

Injection Molding utilising Rapid Hot Cold Vacuum (for standard, sequential & injection-compression molding)

FIELD OF INVENTION

The invention relates to a method pertaining to molding of thermoplastic materials in particular, so as to improve on the part quality by eliminating defects such as weld-lines, inclusion as well as improving the process cycle time and cosmetic aspect such as uniform glossiness etc. The method involves rapid mold heating and application of vacuum inside the mold cavity followed by rapid cooling for the plastic material to solidify. The method can be used in an injection molding system comprising of either standard cavity mold or multiple cavities mold moving in a sequential motion as well as for injection-compression molding, and is controlled by a separate external self-contained control system. The detailed operation for the injection-compression molding can be found in the UK patent application GB 1017998.4 filed on 26 October 2010 and its subsequent PCT application WO 2012/056395 A2 filed on 3 May 2012.

The present invention here serves to differentiate itself from the rest of the processes that utilise rapid mold heating and cooling. The use of dehumidified hot air in the heating process helps to reduce some of the problems commonly associated with using steam and induction heating and this will be elaborated further in the subsequent paragraphs mentioned here. The uniqueness of using vacuum via the same hot air line as well as the use of super-cold water for localised rapid cooling of the plastic part will also be further elaborated in the subsequent paragraphs mentioned here. Moreover, another differentiating factor is that all the equipments needed to perform the rapid mold heating, vacuum and cooling as per the invention described here are all compacted inside a

movable and mobile chassis within the separate external self-contained control system or control unit.

BACKGROUND OF THE INVENTION

For many thermoplastic materials to achieve an easier flow, it will require a higher processing temperature. But it is common in the prior art that most of the conventional injection molding processes require the mold temperature to stay at a constant temperature that is below the melting temperature of the material.

It is well known in the field of plastic molding that auxiliary heating and cooling equipment is usually employed for the purposes of maintaining constant mold temperature. However conventional processes in the injection molding industry also do produce problems caused by mold temperature differences between the material and the mold. These will result in poor quality products with weld lines and other residual stresses. The ideal molding condition would be to have a built-in system with a variable hot and cold mold that is controllable within a specific area for heating and cooling of the plastic part. For optimum results, it was shown that molding systems with rapid heating and cooling capability do help in improving the quality of the finished parts. There are prior art out there that describes the various methods of rapid hot cold molding for plastics. Common prior art heating methods involves heating via steam and induction heating using high frequency electrical current. Cooling is commonly done using cooling water for the prior art which will be described in the coming paragraphs.

Examples of Steam Heating Prior Art

Representative examples of prior art using steam heating include US patent nos 4,201,742, 4,442,061, 5,055,025 and 6,290,882. US 4,201,742 discloses a method for heating the mold cavity surface by means of high pressure saturated condensing steam and draining the condensate from the cavity just prior to the injection stage. Cooling is done via passing cooling fluid internally through the mold. However for such a system

utilising hot steam, the presence of moisture and humidity within the steam can potentially create quality issues in the plastic molded part. Besides, localised heating of the part is difficult for steam. Moreover, the auxiliary equipment needed to generate steam are usually quite big, bulky and space-consuming, with equipments like super-heated water generator and containers, external bulky controllers, water purification systems, etc which takes up a lot of space in the limited shop floor.

US 4,442,061 discloses a heat cycle injection compression molding method whereby a temperature control apparatus with water and hot steam is used to reheat the injected plastic inside the mold cavity. Cooling is done by circulating water through mold cavity. However, localised heating of the part is difficult for steam, meaning that all the full cavity of the plastic part will be maintained at the same high temperature, creating an important need for cooling later on. Moreover, the auxiliary equipment needed to generate steam are usually quite big, bulky and space-consuming, with equipments like super-heated water generator and containers, external bulky controllers, water purification systems, etc. which takes up a lot of space in the limited shopfloor.

US 5,055,025 discloses an injection mold apparatus consisting of two halves whereby the mold is heated up to a temperature above the melting point of the plastic material via a circulating heat carrier flowing through a heating device. Cooling is done by circulating the same heat carrier which now passes through a cooling device. Similarly, localised heating of the part is difficult for steam, meaning that all the full cavity of the plastic part will be maintained at the same high temperature, creating an important need for cooling later on. Moreover, the auxiliary equipment needed to generate steam are usually quite big, bulky and space-consuming, with equipments like super-heated water generator and containers, external bulky controllers, water purification systems, etc. which takes up a

lot of space in the limited shop floor. Also, the mold itself is bulky and complex, and will require a bigger machine, hence uses more energy and costs to process the plastic part. In addition in this design US 5,055,025, it removes the possibility to integrate vacuum technology into the system.

US 6,290,882 discloses an injection molding process to reduce knit-line for thermoplastic injection molding using multi-gated non-sequential filled method. The fast heating phase comes from combining high thermal conductivity copper alloy mold cavity materials with very large thermal driving force (high “delta T”) from high heat transfer rate fluids (preferably steam). Cooling is done with circulating heat transfer fluid of a lower temperature source after the mold is filled to solidify the thermoplastic before opening the mold for part ejection. Localised heating of the plastic part such as repetitive ribs is difficult. Moreover, the auxiliary equipment needed to generate the heat transfer fluid and steam are usually quite big, bulky and space-consuming, with equipments like super-heated water generator and containers, external bulky controllers, water purification systems, etc. In addition for this design disclosed in US 6,290,882, it removes the possibility to integrate vacuum technology into the system.

Examples of Induction Heating Prior Art

Representative examples of prior art using induction heating include US patent nos 4,340,551, 4,390,485, 5,762,972 and 6,846,445. US 4,340,551 discloses a method that selectively only heats up the superficial layer of the inner wall surface of the mold by high frequency induction heating such that the temperature is above the heat-distortion temperature of the thermoplastic resin prior to injection molding and cooling and solidifying the resin. However, such an induction system is limited to simple uniform plastic parts and is difficult to have localised heating for plastic parts with complicated

shapes and sizes. It is clear that the use of the induction coil on an undercut area release by lifter or slider will make the tool particularly bulky.

US 4,390,485 discloses a mold design that facilitates the rapid heating and cooling of the mold cavity by employing one or more thin metal sheets or bands of high electrical resistivity in the mold cavity heated using electric current. These thin metal sheets or bands cover certain portions of the mold surface where a smooth surface finishing on the product is desired. However, such an induction system is limited to simple uniform plastic parts and is difficult to have localised heating for plastic parts with complicated shapes and sizes. Similarly, it is clear that the use of the induction coil on an undercut area release by lifter or slider will make the tool particularly bulky.

US 5,762,972 discloses an apparatus that utilises the induction heating or dielectric heating of a mold in an injection molding system up to a desired temperature within the short time by using high frequencies or microwaves. The electric current of high frequency generated from a high frequency generator flows through a coil that is embedded inside the mold to heat the mold via induction, and microwaves from a microwave generator heats up the dielectric material within the mold, thereby preventing cooling of the mold when a resin fluid is injected into a cavity. However, it is difficult to have localised heating for plastic parts with complicated shapes and sizes. Similar to previous prior arts, it is clear that the use of the induction coil on an undercut area release by lifter or slider will make the tool particularly bulky.

US 6,846,445 discloses a method for rapid mold heating on surface heating generated by surface current due to proximity effect on the mold insert powered by radio-frequency or high-frequency current. Due to this proximity effect, the electrical current flows on the

inner surfaces of the two cavity halves, thus rapidly heating the mold cavity. Proper use of insulation behind the cavity surface helps increase heating efficiency. However, such an induction system is limited to simple uniform plastic parts and is difficult to have localised heating for plastic parts with complicated shapes and sizes. It is clear that the use of the induction coil on an undercut area release by lifter or slider will make the tool particularly bulky.

