which inflated in mould to asked shape. Then liquid CO_2 is injected in time enough shape stability by opened venting valve. It made possible to circulation CO_2 and so effective reduce heating from inside part. It is logically that when it is injected more CO_2 increase system efficiency. The question was if venting is enough. The non correct venting could lead to mould opening which evocated reject production. From experimental measuring It was explored that venting is enough and system could be maximally used (as long injection as possible) for all examined products [8].

COOLING POSSIBILITIES OF SYSTEM:

The increasing cooling efficiency by cooperation cooling system of mould with injection liquid was explored on the three products. The product difference should ensured objective evaluation. The group small and shape complexity product is represented with “Hippo”. It is product with volume 50 ml, wall thickness 2 mm. The products periodic shapes are substituted with bottle of 250 ml volume and thickness 1 mm. The container for liquid is third product which is represented big products. Container has volume 7 liters and thickness 5 mm. The efficiency is evaluated with noncontact optical method - thermo camera. It was chosen critical points during the product long where it was expressed concretely values of temperature. These points were next compared by different processing setting and made possible to do objective evaluation.

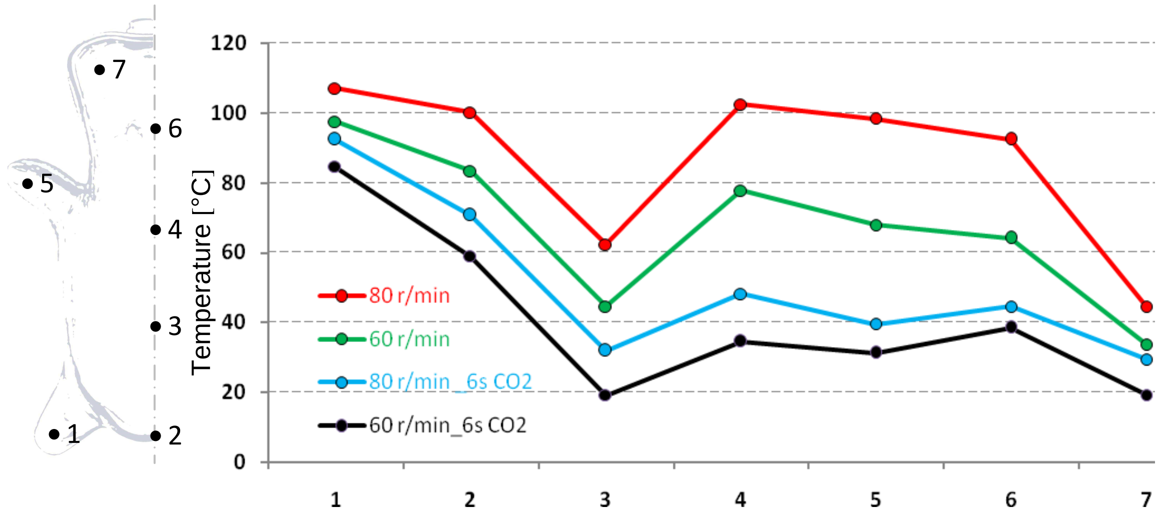

Fig. 5. *Comparison temperature of Hippo at the selected points*

The figure 5 is described temperature distribution of “Hippo”. The red and green curves are shown temperatures distribution by using only cooling system of mould. The difference is in a period of cooling which is predetermined with speed of screw. Faster speed of screw bringing shortening cycle time and cooling time so. The temperatures exceed 100 °C by speed of screw 80 rounds per minute. This temperature is generously considered as limited ejection temperature for used material (polyethylene). The correct setting was found by speed of screw 60 rounds per minutes (green line). Next it was connected and injected liquid CO_2 in period 5 second. The black line is shown level degrease of temperature in evaluated points. For expression increase of cooling efficiency it was increase speed of screw on original value (by the same timing of CO_2). The blue line is proved no exceed temperature which was got by using only cooling system of mould with speed of screw 60 rounds per minutes. This result means that injection 5 second period of CO_2 was saved 6 second of cycle time. The curve described cooperation common cooling system of mould and CO_2 system is shown expressively degrease of temperature in evaluated points. The problem place which limited more efficiency of system is back leg. The reason could be found in product shape complexity. The shape complexity here influences CO_2 flow which couldn´t got to end of legs and reduced temperature more effectively.

