



How to cite this article:

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Title of article: „Diagnostowanie i czyszczenie kanałów chłodzących form wtryskowych” (“Diagnosing and cleaning of injection mould cooling channels”)

Mechanik, Vol. 91, No. 4 (2018): pages 280–283

DOI: <https://doi.org/10.17814/mechanik.2018.4.45>

Diagnosing and cleaning of injection mould cooling channels

Diagnostowanie i czyszczenie kanałów chłodzących form wtryskowych

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Technology for making plastic elements often requires cooling of the process. In the case of injection moulds, the process is cooled down by coolant passing through mould channels, which cool the mould form. Unfortunately, due to factors described in the article, the coolant flow becomes gradually blocked and at times comes to stop, damaging the forms. The article presents an innovative technological tool allowing for assessment of cooling channels pollution, but more importantly – designed for removing sedimentation, and sludge from the cooling channels.

KEYWORDS: mould channel cooling, mould channel pollution, CoolingCare CA-6 – tool for cooling channel testing and cleaning

Injection is one of the most popular methods used in plastics processing. In a simplified way, the process of detail production can be divided into the following phases: mold closing, injection, pressure, cooling, plasticizing, mold opening and ejection.

The longest and at the same time one of the most important phases of the process is the cooling of the injection mold. The solidification and crystallization temperatures of plastics vary, so it is necessary to adjust the cooling temperature of the compact in the mold to the parameters of the given plastic.

The characteristics of the cooling process have a direct impact on the quality of the molding and the efficiency of the entire process [2], as the cooling time can be over 60% of the total cycle time during the production of the compact. Properly designed, efficient cooling shortens the cycle and thus increases the overall productivity of the mold.

The ducts should be arranged in such a way as to ensure an even temperature distribution on the surface of the forming cavity, thus avoiding too large a temperature gradient on the cooled surface. The cooling intensity should decrease in the direction of flow of the material [2].

To ensure proper cooling of mold cavities, the temperature difference at the entrance to the mold and leaving it should not exceed 2 ± 4 °C. This can be achieved by properly designing the geometry of the channel (shape

and size) and distance from the surface of the forming cavity.

Most often, due to technological possibilities, the channels have a circular cross-section. The diameters of the cooling openings are usually from 6 to 20 mm, the holes should be as large as possible – with small diameters the flow of liquid is hindered and thus the cooling of the mold is inferior, and if the diameter of the circular channel is too large, the cooling intensity does not increase, on the other hand, the amount of liquid used for cooling [3] is undesirably increased.

The easiest way to make cooling ducts is to drill straight holes in the mold elements. This traditional, relatively cheap method has the basic disadvantage of limiting the geometrical shape and course of the channels, which translates into the flow of cooling liquid and heat removal from individual mold fragments (the distance of the cooling channel from the forming surface is different in each place of the mold). The disadvantage of this method is also the possibility of violating the integrity of two adjacent channels (leakage), which can disrupt the proper functioning of the cooling system.

The effort to eliminate channel imperfections and increase the efficiency of injection technology has contributed to the development of modern injection mold cooling systems, such as conformal channel systems, contouring cooling or BFMOLD technology [6].

Regardless of the way, the mold channels are made, in the production process, the ability to receive heat by the cooling medium is often lost gradually due to contamination of the channels with corrosion products and stone. The decrease in cooling efficiency translates into the time needed to efficiently collect heat from the cavity, which in turn has a negative effect on the cycle time. The costs of manufacturing plastic components are estimated to a large extent based on the time of manufacturing parts. That is why today – when companies are expected to constantly increase efficiency and reduce costs – maintaining high cooling efficiency throughout the life of the mold may prove to be a key factor.

Contamination of cooling channels of forms

Most often used in the processing of plastics for cooling water is used. Its flow together with the increase of temperature intensifies the precipitation of impurities in the form of sludge and sediments, which, settling on the walls of the channels, reduce the flow of the cooling medium and

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thus prevent uniform heat dissipation from the compact. This, in turn, can lead to high stresses causing distortions and cracking of details, as well as other surface defects, such as imperfections, streaks or visible lines of joining. Not without significance is the fact that the difficult heat dissipation translates into an increase in the cycle time, which reduces the efficiency of the injection process.