The general negative aspect of all these induction systems is that they are incompatible with a vacuum system or solution. Induction coil and insulation systems necessary to provide a good heating will remove the possibility to access the recommended vacuum area.

Hence to summarise, all the systems disclosed in the prior art as highlighted previously would normally involve just the two (2) processes of heating and cooling portion for the mold cavity.

For systems utilising hot steam for heating up the mold, the limitations are generally:

1. Presence of moisture and humidity within the steam can potentially create quality issues in the plastic molded part.
2. Besides, localised heating of the part is difficult for steam, although it can be done by increasing other molding variables like the pressure, etc, which will affect the cycle time.
3. Moreover, the auxiliary equipment needed to generate steam are usually quite big, bulky and space-consuming, with equipments like super-heated water generator and containers, external bulky controllers, water purification systems, etc.

4. Possibility of being compatible with a vacuum system or solution, but this would result in another overall bulky system that is space-consuming.

For systems utilising induction heating for heating up the mold, the limitations are generally:

1. Limited to simple uniform plastic parts and is difficult to have localised heating for plastic parts with complicated shapes and sizes.
2. Use of induction coil will result in a bulky tool or mold.
3. Incompatible with a vacuum system or solution. Induction coil and insulation systems necessary to provide a good heating will remove the possibility to access the recommended vacuum area.

Advantages of the Present Invention

The present invention serves to differentiate itself from the rest in the prior art by providing a separate self-contained control system, which may be readily attached to and readily removed from the molding machine, tool/mold, and/or auxiliary equipment.

Its advantages are as follows:

1. The chance of having moisture or humidity present inside the system is negligible. The present invention utilises hot dehumidified air which is heated up to a temperature of 400 Degree Celsius from the control system, and is being used for heating up the mold cavity while the cooling of the plastics is done by pumping in super-cold water at minus 15 Degree Celsius through the standard cooling channel of the tool for rapid cooling of the mold. Also the hot dehumidified air can help to reduce the chances of rust formation within the pipes and tubings overtime as compared to other processes that uses other heating elements like super-heated steam which contains moisture.

In the present invention, prior to rapid cooling, a vacuum at 25 Torr is applied at the same time as the plastic is injected so as to enable the plastic material to adhere closely to the mold before application of super-cold water at minus 15 Degree Celsius during the cooling process. This vacuum will enable the plastic materials with special fibre additives to process more uniformly. The application of vacuum also helps to remove any possible moisture present inside the pipes and tubings. This is another differentiating feature that exists inside the present invention.

2. Ability to have localised heating for simple parts as well as parts with complicated shapes and sizes. This will be described in greater detail under the “Detailed Description of One Preferred Embodiment of the Present Invention” portion.
3. No space-consuming auxiliary equipment is needed to generate the hot dehumidified air. This is because auxiliary equipment needed for the present invention can be compacted inside a self-contained control system.

The present invention described here can be applied to either a tool (or mold) either standard cavity mold or multiple cavities mold moving in a sequential motion. This unique feature helps to reduce the cost of production and increases the output. The sequential technology is included inside the self-contained control system which helps to control the latch necessary to create the sequential function. Details of the mold latch technology are disclosed in the patent number GB 2470285. By incorporating the rapid hot cold vacuum process into a standard cavity mold or multiple cavity mold moving sequentially, the plastic parts being produced are of a better quality product with defects

such as weld-lines, cosmetic aspect such as uneven glossiness etc. being eliminated.
All these will be elaborated in detailed in the subsequent paragraphs.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings attached here are to aid in better understand the description of the invention here. The drawings are not to scale and they are to be used for merely illustrating the principles and concepts of the invention. The description of the invention will be explained using the operation of a standard cavity mold, a two (2) parting layer sequential mold as well as injection-compression molding. The detailed operation for the injection-compression molding can be found in the UK patent application GB 1017998.4 filed on 26 October 2010 and its subsequent PCT application WO 2012/056395 A2 filed on 3 May 2012.

To aid in the description of the invention, the drawings are separated into the various Figures as described below:

Fig 1 illustrates a full section of how a process described in the invention works with a single one (1) parting layer mold with an external control system/unit.

Fig 2 illustrates a full section of how a process described in the invention works with multiple cavities mold in sequential motion with an external control system/unit.

Fig 3A introduces a perspective view of a plastic product and its pre-selected skin surfaces in which the surface is defined as a lens area.

Fig 3B illustrates a full section of how a process described in the invention works with injection-compression molding connected to an external control system/unit.

Fig 4 schematically illustrates the heating method using other conventional heating methods like steam.

Fig 5 schematically illustrates the heating method for the present invention using “Hot Dehumidified Air Technology”.

Fig 6 schematically illustrates the close-up of diffuser as shown in Fig 2.

Fig 7 schematically illustrates a close-up portion of a plastic part to highlight the advantages of “Hot Dehumidified Air Technology” for a hard-to-fill area of the part.

Fig 8 schematically illustrates an overview of the overall control system in the present invention.

Fig 9 schematically illustrates an overview of the “Hot Dehumidified Air Technology” for the system.

Fig 10 schematically illustrates an overview of the “Vacuum” portion for the system.

Fig 11 schematically illustrates an overview of the “Super-Cold Technology” for the system.

Fig 12 schematically illustrates an overview of the different positional input and output sequences for the valve solenoid.

REFERENCE NUMBERS

1	External tool controller
6	Tool / Mold
8	Injection Molding Machine
12	Connection Block
13	Connection Block
14	Connection Block
60	Standard Mold
70	Sequential Mold
80	Platen
81	Tie-Bar
82	Barrel
83	Injection Screw
84	Connector
85	Bed
100	Hot Dehumidified Air Technology
101	Air Output
110	Air Treatment System
111	Air Input
112	Air Regulator
113	Adjustable Control Valve
114	Air Filter Dryer
115	Auto Purge
116	Pressure Gauge
117	Hot Air Flow Adjust Device
118	Check Valve
120	Air Exchanger
121	Heat Sink
122	Heat Sink
123	Insulator
124	Insulator
125	Aluminum Heating Block
126	Cartridge Heater

127	Cartridge Heater
130	Air Control Adjust System (Hot Dehumidified Air Technology)
131	Hot Air Input route
132	Thermocouple
133	Valve Solenoid
134	Output route
200	Vacuum Technology
201	Vacuum Output
210	Air Treatment System
211	Valve Solenoid
212	Valve Solenoid output
213	Air Filter
214	Inlet Filter
215	Vacuum Pump
216	Scuba Tank
217	Sensor
218	Air Regulator
219	Vacuum Input
220	Air Exchanger System
221	Sensor
230	Vacuum Control (Vacuum Technology)
231	Valve Solenoid Output
300	Super-Cold Technology
301	Cooling Output
311	Water Tank Exchanger
312	Heat Exchanger
313	Pump
314	Motor
315	Sensor
316	Water Exchanger
317	Line / Route
318	Valve Solenoid
320	Cooling Control (Super-Cold Technology)
321	Refrigerant Accumulator

