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INFLUENCE OF SCALE DEPOSITION ON MAINTENANCE OF INJECTION MOLDS

WPŁYW ODKŁADANIA SIĘ KAMIENIA NA EKSPLOATACJĘ FORM WTRYSKOWYCH*

The cooling system of an injection mold serves a substantial role in the process of plastic injection. It is responsible for efficient dissipation of heat from the injection mold, generated by the plasticized material which during the injection phase is introduced into the mold. Apart from rapid heat dissipation, it is important to achieve uniform distribution of temperatures on the surface of the molding cavity. This study focuses on the phenomenon of lime scale deposition in injection mold cooling systems. Lime scale deposition results in reduction of the cooling canal's section diameter, as well as a clear reduction in cooling efficiency due to its lowered thermal conductivity. The study specifies the influence of many factors (geometry of the cooling system and molded piece, coolant temperature, type of plastic material) on the utilization of the injection mold as a result of the occurrence of lime scale in the cooling system. The conducted numerical simulations have allowed to account for the impact of the deposit layer's thickness on the distribution of temperatures on the molding cavity's surface, the average injection mold temperature, as well as the time required to solidify the plastic material products.

Keywords: *injection mold, cooling phase, lime scale, fouling.*

Układ chłodzenia formy wtryskowej odgrywa niebagatelną rolę w procesie wtryskiwania tworzyw sztucznych. Odpowiada on za sprawny odbiór ciepła z formy wtryskowej dostarczonego przez uplastycznione tworzywo, które w fazie wtrysku jest wprowadzone do formy. Oprócz szybkiego odbioru ciepła istotne jest, aby rozkład temperatury na powierzchni gniazda formującego był równomierny. W niniejszej pracy skupiono się na zjawisku osadzania się kamienia w układach chłodzących form wtryskowych. Kamień powoduje zarówno zwężenie przekroju kanału chłodzącego, jak i wyraźny spadek wydajności chłodzenia ze względu na jego niską przewodność cieplną. W pracy określono wpływ wielu czynników (geometria układu chłodzenia oraz wypraski, temperatura cieczy chłodzącej, rodzaj tworzywa) na eksploatację formy wtryskowej w wyniku pojawienia się kamienia w układzie chłodzącym. Przeprowadzone symulacje numeryczne pozwoliły uwzględnić wpływ grubości warstwy osadu na rozkład temperatury na powierzchni gniazda formującego, średnią temperaturę formy wtryskowej, a także czas potrzebny do zestalenia wyrobów produkowanych z tworzyw sztucznych.

Słowa kluczowe: *forma wtryskowa, faza chłodzenia, kamień osadowy, zanieczyszczenia.*

1. Introduction

Injection molding is one of the most popular methods of plastic processing. It involves cyclical plasticizing of the material, injecting it under pressure into a mold, filling out defects associated with its solidification, cooling and removal of the finished product from the mold. The longest part of the injection molding cycle is the cooling phase, whose duration is a result of the insulating properties of plastic materials. An optimally designed cooling system enables efficient heat dissipation from the plastic material [9, 12].

Apart from the cooling system's geometry, the efficiency of heat dissipation is affected by the type of material used to manufacture the injection mold and its elements. The parameter responsible for heat dissipation is heat conductivity of mold material, coolant type and its flow rate. In order to increase the rate of heat dissipation, inserts are used which are made out of copper alloys, e.g. beryl bronze, Ampco 940, Ampco 944, MoldMax XL. These allow to increase the speed of heat dissipation, resulting in the ability to achieve the same mold temperature within up to 29% less time through the use of an appropriate insert material [6].

During utilization of an injection mold water flows through the cooling system, where the precipitation of scale and its deposition on the surface of cooling canals occurs. Lime scale is characterized by very low heat conductivity, comparable or slightly higher compared to the heat conductivity of plastic materials. Scale deposition results in the generation of additional resistance on the heat flow path from the plasticized plastic to the surface of cooling canals, from where it is further removed on the heat flow path [13].

Depending on the chemical composition of water used for cooling, different types of scale with varying thermal properties may be deposited. Regardless of the type, their heat conductivity is 5-600x lower than the conductivity of steel (approx. 30 W/m/K), which is presented in Table 1. This means that a layer of scale deposit with a thickness of 1 mm is equal respectively to 5-600 mm of steel. This illustrates how important it is to ensure high heat conductivity of the injection mold.