The main contaminants of cooling channels are corrosion products and scale (fig. 1). The corrosion effect of iron is a rusty, hard precipitate (scale) or black sludge, consisting of iron oxide – magnetite (an oxygen corrosion product). It may be with the addition of red or brown rust (red iron oxide). The sludge not only stops the flow of water, but also causes subsequent damage under its layer by continuously developing pitting corrosion, leading to the perforation of the channel walls, and even to leaks between them. It is only after cleaning to clean metal that this process can be interrupted.

The calcium and magnesium hydrogen carbonates contained in the water are thermally unstable and, during heating, disintegrate to form carbonates and thus stone. The hardness of water and its temperature favors the deposition of stone – the higher they are, the more stone will settle.

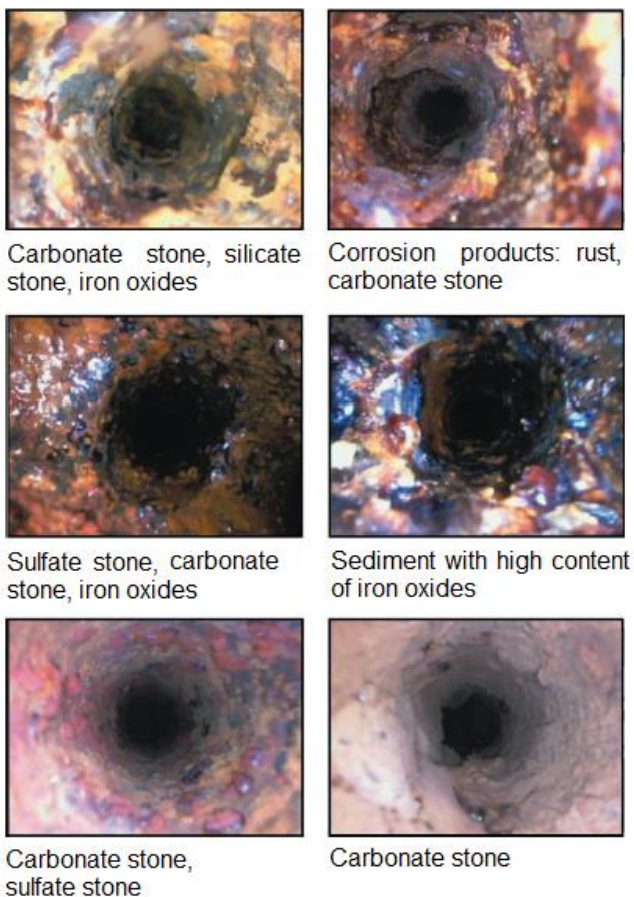


Fig. 1. Examples of contamination of cooling channels of the injection mold

The stone precipitated from the water is a mixture of such substances as: insoluble calcium carbonate CaCO_3 , more easily soluble magnesium carbonate MgCO_3 , magnesium hydroxide, calcium sulfate and dehydrated silicic acid (so-called silica). Depending on the relationship with the most, there are: carbonate stone, sulfate stone and silicate stone [1, 7].

The boiler scale is a thermo-insulator between the cooling medium and the form (1 mm of stone insulates like 10 mm steel) and its accumulation in the mold cooling channels reduces the cooling efficiency of the compact like

the distance of cooling channels a few millimeters from the forming surface [4].

Method for diagnosing channel patency and removing impurities

The degree of channel contamination can be diagnosed by comparing the cooling parameters of the new mold and mold during use. The temperature distribution of the mold is determined by a thermovision camera or by comparing the flow rate through the individual mold channels after the mold production process with the expenditure measured after a specific working time. In case of deterioration of the measurement results, it is recommended to clean the cooling channels.