322	Expansion Valve
323	Solenoid Valve
324	Sight Glass
325	Filter Dryer
326	Refrigerant Receiver
327	Condenser
328	Compressor
329	Pressure Switch
350	High Pressure Control
360	High Pressure Output
361	High Pressure Line
370	Injection Compression Control
380	Injection Compression Output
381	Injection Compression Line
382	Sliding Plate
383	Wedge Block
384	Moving Apparatus
385	Moveable Core
386	Compression Area
600	Moving Side (of tool/mold)
601	Plastic Product
601a	Pre-Selected Skin Surface
601b	Pre-Selected Skin Surface
602	Diffuser
603	Ejector Pin
603a	Ejector Pin
603b	Ejector Pin
603c	Ejector Pin
603d	Ejector Pin
603e	Ejector Pin
604	Heating Line Route
605	Air Venting Area
606	O-Ring
607	High Cooling Line Route

608	Cooling Line
609	Core
610	Fixed Side
611	Cavity Plate
612	Cavity
614	Gate
615	Thin-Walled Area
616	Weld-line
617	C-Shaped Opening
618	Flow Curves
620	Parting Line
699	Process Room
700	Floating Side
730	Connector
750	Steam Canal
751	Steam Area
900	Route / Line (in Air Treatment System)
901	Route / Line (in Air Control Adjust System)
902	Route / Line (in Air Exchanger System)
903	Route / Line (in Air Exchanger System)

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT FOR PRESENT INVENTION

In the following description, details are provided to describe the embodiment of the application. It shall be apparent to the person skilled in the art, however, that the embodiments may be practiced without such details.

Some parts of the embodiments, which are shown in the Figures below, have similar parts. The similar parts have the same names or similar part numbers. The description of one similar part also applies by reference to another similar part, where appropriate, thereby reducing repetition of text without limiting the disclosure.

PROCESS OCCURRING WITHIN THE TOOLING MOLD

Figures 1 to 7 illustrate the concept of how and where the heating, vacuuming and cooling process works within a tooling mold as described in the present invention, with Figures 1 and 2 illustrating how the present invention can be applied to either single parting layer standard mold or more than 2 parting layer sequential mold.

Referring to **Figure 1**, it illustrates how the present invention can be applied to a single parting layer standard mold 60 with parting line 620 in between two (2) mold blocks comprising of moving side 600 and fixed side 610 for a typical injection molding machine 8. This molding machine 8 include two (2) conventional platen 80, guided by tie-bars 81, and fed by a barrel 82 including an injection screw 83. The full section of the tool refers to the cavity plate 611, cavity 612, a section of the plastic product 601 and also comprises of the core 609 including its cooling line 608 at the moving side 600. As shown in Figure 1, the “Hot Dehumidified Air Technology” portion for heating up and the “Vacuum” are plugged to the external self-contained controller/control system 1 via the

heating line route 604. The “Super-Cold Technology” portion for cooling the product is plugged to the external self-contained controller/control system 1 via the line 607. The control of the machine sequence is also connected to the external self contained controller/control system 1 via a standard or a specially customised connector 84.

Similarly in **Figure 2**, the present invention can be applied to a two (2) parting layer sequential mold 70 with at least three mold blocks 600 (i.e. moving side), 610 (fixed side) and 700 (floating side). A similar injection molding machine 8 including two (2) conventional platen 80, guided by tie-bars 81, and fed by a barrel 82 and injection screw 83 is connected to the external tool controller 1 via the same standard or a specially customised connector 84. A basic difference between Figure 1 and 2 is that Figure 2 comprises of an added connector 730 on the tool necessary to communicate with the external tool controller 1 which side of the mold is under the injection sequence or cooling sequence. The other difference is that there are 2 parting layers for the tool shown in Figure 2, whereby what has been described for the first (1st) parting layer in Figure 1 will also be repeated on the second (2nd) layer of the plastic product 601 and the tool components including cooling line 608, core 609, cavity plate 611 and cavity 612. As shown in Figure 2, there is one (1) “Hot Dehumidified Air Technology” connection via heating line 604 for each side of the tool and also one (1) “Super-Cold Technology” connection via high cooling line 607 on each side of the tool as well. It is clear that these connections 604 and 607 will be alternately activated by the external tool controller 1 relative to the information collected from the connector 730. The “vacuum” portion will be sharing the same route as the “Hot Dehumidified Air Technology” portion, i.e. via the two (2) heating line routes 604 as shown in Figure 2.

Figure 3A introduces a perspective view of a product 601 and its pre-selected skin surfaces 601a and 601b on which the surface 601a is defined as a lens area particularly difficult to inject considering the high optical aspect. To solve this difficulty, the type of tool will be an injection-compression tool which is represented on this simplified view by sliding plate 382, wedge blocks 383 and moveable core 385. It will be easy to understand that with the position of the gate 614, it will be difficult to fill the pre-selected skin surfaces 601b and also to bring the correct amount of plastic resin to the pre-selected skin surface 601a. It is clear that for a correct compression, the amount of plastic resin in the pre-selected skin surface 601a should be accurate and in good condition of melting in order to improve the final optical aspect of the lens area. The advantage of the present invention will be elaborated in **Figure 3B**, showing us a full section of this part 601 inside a tool 6.

Figure 3B schematically illustrates a full section of how the present invention works with an injection-compression molding system connected to an external control system/unit. A simplified view of a conventional injection molding machine 8 is represented by bed 85 on which the tool 6 is fixed. A key difference between **Figure 3B** and **Figure 1** and **2** will be that a compression molding system is being incorporated in **Figure 3B** and represented by sliding plate 382, wedge blocks 383, moving apparatus 384 and the moveable core 385. As highlighted previously, the detailed operation for the injection-compression molding can be found in the UK patent application GB 1017998.4 filed on 26 October 2010 and its subsequent PCT application WO 2012/056395 A2 filed on 3 May 2012. A basic reminder of the principal function of this system will be to understand that after partial filling of the part, a hydraulic action via injection-compression line 381 connected to the moving apparatus 384 will create the sliding of both wedge blocks 383, which will activate the perpendicular movement of the sliding plate 382. This sliding

plate 382 will create a movement of the moveable core 385 in order to compress the compression area 386. As described previously in **Figure 3A**, the area 601a will have to be considered as an optical lens area and the filling process will be completed by the compression of the area 386. Of course it will be very important to bring the correct amount of plastic resin in a particular good melting condition in order to achieve the compression correctly. It is clear that by having a variable amount of plastic resin or inadequate temperature; it will be difficult to achieve the specified dimensions or the optical transparency required by the optical functions of the lens. This view in Figure 3B introduces how to fix these problems by using a diffuser 602 including its own o-ring 606 and process room 699. As it will be described later in Figure 5 and 6, the “Hot Dehumidified Air Technology” will heat the pre-defined skin surfaces 601b via the heating line 604 and diffusion by the air venting area 605 which are provided around both ejector pins 603a. Both pre-defined skin surfaces 601b will be pre-heated at a defined temperature, re-melting the plastic resin during filling inside the pre-defined skin surface 601a, and then activate a vacuuming action to have a stable void during all the filling time to provide a perfect and stable process condition before compression of the area 386. This operation will be completed by using super-cold water at both areas 607 that is experiencing higher temperature due to the release of hot dehumidified air.

Figure 4 and 5 schematically shows a comparison of the present invention with other conventional heating methods using steam.

In this first case, **Figure 4** schematically illustrates a possible conventional heating method using steam. As shown in Figure 4, the full section of the tool refers to the cavity plate 611 with the cavity 612 and core 609, with a section of the plastic product 601 to be molded and ejected out via ejector pins 603. Typically the steam enters via steam

canal 750 and/or steam area 751 to heat up the mold cavity for the plastic product 601 to be molded.