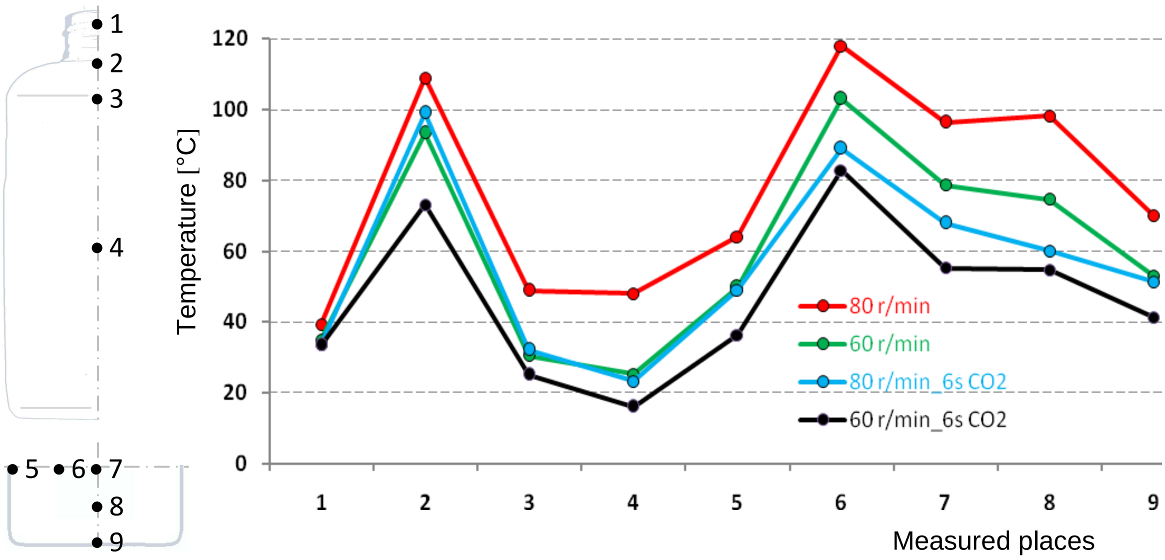

Fig. 6. *Comparison temperature of bottle at the selected points*

The experimental measuring of bottle was made in the same way. Also here the common cooling system wasn´t worked sufficiently by speed of screw 80 rounds per minutes (red line). The result was creation of defects as dropped in place of neck and bottom. The correct product was made by setting speed of screw 60 rounds per minutes (green line in figure 6). Next it was applied CO_2 system in long of injection 6 second. The blue line is show increase of cooling efficiency. Also here there are place which is limited higher efficiency of system. This place is neck. It is place where entered blowing ping (figure 2). The blowing pin and shape of neck probably restricted ideal CO_2 flow in this area. The injection liquid CO_2 in long 8 second made possible increase speed of screw on value 80 rounds per minute. It ensured saved 7 second of production cycle time.