There are multiple models which describe the deposition of scale over time. In the case of canals with a circular section, the deposit thickness may reach very high values [7, 10] – which in the case of molds utilized over long periods of time may cause significant issues with cooling efficiency. This is especially important in the case of injection molds which do not have temperature sensors installed, and the only factor measured during the cooling process is the liquid temperature in the thermostat.

No studies have been found regarding the issue of scale layer deposition in the cooling canals of injection molds and the impact of such a layer on the cooling process. On the other hand, it is a notion very

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl***

Table 1. Heat conductivity of different types of scale deposits [1]

Scale Type	Calcium Carbonate Scale	Calcium Sulphate Scale	Calcium Silicate Scale	Organic Sediment	Soot
Thermal Conductivity [W/mK]	0,6 – 6	2,3	0,3	0,1	0,2

widely discussed in process engineering, as it has a key effect on the efficiency of heat removal [3, 5, 11]. An example may be petroleum distillation equipment, where the impact of scale deposits on cooling efficiency has been determined. After a year of system operation without the use of compounds halting the deposition of scale, the efficiency of such equipment was reduced by over 40% [3].

For correct performance of injection mold cooling, the liquid flow rate should be high enough in order for the difference between its temperature at the input and output should be lower than 3ºC [2]. Unfortunately, the measurement method does not provide diagnostic information regarding the utilization of the injection mold, as the scale will cause minor coolant liquid temperature reductions at the output due to a reduction of the cooling efficiency (provided a properly selected volume flow intensity). The lack of a mold temperature monitoring tool (especially in the case of less expensive solutions) may lead to the occurrence of an issue with the manufacture of molded piece with the desired dimension tolerances.

3. Discussion of the Issue

This study involved the performance of a range of numerical analyses with the objective of indicating the impact of clogged injection mold cooling canals on cooling efficiency. For the purpose of comparison, an analysis of heat transmission averaged over time was incorporated, using the Autodesk Moldflow® software. The software enables 2 types of analysis – with a defined cooling time and with its automatic determination. Analysis with a defined cooling time involves specification of a temperature field with the assumption of a given temperature of the injected plastic material and initial mold temperature (40ºC by default). With the above data, the software determines the average temperature distribution, which is substituted in the subsequent equation instead of the default mold temperature. The process is iteratively repeatable for as long, as the difference between subsequent cycles (which are the de facto injection cycles) is below 0,1ºC. In the case of seeking to establish the cooling time, the software commences the search from the initially assumed cooling time (30 s) and conducts an iterative analysis verifying the fraction of the solidified plastic material, its temperature and temperature distribution on the mold's surface. After achieving the assumed convergence (difference of temperatures between cycles below 0,1ºC) the software evaluates, whether the criteria presented above have been fulfilled. If not, the software modifies the cooling time and conducts an iterative analysis in order to arrive at the expected values. After receiving the expected values, the analysis is stopped.

The simulation assumes that the entire molding cavity is filled with plastic material (this simplification arises from the fact that the time of cavity filling by the material compared to the cooling time is relatively short).

In order to acquire the fullest extent of information, analyses were conducted by introducing modifications to the base model. Changes were made to:

- the geometry of the cooling system, the molded piece and mold (diameter of cooling canals, distance between cooling canals, distance from the cooling canals to the molded piece surface, molded piece thickness and shape, injection mold thickness),

Table 2. Compilation of constant parameters

Dimensions of the injection mold base [mm]	156 x 156
Dimensions of the molded piece base in the shape of the base [mm]	100 x 100
Dimensions of the molded piece in the shape of the edge [mm]	51,5 x 51,5 x 100
Molded piece thickness in the shape of the edge [mm]	3
Set Parameters	
Volume based flow intensity [l/min]	3,387 (for a cooling canal diameter of 8mm) 2,54 (for a cooling canal diameter of 6mm)
Mold opening time [s]	1
Analyzed cycle time (without the mold opening time) [s]	20
Cooling time selection criteria	
Exit temperature of the molded piece from the mold [ºC]	103 (Moplen HP500N) 148 (Tarnamid T27 natural)
Percentage of solidified plastic material during removal of the molded piece from the mold	100%
Scale deposit material properties	
Density [g/cm^3]	1,4
Specific heat [J/kgC]	500
Heat conductivity [W/mC]	0,5
Tool steel material properties	
Density [g/cm^3]	7,8
Specific heat [J/kgC]	460
Heat conductivity [W/mC]	29

- the type of plastic material and set parameters (plastic material temperature, coolant liquid temperature, assumed injection mold temperature).