In the second case, **Figure 5** schematically illustrates a cross-sectional view of a typical single parting layer mold in which the heating method for the present invention uses hot dehumidified air. As shown in Figure 5, the full section of the tool refers to the cavity plate 611 with the cavity 612 and core 609, with a section of the plastic product 601 to be molded and ejected out via ejector pins 603. Hot dehumidified air flows via heating line route 604 to the tooling mold and then after passing through the diffuser system 602, it will heat up the skin surface of the core 609 and cavity 612 and especially heat-up the pre-selected skin surface in diffuser system 602. As illustrated in Figure 5, cooling happens with super-cool water flowing through cooling insert 607 and normal cooling water flowing through cooling line 608 located on the core side 609 of the mold. After this introduction of the diffuser area 602, it will now be easy to understand that the present invention will not try to over-heat and over-cool all the core 609 and cavity 612, but only some area detected as sensitive by the tooling designer/engineer, depending on the shape and configuration of the plastic product 601 to be molded, i.e. succession of ribs, thin area, clips etc. The hot dehumidified air will be used on this diffuser area 602 to improve the flow of the molten plastic and then the super-cool water will be used to balance the temperature of this area 602 and to bring back the temperature of this area to the average post-injection temperature for all the plastic part before the final ejection without increasing the cycle time. Details of the close-up portion for diffuser 602 will be highlighted further in **Figure 6**.

Figure 6 illustrates a close-up portion of 602 that was shown and described in Figure 5. As highlighted in Figure 6, hot dehumidified air flows through heating line route 604 via

its insert and onto the process room 699. There are o-rings 606 to prevent the hot dehumidified air from escaping as well as to help insulate the hot dehumidified air and maintain it within the heated temperature range of close to 400 Degree Celsius. Ejector pins 603 are for ejecting the part out from the mold after it has been cooled and solidify, followed by venting out the hot dehumidified air through air venting area 605 present inside diffuser 602. This action will heat up the area cover by the diffuser 602 in order to prepare the sensitive surfaces for the next injection. The heating time will happen during the mold closing and high-clamping stage of the molding process, which is around 5 seconds long. The skin surface of the mold will be heated up gradually to a pre-determined temperature estimated to be between 200 to 300 Degree Celsius, depending on the type of plastic material to be molded. For plastic parts which have complicated shapes and sizes, the air venting area 605 for the hot dehumidified air to flow through will be positioned such that there will be more hot dehumidified air flowing in to heat up the skin surface of those difficult to reach and complicated areas. For those areas that are easier to reach, lesser hot dehumidified air will be channelled i.e. using a smaller air-venting area 605 to heat up the skin surface of the core 609 and cavity 612 in contact with the part. Such a configuration will lead to more efficient heating of the skin surface of the core 609 and cavity 612 as compared to other conventional means of heating which uses heating medium like steam and induction heating via high frequency electric current which is usually more energy intensive. In addition, the vacuum process for the present invention will follow the same reverse way in which it will be vacuumed through core 609 and cavity 612 from the air-venting area 605 and evacuate passing through process room 699 to heating line route 604 just after the end of the heating and during the plastic injection filling process. As mentioned earlier, a comparison on the use of hot dehumidified air as described in the present invention with steam will be covered under the "Advantages of Using Diffuser 602" section of this write-up here.

ADVANTAGES OF USING DIFFUSER 602

The present invention uses hot dehumidified air to heat up the mold cavity surface for the plastic product to be molded. By comparing the use of hot dehumidified air with steam, there are certain limitations for the use of steam.

One of the advantages of this present invention is to provide a new method of rapidly and efficiently heating, vacuuming and cooling the mold surface without incurring high energy costs. The new method utilises hot dehumidified air to rapidly heat up only the pre-determined skin surface of the metallic core 609 and cavity 612 which is in contact with the plastic part. This is important as it will help to enhance the quality of the molded part to eliminate weld-lines, especially for hard-to-reach areas in which other heating methods like steam might be difficult to reach. It will be important to remember that the heating, cooling and vacuum process described in the present invention happened only at the pre-determined area of the plastic product, reducing the need for energy at the minimum requested by the plastic product. The following Figure 6 will highlight another possible use of the present invention on a totally different plastic product.

Another advantage will be illustrated with the help of Figure 6. In **Figure 7**, it shows us a common plastic product 601 including hard-to-reach part as shown at the extreme end with a thin-walled area defined as 615. Another distinguishable feature of this plastic product 601 is the presence of a c-shaped opening 617. In a conventional molding process, there will be some difficulty for the plastic to flow when there is any c-shaped opening or pin during the filling process within the mold cavity, which in turn will result in a visible weld-line 616. Also shown in Figure 7 is an illustration highlighting the way in which a typical plastic flows as defined under the flow's curves denoted via numeral 618.

As shown in **Figure 7**, the gating of the part shown as 614 and from the weld line 616, the flow curves 618 demonstrated that the molten plastic resin will lose speed and inertia once it reaches the area near the weld line 616 and that only the heating action will help in assisting the molten plastic material to be able to fill the part. This action could be created by blowing hot dehumidified air using the ejector pins 603d and 603e during the mold closure period. This action will heat the surfaces at the origin of the welding line, creating in this area a possibility to re-melt the molten plastic, removing the weld-lines 616 and improving the filling on those hard-to-reach areas. This heating action happens from the time when the previously finished part is being ejected and closing of the mold to the time where it is the end of the high clamping of the mold.

As shown in **Figure 7**, after the heating has been done, a vacuuming action will be actuated from the position of the different ejector pins 603a to 603e in concurrent with the injection of the molten plastic material into the cavity. This vacuum action could be done using a variable pressure during the sequence but also a variable timing where the vacuuming will be maintained longer and more powerful for the area near to the end of filling where it is hard to fill. This vacuum action in concurrent with the injection process will assist in “pulling” the flow of the molten plastic resin onto the mold cavity which in turn will help create a nice and balanced finishing on the plastic part, removing the risks of short shot and reducing the cycle time. A final action using an improved cooling system via super-cool water will help to solidify and remove the un-even temperature at the surface of the plastic part such that warpage of the plastic part will not occur when the part is ejected.

In doing so, the whole process described in the present invention will help to minimise the energy that is required for heating up the tooling mold since the hot dehumidified air

can be effectively controlled at certain spots that require localised heating in order for the heating to be more effective. As a result, this will indirectly contribute to potential savings in energy consumption especially when compared to conventional heating methods like induction heating via using high-frequency electric current (as per quoted in patent US 5,762,972 and US 6,846,445). The present invention utilises low wattage for heating as compared to high frequency electric current which typically uses high wattage.

Another advantage of the invention is that it has the potential of shortening the molding cycle time by having this system of rapidly raising the mold surface temperature as compared to using other heating methods like steam. This rapid heating of mold surface temperature followed by vacuuming and rapid cooling of the mold surface can significantly reduce the total cycle time as well as producing better and improved quality plastic parts with problems like warpage being eliminated.

Furthermore, this present invention does allow ease of customisation as and when required by the toolmaker during the initial trial or prototyping stage of the mold design. In any mold design, ejector pins 603a to 603e in **Figure 7** or those ejector blades 603 shown in **Figure 4, 5 and 6** are usually placed at areas where the flow of plastic in the part is constrained. The tight air venting channels can be easily machined at places located near to where the ejector pins 603 or ejector blades 603a to 603e are situated in order to allow the integration of a diffuser 602 to improve the filling of the parts by using "Hot Dehumidified Air Technology". Compared to the present invention, customisation on the tool is not as easy for other conventional methods like steam whereby the inserts for the steam input that were already drilled in the hardened core and cavity inserts would not be so easily changed or adjusted.