Common methods for flushing the channels with a chemically active medium are commonly used. This type of cleaning, especially when using aggressive cleaning media based on, among others phosphoric acid and salt, carries the risk of damaging the mold or its components, such as gaskets or cooling divisions. In turn, the efficiency of safe solutions, based on ultrasonic cleaning, is low in the case of cleaning cooling channels due to the difficult access to the internal surfaces of the channels. Hence the need to search for effective and at the same time safe methods for cleaning cooling systems.

As a result of many years of searching, a CoolingCare CA-6 device was created (fig. 2) intended for the diagnosis, cleaning and maintenance of cooling channels, including complicated conformal cooling channels for injection molds [5].



Fig. 2. CoolingCare CA-6 system [5]

Due to a specialized, different for each circulation of the pump, it allows independent, efficient and effective cleaning simultaneously six mold channels with a wide range of diameters – from 2 to 20 mm (which is particularly important in case of conformal cooling) and regardless of their length.

CoolingCare has been equipped with a number of functions to improve the maintenance of high efficiency of injection molds' cooling. Intuitive software along with full automation of the cleaning process contribute to minimizing the time required for the operator to operate the device. The advanced data archiving system allows you to save the flow expenses of individual channels, and then – cleaning until

you reach the reference expenses, defined by the user during the first cleaning.

The patented Dynarince channel cleaning process, characterized by high dynamics of pulsation of the medium inside the duct, allows using less aggressive chemistry, safe for steel and non-ferrous metals, and at the same time results in increased amount of removed impurities. The device's operating mode can be adapted to the degree of channel contamination and flow resistance for optimal results. After cleaning, the device automatically dries the system with compressed air.

The process of cleaning, neutralizing and emptying the installation is automatic – it allows to improve maintenance work. After its completion, the automatic passivation of the channels also takes place – thanks to this the cooling system is additionally protected against corrosion

A unique solution for cleaning stations is the use of a channel patency test in the CoolingCare CA-6 (in the case of obstruction of one of the channels, it is possible to push it through the built-in unblocking module). The patency test function allows you to define the flow reference parameters for a given channel, which are stored in the device database and can be used as a reference point during subsequent or repeated cleaning. Three cleaning programs in conjunction with full archiving of data assigned to a particular form enable tracking of progressive layout changes.

The applications implemented on the device enable: preview of the operation of the device online, review of cleaning results from the archive on mobile devices and sending alerts in the form of SMSs at the end of cleaning or in the case of undesirable events, e.g. lowering the level of liquids in tanks, drop in liquid temperature or the lack of tightness of the form.

All these built-in functions make CoolingCare CA-6 not only a tool for clearing the cooling channels and conducting technical supervision of cooling in injection molds, but also allows to evaluate the flow of channels of newly created forms (the possibility of detecting e.g. irregularities associated with mold assembly) and attach such a report to documents sent to the recipient.

The device has been equipped with an online self-diagnosis application to identify the causes of a possible failure. The monitoring of the membrane pumps mounted in the device in terms of the number of hours worked allows for the timely performance of, for example, membrane replacement.

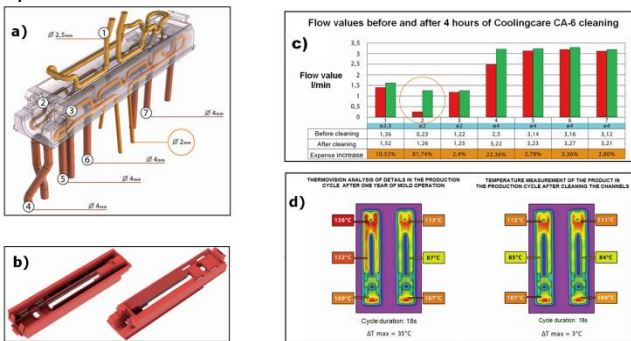


Fig. 3. Analysis of the cleaning efficiency of two-cavity mold channels: a) cooling molds injection mold diagram for the production of tobacco filler element, b) molding, c) flow expenditure diagram through cooling channels before and after cleaning, d) thermovision analysis of cooling efficiency of molded parts before cleaning (left image) and after cleaning (right image)

Results of research on the effectiveness of channel cleaning with CoolingCare CA-6

The effectiveness of cleaning with the CoolingCare CA-6 was confirmed in practice both for classic, drilled channels and for conformal cooling. Fig. 3 shows the effectiveness of

cleaning the cooling channels of a two-slot mold cooled with seven channels of various diameters, used to produce a tobacco filler element.