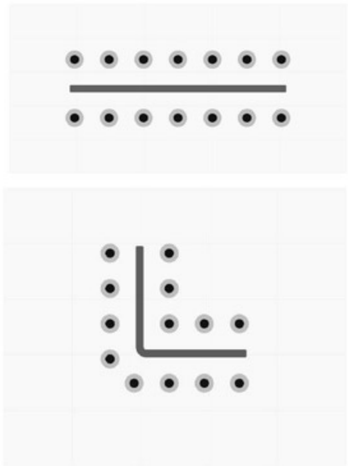

Fig. 1. Geometry of analyzed molded pieces, injection molds and cooling systems with scale deposit layers.

Within the scope of the analyses one modification was performed at a time to make it possible to illustrate the influence of a given factor on the studied aspects. An exception was found in the change of the plastic material type, where the impact of the coolant liquid temperature was investigated. It is assumed that the coolant liquid temperature should be 10–20°C lower than the expected mold temperature. In order to gain a full perspective of the situation, in the case of the second plastic material liquids with a temperature 10 and 20°C lower than the mold temperature were used, as well as with a temperature assumed for the base plastic material. All constant values are presented in Tab. 2, while all variable values are presented in Tab. 3 (base values emphasized with a bold font). Fig. 1 illustrates a view of the geometry which was subject to modification. The molded pieces have been placed in such a way, that they are located in the exact middle of the mold (taking into consideration their dimensions).

The analyses assumed the introduction of a layer of lime scale of varying thickness injection mold cooling channels in order to illustrate the impact of the lime scale layer size on the cooling system's efficiency. The averaged material data of the lime scale deposit have been established on the basis of Tab. 1 and scientific studies [3, 4, 8] and also presented in Tab. 2.

The initial cooling time was determined for the base model, so that the entire molded piece is subject to solidification (rounded up to full seconds). In order to compare the influence of a layer of lime scale, the following results have been compared: the minimum, maximum and average temperature of the molding cavity, average temperature of the injection mold, percentage of the solidified plastic material, as well as the time to which the cooling process should be extended in order to achieve complete solidification of the molded piece and the assumed mold temperature.

The above results are significant to the utilization of the mold as a tool used for manufacturing of a product which meets assumed quality criteria. The average molding cavity temperature impacts the size of distortions associated with plastic material contraction – this is directly associated with the time required to cool the molded piece. The longer the cooling time, the more significant the contraction inside the molded piece, which leads to problems with maintaining the assumed dimensional tolerances. On the other hand, the difference between the minimum and maximum mold temperature results in non-uniform contraction, which further intensifies molded piece deformations. The average mold temperature, on the other hand, has a very significant effect on the utilization of the mold itself and its reliability. As the mold's temperature rises, its dimensions increase due to the material's thermal expansion. This has a very significant effect on its utilization and reliability. On the one hand, the increase of the mold's linear dimensions causes a change in the linear dimensions of the molding cavity, which leads to manufactured products with dimensions different from the ones assumed in case of a properly cooled mold. On the other hand, an increase in tool temperature leads to problems with fitting the individual moving elements of the mold (e.g. slides, ejectors), which may result in decreased longevity of such elements. The percentage of solidified plastic material tells indicates what scale layer thickness can lead to large distortions of the molded piece, which without support in the form of the molding cavity will be able to freely deform during solidification outside the mold. The time to which the cooling process should be extended is a measure of the cooling system's degree of degradation in the event of its utility with a given layer of scale deposit.

3.1. Numerical calculation results

In this study results were analyzed in 3 areas divided by the type of modification to the base model (change to the cooling system's geometry, molded piece and mold, as well as change of the plastic material and set parameters).