In addition as mentioned earlier under the “Background of the Invention” portion of the write-up, hot dehumidified air is almost free of moisture and will help to reduce the chances of rust formation within the inserts, pipes and tubings over longer period of time as compared to other processes that uses other heating element like super-heated steam which contains moisture. Hence this would also mean that for processes that use super-heated steam as the heating element, the tooling mold would need to be constructed using good quality steel or metal which is extremely resistant to rust, thus indirectly increasing the costs of making the mold. Therefore if certain plastic materials are susceptible to burn marks when using with PP resin for example or pigment discoloration applied on grey, white, red colours etc, the use of super-heated steam would have its limitations.

Moreover, as compared to prior art e.g. US 5,762,972 and US 6,846,445, the present invention of using cooling water for cooling the system presented a much more safer alternative as compared to those using high-frequency electric currents. Potentially the presence of water and electricity when mixed together, can present a much more dangerous option if not handled properly during normal operation by the operators or end-users.

PROCESS OCCURRING WITHIN EXTERNAL TOOL CONTROLLER

Next, the following description will be for **Figures 8 to 11**, which illustrates how the three (3) different key processes, i.e. the “Hot Dehumidified Air Technology”, “Vacuum” and “Super-Cold Technology” portion of the system function in generating the necessary hot dehumidified air for heating, followed by vacuuming process in concurrent with the

injection process, and then lastly cooling the mold with super-cool water through the conventional cooling channel.

Figure 8 illustrates an overview of the relationship between the external tool controller 1 with the injection molding machine 8 and with the tool 6, which are clearly represented. In **Figure 8**, we can see 3 different blocks of connection. The first block 12 includes the air control 130 of the “Hot Dehumidified Air Technology”, the vacuum control 230 of the “Vacuum Technology”, the cooling control 320 of the “Super-Cold Technology”, the high pressure control 350 necessary for a sequential technology and the injection compression control 370 necessary for injection compression molding. This first block is connected to an interface including thermocouple control and analogue control in order to maintain proper control of all the processes within the system.

The second block 13 includes the air output 101 of the “Hot Dehumidified Air Technology”, the vacuum output 201 of the “Vacuum Technology”, the cooling output 301 of the “Super-Cold Technology”, the high pressure output 360 necessary for a sequential technology and the injection compression output 380 necessary for injection compression molding. This second block corresponds to all the logic output and is using the different valve solenoids 133, 211 and 318 to activate the corresponding route 604, 607, 361 and 381 in order to create the proper sequence for heating, vacuuming, cooling, sequential movement and injection-compression movement of the tool 6.

The third block 14 includes the standard or specially customised connector 84 of the injection molding machine 8 and connector 730 of the tool 6. This third block

corresponds to all the logic input and is connected to a logic interface in order to maintain proper control of all the processes within the system.

Hot Dehumidified Air Technology

Figure 9 illustrates the principle of how the “Hot Dehumidified Air Technology” portion of the system operates. For this “Hot Dehumidified Air Technology” portion of the system as illustrated in 100 of Figure 9, the process comprises of air treatment system 110, air heat exchanger 120 and air control adjustment system 130. Within air treatment system 110, it comprises of air regulator 112, adjustable control valve 113, air filter dryer 114 and auto-purge outlet 115. Pressure gauge 116 could either only be a visual control gauge helping to inform the user of the pressure load inside the system or it could be also under its electronic form directly connected to the analogue board in order to maintain proper control of all the processes within the system. Similarly, the hot air flow adjust device 117 could be under its manual form adjusting the same flow during all the molding process or under its analogue form with the user/operator having the possibility to modify the flow of the hot dehumidified air during the molding process. The last component of this section is a check valve 118 whereby it will be there only to remove the possibility for the hot air to flow back inside the previously described analogue components that are sensitive to the high temperature. For air heat exchanger system 120, the core component comprises of aluminium heating block 125 which is heated by cartridge heaters 126 and 127, with insulators 123 and 124 being provided to maintain the temperature of the heating block at 400 Degree Celsius. Heat-sinks 121 and 122 are provided to cool the whole air heat exchanger system 120 and also to help in maintaining the heating block at 400 Degree Celsius. Finally within the air control adjustment system 130, it consists of hot air input via route 131 whereby hot air from the heat exchanger 120 system flows via route 901 to valve solenoid 133. Thermocouple

132 is used for measurement purposes in detecting the temperature of the hot air exiting out from the air exchanger 120. The purpose of valve solenoid 133 is incorporated for controlling the flow of hot dehumidified air flowing from hot air input route 131 to the tooling mold and vice versa out via route 134.

Operationally, air is supplied to the system at a pressure of 6 to 10 bars with a temperature ranging from 15 to 30 Degree Celsius on the air input 111. Supply air here refers to ambient air from the environment, which usually contains fair amount of moisture or humidity. The supply air is then passed through air regulator 112 whereby the air is then regulated at 6 bar pressure and is controlled and adjusted via control valve 113 upon entry to air filter dryer 114 as shown in **Figure 9**. Within the air filter dryer 114, air is then dried and dehumidified to remove any moisture and oil traces that are present inside before entering the air heat exchanger 120 via route 900. Over long period of usage, moisture water and some traces of oil would have accumulated inside the air filter dryer due to the dehumidification process, with an auto-purge 115 installed at the base of the air filter dryer 114 to purge off any accumulated water and traces of oil. It is being purged to the water tank exchanger 311 which is being maintained at minus fifteen (-15) Degree Celsius with a volume of 75,000 cubic centimetres. The purpose of having the water tank exchanger 311 will be described in the subsequent paragraphs under the "Super-Cold Technology" 300 portion of the process described in the present invention. The frequency of the purge can be set at regular intervals depending on the operator's requirements.

Dehumidified air at ambient temperature between 15 to 30 Degree Celsius enters the air heat exchanger 120 via route 900. The air heat exchanger 120 is an aluminium heating block that is heated to 400 Degree Celsius. The size of the aluminium heating block is

approximately 1200 cubic centimetres and is heated up by 2 cartridge heaters 126 and 127. Dehumidified air that enters via route 900 goes through a series of tubes that are coil round the cartridge heaters 126 and 127. The dehumidified air is then heated up by the cartridge heater at 400 Degree Celsius via heat transfer through the tubes.

Dehumidified air heated up at about 400 Degree Celsius then exits via route 901 to the air control adjustment system 130. As it exits the air heat exchanger 120, there will be some form of temperature loss as it enters the valve solenoid via the hot air input route 131. A thermocouple 132 will be inserted into the aluminium heating block at the output portion of the air exchanger 120 to measure the temperature of the hot dehumidified air so that necessary action can be taken to heat up the dehumidified air further if the temperature is around the 200 to 300 Degree Celsius range. Using the information collected from the thermocouple 132, the operator will also have the possibility to regulate the output temperature in order to conform to the plastic resin injected inside the tool.

Valve solenoid 133 is installed at the base of air exchanger 120 and is used to control the flow of hot dehumidified air to the tooling mold via output 134.

As shown in **Figure 5 and Figure 6**, hot dehumidified air flows via output 134 to the tooling mold in which the hot dehumidified air is then channelled via heating line route 604 as shown in **Figure 5 and 6** to the mold itself and then heat up the skin surface of the mold, especially the surface that is in contact with the plastic product 601 as shown in **Figure 5 and 6**.