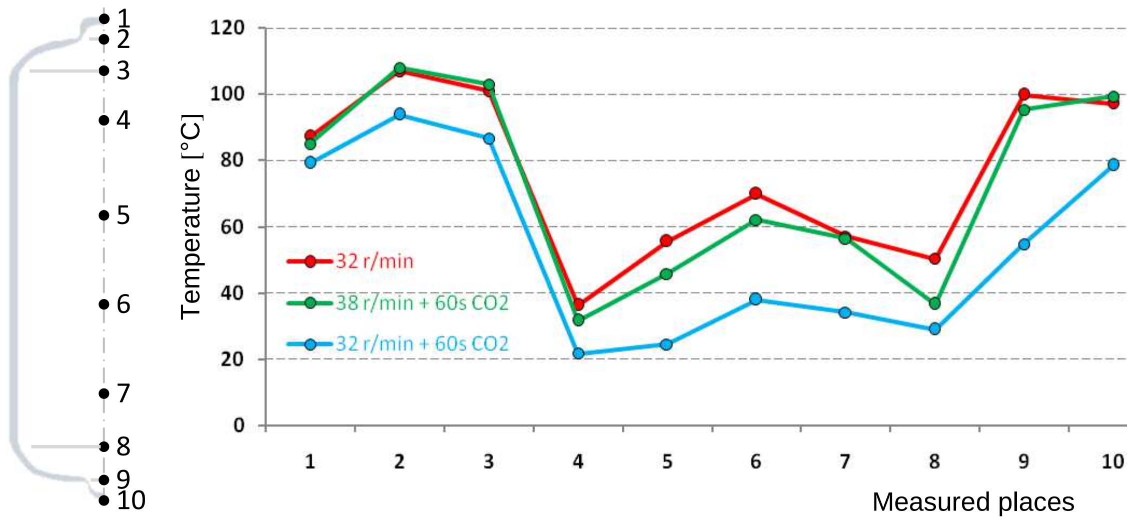

Fig. 7. *Comparison temperature of container at the selected points*

The last experimental measuring was made on 7 liters container. Maximum production setting was found by speed of screw 32 rounds per minute. With this setting the cooling system of mould was able to ensured production of product without reject (red line). Next it was connected CO_2 system which injected CO_2 in a period 60 second. Also here there is the most problematic places booth end of products (neck and bottom). The increase of efficiency is shown blue line in chart of figure 5. Injection 60 second made possible increase speed of screw on 38 rounds per minute and saved 15s production time.

CONCLUSION:

The article deals with applicability additional system injection of liquid CO_2 to blow moulding process. The integration and batching of CO_2 was explored at first. The results are proved possibilities of brought CO_2 trough capillary inside core of pin. The open venting valve is ensured sufficient venting. It made possible created continual flow of expanded CO_2. It was also explored that timing injection of CO_2 couldn´t be load after enough shape stability of product. It is because using CO_2 as blowing medium led to surface defects under nonsufficient venting of mould.

The efficiency of system was tested on group products characterized different volume, shape and thickness. The 5 second injection of CO_2 is brought increase 15-45% of cooling efficiency for small product – Hippo. It made possible

24% increasing of productivity. The problematic places which restricted better effect of CO_2 were back legs. The shape complexity here negative influenced circulation of CO_2 and restricted ideal flow. The periodic shape product - bottle of middle volume is got cooling increasing 10-25% by 8s periodical injection of CO_2. It is brought 22% increase of productivity. The 15 second injection of CO_2 was evoked improve cooling efficiency in range 15-35% for product large volume – container. Increasing productivity was 17%. The increasing efficiency is evident in every case. From results it obviously that there are limited places which restricted else more increasing of productivity. There places were located in top (neck) and bottom of product (legs). Therefore it will be next effort focused to optimize cooling of problematic places and ensured maximal utilizing capacity of CO_2 system.

The increasing productivity is sure for producer one of the most important aim. But the faster cooling could bring also negative effecting quality of products. The behavior of plastic materials is predicted among others by macromolecular structure which is build during the cooling process. Therefore experimental measuring influence fast of cooling on behavior applied semicrystal material (polyethilen) was made. The testing of mechanical behavior not registers considerable change. Also optical behavior looked without change. It made possible to say that fast cooling didn´t change used behavior our experimented products. It is important to say that it was tested only one used materials. It is question if the fast cooling influenced material with more crystallization ability.

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