The first analyzed aspect was the average temperature on the surface of the molding cavity. Within the studied scope for each modification implemented to the base model it is possible to approximately assume ($R>0{,}95$) a linear correlation between the scale deposit thickness and the increase of the mold's average temperature (Fig. 2). In the case of no scale deposit, depending on changes to the geometry, it ranged from 38 to 42°C. The differences became clearer only with a scale deposit thickness equal to 1 mm, to then reach larger variations with a scale deposit thickness of 2 mm. The smallest change to the average cavity surface temperature was observed for the removal of cooling canals away from the molded piece surface and thickening of the injection mold. A significant rise of the average cavity temperature

Table 3. Compilation of variable parameters

Diameter of the cooling canal c [mm]	Distance between cooling canals c_s [mm]	Distance from the cooling canal to the molded piece surface c_d[mm]	Molded piece thickness g_t [mm]
6, **8**	**16**,24	**12**, 18	**3**, 5
Molded piece geometry g	Injection mold height m_h [mm]	Plastic material type p	Plastic material injection temperature p_t [°C]
base, edge	**88 (126 in the case of the edge)**, 126	Moplen HP500N,	**235**, 250
		Tarnamid T27 natural	270
Coolant temperature m_{ct} [°C]		Assumed cavity surface temperature m_t [°C]	
15, **25**		**35**, 50	
25, 60,70		80	

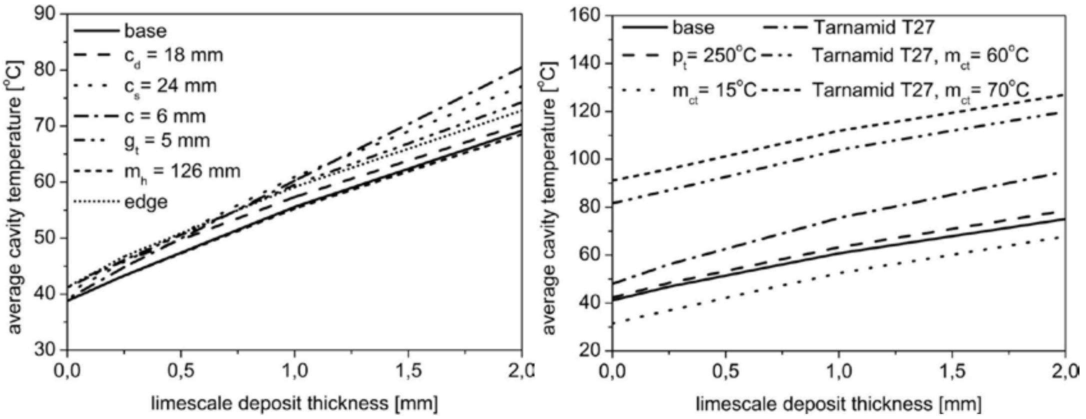

Fig. 2. Graph of the average temperature on the molding cavity surface

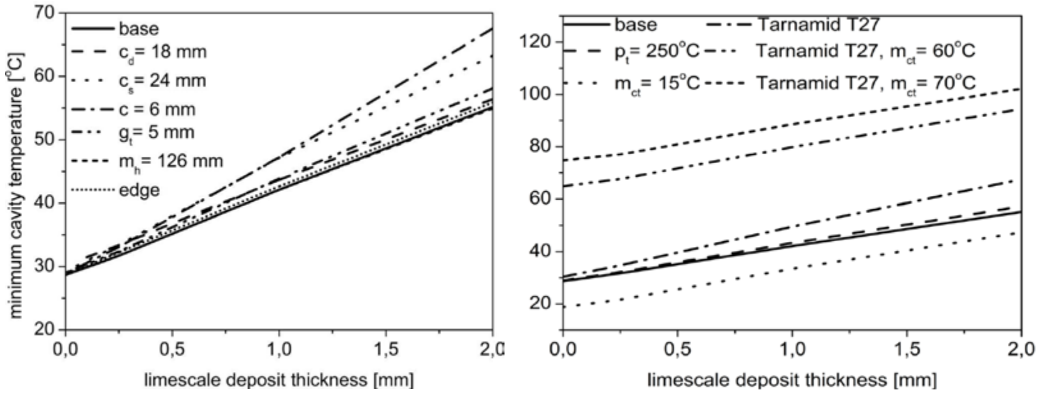

Fig. 3. Graph of the minimum temperature on the molding cavity surface

was observed in the case of modifying the molded piece geometry from a base to an edge, which resulted from the fact of hindered heat dissipation from the edge area. An even greater rise was observed in the case of molded piece thickening (the increase arises from a greater degree of heat needed to be dissipated during the cycle). The greatest changes were observed in the case of increasing the distance between canals (approx. 10°C) and reduction of the canal's diameter (approx. 15°C). In both cases the number of heat dissipation sources was reduced measurably (smaller area of the cooling canal in the case of diameter reduction and smaller number of cooling canals in the case of larger distances between canals). Were the number of cooling canals maintained, the average temperature increase on the cavity's surface would be less than 5°C.