Vacuum Technology

Figure 10 illustrates a schematic view of the “Vacuum Technology” 200 portion of the system. It consists of air exchanger system 220, air treatment system 210 and vacuum control system 230. Operationally, the hot dehumidified air that is present inside the mold during the heating process is being vacuumed out via valve solenoid output 231 through the valve solenoid 133. After heating of the mold during the high clamping process, vacuum is applied during the injection of the plastic part till end of injection. The hot air has absorbed some of the moisture that might have been present within the mold itself, hence making it “less dehumidified”. As shown in **Figure 10**, the hot air flows out from the valve solenoid 133 via route 902 into an air exchanger system 220 which comprises of water tank exchanger 311 which is maintained at minus fifteen (-15) Degree Celsius. The water tank exchanger 311 with cold water at minus fifteen (-15) Degree Celsius is being used within a volume of 75,000 cubic centimetres to provide the necessary heat exchange with the hot air. The cold water temperature cools down the hot air through heat exchange such that the air that exits via route 903 reached an acceptable temperature compatible with the specification requested by the system necessary for air treatment 210. After activation by the valve solenoid 211, the air from route 903 enters via valve solenoid output 212 to a pressure sensor 221 which could be a visual control gauge helping to inform the user of the pressure load inside the system or it could be also under its electronic form directly connected to the analogue board in order to maintain proper control of all the processes within the system. The purpose of the air filter dryer 213 is to reject the moisture inside the water tank exchanger 311, in doing so, this helps to ensure that the vacuum pump 215 is not in contact with any moisture that might damage the vacuum pump equipment in the long run. The air filter dryer 213 is installed with an auto-purge system which is set to regularly purge out any

accumulated moisture from the drying process out from the dryer. The purging can also be set by the operators handling the whole process.

As shown in **Figure 10**, there is a vacuum pump 215 that is installed to help create the vacuum effect necessary in order to suck out any air creating a void so as to improve the flow of the plastic inside the tool. The vacuum pump is being sized at 16 cubic metres per hour with a pressure of 20 Torrs necessary to maintain a reasonable pressure included between 20 – 25 Torrs and a volume of 12 litres inside the scuba tank 216. The pressure inside the scuba tank 216 is being regulated by a pressure sensor 217 which could be a visual control gauge helping to inform the user of the pressure load inside the system or it could be also under its electronic form directly connected to the analogue board in order to maintain proper control of all the processes within the system. Pressure sensor 217 will activate the vacuum pump to start running if the pressure is more than 25 Torrs and will deactivate the vacuum pump when the pressure will have reached 20 Torrs. Inlet filter 214 helps to regulate and filter the air that is passing through the vacuum pump 215. The air regulator 218 could be a passive component that auto-controlled by itself a fixed pressure of 25 Torrs requested by the system or variable controlled by the previously described pressure sensor 221 in order to fine-tune the vacuum process inside the tool.

Super-Cold Technology

Figure 11 illustrates an overview of how the “Super-Cold Technology” operates. As shown in Figure 11, it comprises of air exchanger 220 located inside water tank exchanger 311, which was already mentioned in Figure 10. Also in Figure 11, there is a water exchanger 316 that is located within water tank exchanger 311 as well. The water exchanger 316 comprises of water at ambient temperature entering via route 317 and

exit out to the molding tool via valve solenoid 318 to super-cool the plastic part via the cold circuit line 607 mentioned in Figure 1, 2 and 3. This cold output from the valve solenoid 318 will be used in all the pre-selected area in order to remove the un-even temperature at the surface of the plastic part as previously explained in Figure 7. At steady-state, the water inside the water tank exchanger 311 is maintained at minus fifteen (-15) Degree Celsius within a tank volume of 75,000 cubic centimetres via heat exchanger 312. The cold water temperature of minus fifteen (-15) Degree Celsius provides the necessary heat transfer and exchange for the following:

- (a) for the hot air coming in from route 902 to the valve solenoid 133 within air exchanger 220 so that it exits out at a lower temperature via route 903, and
- (b) for the water at ambient temperature entering via route 317 within water exchanger 316 and it exits via valve solenoid 318 at a cold temperature to the mold via the super-cold line 607 shown in Figure 1, 2 and 3.

As shown in **Figure 11**, heat exchanger 312 is part of the vapour-compression refrigeration process being used to maintain the temperature of the water tank exchanger at minus fifteen (-15) Degree Celsius. The refrigerant is being used as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. The circulating refrigerant enters the compressor 328 in a thermodynamic state known as saturated vapour at low pressure. It is then compressed to a higher pressure, resulting in a higher temperature as well when it exits compressor 328. A pressure safety switch 329 helps to maintain and regulate the pressure within safety limits as defined by the manufacturer of the system.

As shown in **Figure 11**, the hot compressed vapour that exits compressor 328 is then in a thermodynamically state known as a superheated vapour. The superheated vapour

then enters the condenser 327. Within condenser 327, the superheated vapour is cooled and condensed into a liquid by flowing through a coil or tubes with cool air flowing across the coil or tubes. The condensed liquid refrigerant in the thermodynamic state is known as saturated liquid, whereby it will be routed to refrigerant receiver 326 for storage. At certain intervals as required by the process parameters, the saturated liquid from the refrigerant receiver 326 will then be routed to filter dryer 325 to remove any impurities moisture present inside the saturated liquid, followed by flowing through the solenoid valve 323 for flow control. A sight glass 324 is installed after the filter dryer 325 in order to ensure that the liquid is free from any impurities before flowing through the solenoid valve 323. The saturated liquid is then routed to expansion valve 322 whereby it undergoes an abrupt reduction in pressure. This reduction in pressure will result in adiabatic flash evaporation of a part of the liquid refrigerant. It results in lowering the temperature of the liquid and vapour refrigerant mixture coming out from expansion valve 322.

Figure 11 also highlights a temperature sensor 315 to determine if the liquid and vapour refrigerant mixture coming out from expansion valve 322 will by-pass the heat exchanger 312 or to pass through the heat exchanger 312 in order to maintain the temperature of the water in the water tank exchanger 311 to be at minus fifteen (-15) Degree Celsius. At this stage, the liquid-vapour mixture will be converted to mainly vapour and will be routed to the refrigerant accumulator 321. This cycle at heat exchanger 312 will be repeated till steady-state is achieved in which the temperature sensor 315 detects that the set-point has been attained. Within refrigerant accumulator 321, most of the liquid that might be present inside the vapour mixture will be settled down and the mixture that exits out from the refrigerant accumulator 321 will be mainly vapour at low pressure and is routed to compressor 328. The whole refrigeration cycle is then repeated.

POSITIONAL INPUT/OUTPUT SEQUENCES for VALVE SOLENOID

Figure 12 illustrates a close-up view of the various positional input/output sequences for valve solenoid 133 and 211. At the same time, **Figure 12** also summarises the various process stages in which heating and vacuuming are activated independently using the same line to blow and heat the tool or vacuum the pre-selected skin surfaces. The solution to establish a series connection of both valve solenoid 133 and 211 removes a possible unacceptable situation in which both vacuum and heating will be activated at the same time.