A decrease in the flow of the cooling medium in one of the circuits caused the temperature of the compact to increase and its deformation. In order to obtain the required dimensional tolerances of the detail, it was necessary to extend the cycle time from 18 to 26 s. After cleaning the cooling channels, both mold cavities were cooled similarly intensively – the maximum temperature difference at socket points was 3 °C [5].

Fig. 4 shows the effectiveness of cleaning a two-socket mold cooled with six channels of the same diameter. The form is intended for the production of roller shutter systems.

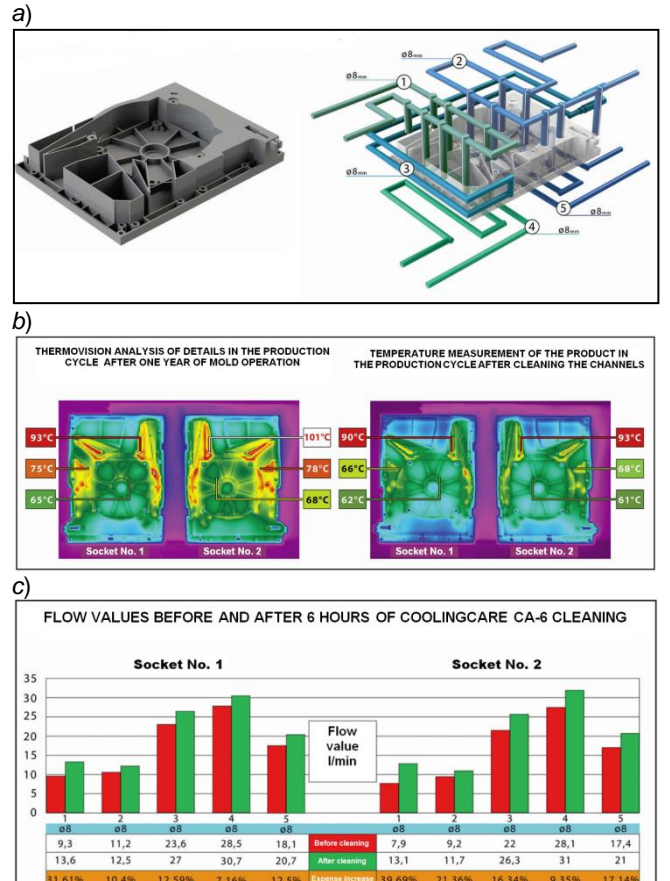


Fig. 4. Results of cleaning the cooling channels (of the same diameter) of the double-jacketed mold: a) molding and cooling molds diagram, b) thermal analysis of the cooling efficiency of the moldings, c) cooling flow diagram of the cooling liquid before cleaning and after six hours of cleaning

The descaling of the cooling channels of this form resulted in a reduction in cooling capacity and an increase in the temperature of the molding, which forced the injection cycle time to increase from 43 to 47 seconds.

After six hours of cleaning the system, the temperature of the moldings at the same measuring points with the same process parameters decreased and the injection cycle time was 43 seconds again.

Conclusions

The costs of manufacturing plastic components are estimated to a large extent based on the time of manufacturing parts. Therefore, nowadays, when companies are expected to constantly increase efficiency and reduce costs, maintaining high cooling efficiency throughout the life of the mold may prove to be a factor reducing the costs associated with servicing the mold or decreasing its efficiency due to the long cooling time.

Solution to the problem is the effective removal of contaminants from the cooling channels of injection molds. The system for diagnosing and cleaning channels using the innovative prototype CoolingCare CA-6 is used for this purpose. Confirmation of its effectiveness may be the fact that in the last few months several dozens of different injection molds, from four to 10 cooling channels, have been diagnosed and cleaned. In one cycle of work, six channels can be cleaned – in the case of a larger number, the remaining channels can be cleaned in the next cycle.

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Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.



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