In case of modifications to the set parameters and the plastic material it was possible to observe more significant differences in the average mold temperature. Increasing the temperature of the plastic material had the smallest impact. Lowering the coolant liquid temperature for Moplen by 10°C resulted in a balanced reduction of the molding cavity minimum temperature. Changing the plastic material to Tarnamid did not cause any significant change to the minimum cavity temperature in the case of no scale deposit, however with a deposit thickness of 2 mm, the difference was approx. 15°C (maintaining the same coolant liquid temperature). In the case of incorporating a coolant liquid temperature 10-20°C lower than the assumed cavity temperature, a very distinct rise of the minimum cavity temperature was observed, however the change was proportionate to the change of the coolant liquid temperature.

Another analyzed criterion was the minimum temperature on the surface of the molding cavity. In the case of modifying the geometry for the zero scale deposit thickness, the average temperature was equal to approx. 26-30°C. After increasing the thickness to 0,25 mm the average temperature was raised by approx. 5-7°C to 32-37°C (on a case by case basis). Larger discrepancies occurred with further increases of scale deposit thickness. For a 1 mm layer a significantly larger increase was observed in the average temperature of the cooling canal with a smaller diameter and a cooling system with larger distances between canals. This difference would further increase when raising the scale layer thickness to 2 mm. Reducing the heat dissipation area resulted in an increase of the average mold temperature by respectively 10°C (change of the distance between canals) and 20°C (change of the canal diameter). Maintaining the base number of cooling canals would result in the abovementioned temperature rise to be non-existent. In the case of other geometry changes the scale deposit thickness increase results in approximate linear temperature changes with the same straight line slope ratio value.

Changing the plastic material or set parameters resulted only in the upward shift of temperature values, while maintaining the separations between individual graphs, such as in the case of the average molding cavity surface temperature.

In the case of the maximum molding cavity surface temperature a significant deviation was observed for the molded piece geometry change to the edge (even in the case of no scale deposit). This arises from the fact that within the boundaries of the edge heat dissipation is significantly hindered. For that reason the highest maximum temperature is observed for the edge within the full scope of scale deposit thickness. Similarly to the two prior parameters, increasing the mold thickness and distance of cooling canals from the mold surface does not result in changes in relation to the base model. Increasing the molded piece thickness, increasing the distance between cooling canals and reducing the cooling canal diameter also provides the same result as in the case of remaining parameters. Non-removal of cooling canals in the case of spreading them out results in a decrease of the maximum temperature by 6°C in relation to the value presented on the graph for the scale deposit layer thickness.

In order to compare the changes in temperature distribution, Fig. 5 was prepared which marks the minimum and maximum temperature range for a given model. In the analyzed case it can clearly be seen that the application of a smaller cooling canal diameter and a larger distance between canals leads to an increase in difference between the minimum and maximum temperature on the molding cavity surface. Increasing the mold's thickness resulted in a slight reduction of the temperature difference, while increasing the molded piece thickness and raising the temperature of the injected plastic material resulted in a slight increase in the degree of difference. Changing the geometry to a more complex one (edge) resulted in a significant increase in differences between the minimum and maximum temperature, similarly to changing the plastic material type without changing the coolant liquid