Figure 12(a) shows the positional input/output sequence for valve solenoid 133 and 211 when both of the heating and vacuum processes are at the OFF position. This happens from the time after the plastic part has been injected to the period before ejection of the finished part. At this valve position, the heating line 604 is linked to the valve solenoid 133, which in turn is then connected to the valve solenoid output 231. Since there is no heating involved, the hot air input 131 in valve solenoid 133 is disconnected. The valve solenoid output 231 is directly connected to one end of the air exchanger 220 via route 902, with the other end of the air exchanger 220 connected to valve solenoid 211 via route 903. Since at this position the vacuum is at OFF position, at valve solenoid 211, the vacuum input 219 is disconnected with route 903 and hence there is no vacuum link to valve solenoid output 212. It is then clear that in this situation, both input 131 and valve solenoid output 212 are ready to operate but in an OFF position. The speed of the heating or vacuuming will depend only on the length of the heating line 604 connected between the external tool controller 1 and tool 6. It will then be advisable to use an optimum length of the heating line 604 in order to get the best feedback.

Figure 12(b) shows the positional input/output sequence for valve solenoid 133 and 211 when the heating of the mold is at the ON position with the vacuum being at the OFF position, and this happens from the time when the finished part is being ejected to the time whereby it is the end of the high clamping of the mold. This new valve position clearly shows us no difference with Figure 12(a) concerning the air exchanger 220 and the valve solenoid 211 where the status of the vacuuming is OFF. The difference will be concerning the hot air input 131 which is now directly connected to the heating line 604, resulting in heating up the pre-selected skin surfaces.

Figure 12(c) shows the positional input/output sequence for valve solenoid 133 and 211 when the heating of the mold is at the OFF position with the vacuum being at the ON position, and this happens after the high clamping of the mold to the end of filling of the plastic part into the mold cavity. This new valve position shows us the previous situation of the valve solenoid 133 described in Figure 12(a) where the hot heating action is OFF. The difference come from the final position of the valve solenoid 211 where this time the vacuum action is engaged, resulting in vacuuming the pre-selected skin surfaces.

As mentioned earlier, the description of the present invention as per the above-mentioned paragraphs was described using the operation of either standard cavity mold or multiple cavities mold moving in a sequential motion as well as injection-compression molding.

It is to be understood that the foregoing description of the preferred embodiment is intended to be purely illustrative of the principles of the invention, rather than exhaustive thereof, and that changes and variations will be apparent to those skilled in the art, and that the present invention is not intended to be limited other than as expressly set forth in the following claims.

CLAIMS

What is claimed is:

1. A method for the injection molding of parts made of thermoplastic using combined rapid mold heating, vacuuming and cooling techniques, comprising of

- a conventional injection molding device and a tool dedicated thereto, whereby the said tool contains at least one (1) single parting layer with at least single or multiple cavities that correspond to the dimensions of the plastic parts to be molded,

where for one (1) single parting layer tool, the tool comprises of at least two (2) mold blocks which are moveable in relation to each other, and

said mold blocks are being constructed using high thermal conductive metal alloy, and are being maintained in contact with the plastic material to be molded,

which in operation, one of the mold block will advance to press against the other mold block by applying a pre-determined pressure generated along the parting layer that pass through the cavity, followed by

- injecting pressurized hot dehumidified air to rapidly heat up the pre-selected skin surfaces of the core and cavity, followed by

- injecting a pre-determined volume of molten plastic into the mold cavity

and at the same time

- vacuuming the core and cavity in concurrent with the injection of the molten plastic such that the void created will draw the molten plastic to flow better over hard-to-fill areas, which is then followed by
 - cooling of the core and cavity until a releasable temperature,
 - opening of the mold along the parting layer and ejecting of the cooled solidified plastic part out from the core and cavity, and the whole process is then repeated,
 - wherein the parameters for such a process are controlled by a programmable electronic control unit within an external self-contained control system.
2. A method of **claim 1** wherein the external self-contained control system comprises of connection ports which are plugged to
- at least one heating control line via solenoid valve for pre-selected heating of the skin surfaces of the core and cavity, and
 - at least one vacuum control line sharing the same heating control line via solenoid valve for vacuuming of the core and cavity, and

- at least one cooling control line via solenoid valve for cooling of the core and cavity,

whereby the control of the injection molding machine sequence is also connected to the external self-contained control system via a standard or specially customized connector, and

whereby the control of the tool is also connected to the external self-contained control system via a standard or specially customized connector.

3. A method of **claim 1** wherein the external self-contained control system comprises of a block of connection which is connected to an interface including thermocouple control and analogue control, wherein the connection block here includes at least the hot air control, the vacuum control and the cooling control.
4. A method of **claim 1** wherein all the control system and the equipments as described in the present invention needed to perform the rapid hot, cold and vacuum process, are contained in a single mobile chassis for ease of transportation and connection to an injection molding machine.
5. A method of **claim 1** for heating which comprises of injecting pressurised hot dehumidified air at pre-selected skin surfaces of the core and cavity, wherein the flow of pressurised hot dehumidified air can be applied at pre-selected areas of the skin surface of the core and cavity via means of a diffuser.

6. A method of **claim 1** wherein the channel for injecting pressurized hot dehumidified air is the same channel for vacuum action to take place in an injection molding process.
7. A method of **claim 1** wherein said heating is followed by application of vacuum done concurrently with the injection of the molten plastic resin within the core and cavity.
8. A method of **claim 1** of vacuuming wherein the vacuum is applied at a fixed or variable pressure with a variable timing where the vacuuming will be maintained longer and more powerful for the area near to the end of filling where it is hard to fill, and wherein the vacuum action can be controlled at pre-defined areas of the skin surface of the core and cavity via means of a diffuser.
9. A method of **claim 1** wherein said cooling is carried out after/and/or during the application of vacuum on pre-selected skin surfaces of the core and cavity.
10. A method of **claim 1** of cooling which comprises of passing pressurised super-cold water and normal cooling water through their respective cooling lines located in the mold wherein the cooling action can be controlled at pre-defined areas of the skin surfaces of the core and cavity.
11. A method of **claim 10** wherein the temperature of the super-cold water is lower than 0 Degree Celsius via heat transfer using the same tank in which air

exchange takes place concurrently for the hot air that has already been used for heating the core and cavity.

12. A method for the injection molding of parts made of thermoplastic using combined rapid mold heating, vacuuming and cooling techniques, comprising of

- a conventional injection molding device and a tool dedicated thereto, whereby the said tool contains at least two (2) parting layers moving in a sequential manner with at least single or multiple cavities that correspond to the dimensions of the plastic parts to be molded,

where for two (2) parting layer sequential mold, the tool will comprise of at least three (3) mold blocks consisting of the fixed, moving and floating sides which are moveable relative to each other, and

said mold blocks are being constructed using highly thermal conductive metal alloy, and are being maintained in contact with the plastic material to be molded,

which during operation are pressed together against each other along two (2) separating parting layers that pass through the two (2) cavities by applying a pre-determined pressure generated along the parting line that pass through the cavity, followed by

- injecting pressurized hot dehumidified air to rapidly heat up the pre-selected skin surfaces of core and cavity, followed by

- injecting a pre-determined volume of molten plastic into the core and cavity,

and at the same time

- vacuuming the core and cavity in concurrent with the injection of the molten plastic such that the vacuum action will draw the molten plastic to flow better over hard-to-reach areas, which is then followed by
- cooling of the core and cavity until a releasable temperature,
- opening of the mold along the parting layer and ejecting of the cooled solidified plastic part out from the core and cavity, and the whole process is then repeated,
- wherein the opening and closing of the mold along at least one of the parting layer is done alternately at any one time, and
- wherein the parameters for such a process are controlled by a programmable electronic control unit within an external self-contained control system.

13. A method of **claim 12** wherein the external self-contained control system comprises of connection ports which are plugged to

- at least one heating control line via solenoid valve for pre-selected heating of the skin surfaces of the core and cavity, and
- at least one vacuum control line sharing the same heating control line via solenoid valve for pre-selected vacuuming of the skin surfaces of the core and cavity, and
- at least one cooling control line via solenoid valve for cooling of the core and cavity,

whereby the control of the injection molding machine sequence is also connected to the external self-contained control system via a standard or specially customized connector, and

whereby the control of the tool is also connected to the external self-contained control system via a standard or specially customized connector.

14. A method of **claim 12** wherein the external self-contained control system comprises of a block of connection which is connected to an interface including thermocouple control and analogue control, wherein the connection block here includes at least the hot air control, the vacuum control, the cooling control and the high pressure control necessary for sequential technology.
15. A method of **claim 12** wherein all the control system and the equipments as described in the present invention needed to perform the rapid hot, cold and

vacuum process, are contained in a single mobile chassis for ease of transportation and connection to convert a conventional injection molding machine into a sequential injection molding machine.

16. A method of **claim 12** for heating at any one time on either one of the two (2) parting layers of the mold, which comprises of injecting pressurised hot dehumidified air at pre-selected skin surfaces of the core and cavity, wherein the flow of pressurised hot dehumidified air can be controlled at pre-selected areas of the skin surface of the core and cavity via means of a diffuser.
17. A method of **claim 12** wherein the channel for injecting pressurized hot dehumidified air is the same channel for vacuum action to take place.
18. A method of **claim 12** wherein said heating is followed by application of vacuum done concurrently with the injection of the molten plastic resin within the core and cavity.
19. A method of **claim 12** of vacuuming at any one time on either one of the two (2) parting layers of the mold wherein the vacuum is applied at a fixed or variable pressure with a variable timing where the vacuuming will be maintained longer and more powerful for the area near to the end of filling where it is hard to fill, and wherein the vacuum action can be controlled at pre-defined areas of the skin surface of the core and cavity via means of a diffuser.

20. A method of **claim 12** wherein said cooling is carried out after/and/or during the application of vacuum on pre-selected skin surfaces of the core and cavity.
21. A method of **claim 12** of cooling at any one time on either one of the two (2) parting layers of the mold, which comprises of passing pressurised super-cold water and normal cooling water through their respective cooling lines located in the mold wherein the cooling action can be controlled at pre-defined areas of the skin surfaces of the core and cavity.
22. A method of **claim 12** wherein the temperature of the super-cold water is lower than 0 Degree Celsius via heat transfer using the same tank in which air exchange takes place concurrently for the hot air that has already been used for heating the core and cavity.
23. A method for the injection-compression molding of parts made of thermoplastic using combined rapid mold heating, vacuuming and cooling techniques, comprising of
- a conventional injection molding device (without injection-compression option) and a tool (with injection-compression technology) that comprises of a fixed side together with a moving side and one or more moveable cores,
- where the fixed side together with the moving side forms an internal cavity, and

said tool are being constructed using highly thermal conductive metal alloy, and is being maintained in contact with the plastic material to be molded,

which during operation the high clamping is applied on the tool, followed by

- injecting pressurized hot dehumidified air to rapidly heat up the pre-selected skin surfaces of the core, the moving core and cavity, followed by
- injecting a pre-determined volume of molten plastic into the core, the moving core and cavity, followed by
- advancing a moveable core into the internal cavity such that the volume of the internal cavity is reduced, thereby compressing the molten plastic,

and at the same time

- vacuuming the internal cavity in concurrent with the injection of the molten plastic such that the vacuum action will draw the molten plastic to flow better over hard-to-fill areas, which is then followed by
- cooling of the core, the moving core and cavity until a releasable temperature,

- opening of the mold along the parting layer and ejecting of the cooled solidified plastic part out from the core, the moving core and cavity, and the whole process is then repeated,
- wherein the parameters for such a process are controlled by a programmable electronic control unit within an external self-contained control system.

24. A method of **claim 23** wherein the external self-contained control system comprises of connection ports which are plugged to

- at least one heating control line via solenoid valve for pre-selected heating of the skin surfaces of the core, the moving core and cavity, and
- at least one vacuum control line sharing the same heating control line via solenoid valve for pre-selected vacuuming of the skin surfaces of the core, the moving core and cavity, and
- at least one cooling control line via solenoid valve for pre-selected cooling of the skin surfaces of the core, the moving core and cavity,

whereby the control of the injection molding machine sequence is also connected to the external self-contained control system via a standard or specially customized connector, and

whereby the control of the tool is also connected to the external self-contained control system via a standard or specially customized connector.

25. A method of **claim 23** wherein the external self-contained control system comprises of a block of connection which is connected to an interface including thermocouple control and analogue control, wherein the connection block here includes at least the hot air control, the vacuum control, the cooling control and the injection-compression control necessary for injection-compression molding.
26. A method of **claim 23** wherein all the control system and the equipments as described in the present invention needed to perform the rapid hot, cold and vacuum process, are contained in a single mobile chassis for ease of transportation and connection to convert a conventional injection molding machine to injection-compression molding.
27. A method of **claim 23** for heating prior to the injection of the molten plastic inside the internal cavity of the mold, which comprises of injecting pressurised hot dehumidified air at pre-selected skin surfaces of the core and cavity, wherein the flow of pressurised hot dehumidified air can be controlled at pre-selected areas of the skin surface of the core, the moving core and cavity via means of a diffuser.
28. A method of **claim 23** wherein the channel for injecting pressurized hot dehumidified air is the same channel for vacuum action to take place.

29. A method of **claim 23** wherein said heating is followed by application of vacuum done concurrently with the injection of the molten plastic resin within the internal core, the moving core and cavity.
30. A method of **claim 23** of vacuuming during the injection of the molten plastic inside the internal core and cavity of the mold wherein the vacuum is applied at a fixed or variable pressure with a variable timing where the vacuuming will be maintained longer and more powerful for the area near to the end of filling where it is hard to fill, and wherein the vacuum action can be controlled at pre-defined areas of the skin surface of the core, the moving core and cavity.
31. A method of **claim 23** wherein said cooling is carried out after/and/or during the application of vacuum on pre-selected skin surfaces of the internal core, the moving core and cavity.
32. A method of **claim 23** of cooling which comprises of passing pressurised super-cold water and normal cooling water through their respective cooling inserts located in the mold wherein the cooling action can be controlled at pre-defined areas of the skin surfaces of the internal core, the moving core and cavity.
33. A method of **claim 23** wherein the temperature of the super-cold water is lower than 0 Degree Celsius via heat transfer using the same tank in which air exchange takes place concurrently for the hot air that has already been used for heating the internal core, the moving core and cavity.

Injection Molding utilising Rapid Hot Cold Vacuum

(for standard, sequential & injection-compression molding)

ABSTRACT

This invention relates to a method for molding of thermoplastic materials in particular so as to improve on the part quality by eliminating defects such as weld-lines, etc. It comprises of a standard conventional injection molding machine, a tool (or mold) and a separate external self-contained control system which may be readily attached to and readily removed from the molding machine, the tool (or mold) as well as any other auxiliary equipment needed for the injection molding process. The tool or mold could be either standard cavity mold or multiple cavities mold moving in a sequential motion or injection-compression molding. The method involves rapidly heating a mold cavity to a predetermined temperature using hot dehumidified air, followed by application of vacuum over the mold cavity so that the molding material is held rapidly towards the mold before application of super-cold water for the rapid cooling of the molded article.

Use Figure 5

THE END