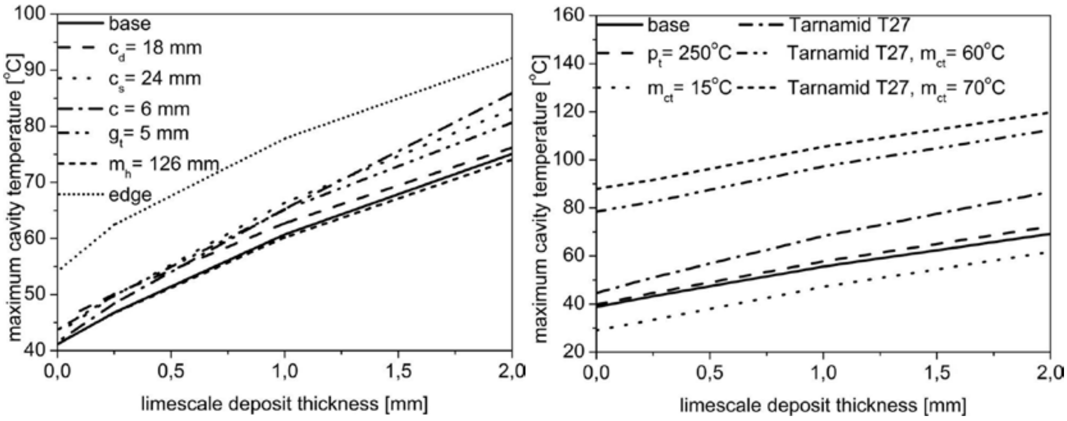

Fig. 4. Graph of the maximum temperature on the molding cavity surface

temperature. This shows that the use of an excessively cold coolant liquid results in large temperature differences between individual locations in the injection mold, which will further result in additional deformations associated with non-uniform contraction. Changing the coolant liquid temperature resulted only in a shift of the minimum and maximum temperature ranges.

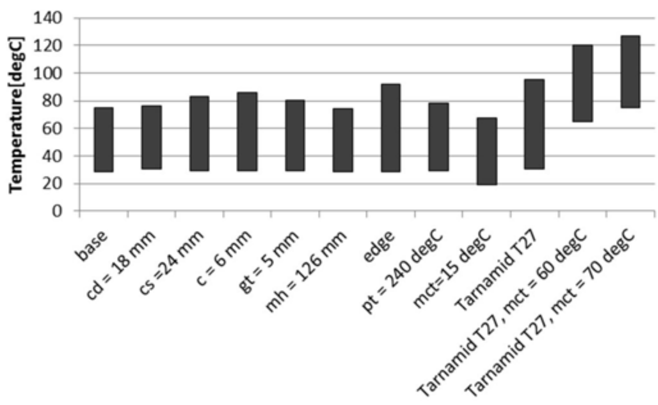

Fig. 5. Graph of the minimum and maximum temperature on the molding cavity surface for a scale deposit layer of 2 mm

Another important parameter is also the average mold temperature. Its value versus the scale deposit thickness is presented in Fig. 6. Similar changes (as in the case of previously analyzed parameters) were observed for increasing the distance between cooling canals and the surface and increasing the mold's thickness. The result for an increased mold volume provides very significant information – regardless of the mold's size, its average temperature remains constant versus the scale deposit thickness. This has a significant impact on the utility of the injection mold, in which an increase of individual linear dimensions occurs due to the rise in temperature.

For other changes in the mold's geometry changes were observed only in the case of narrowing the canal and increasing the distance between canals – in terms of the average mold temperature the highest value was reached in the case of spreading out the cooling canals (and not reducing the cooling canal diameter). In the case of non-removal of cooling canals located further away from the mold's surface the temperature would have been 5°C lower.

In case of changing the set parameters the largest temperature changes were observed when using Tarnamid T27 and maintaining the original coolant liquid temperature (a slightly smaller change was observed in the case of spreading out the cooling canals) and was equal to approx. 27°C. Assuming a linear expandability ratio for P20 tool steel (40CrMnMo9) equal to 0,000012, an increase of the mold's linear dimension was determined for the largest temperature rise. The linear dimension change was equal to approx. 0,04 mm for the 156 mm side o the mold. Knowing that standard injection molds are significantly larger, it was concluded that raising the mold temperature by merely 20°C may result in significant changes to the injection mold cavity size, which would in turn have a significant impact on the dimensional accuracy of manufactured plastic elements. Further, the mold temperature increase has an impact on the injection mold's operational reliability, as issues may occur with the fitting of the injection mold's moving elements, resulting in their excessive wear.

The deposition of scale in cooling systems affects not only temperature distribution of the injection mold, but also the solidification of the plastic material during the cooling phase. In the event of geometry changes for all cases with the exception of molded piece thickness increases, it was concluded that a scale deposit layer of 0,25 mm does not extend the time needed to solidify the molded piece (in all cases the scale deposit did not cause a reduction of the solidified plastic fraction below 100%). A significant reduction was observed for a scale deposit layer of 1 mm. Depending on the system, from 70 to 80% of the molded piece was subject to solidification. Similarly to the previous parameters, minor differences were observed when increasing the mold thickness and increasing the distance of cooling canals to the mold surface. For a scale layer thickness of 2 mm the lowest percentage of solidified plastic material was observed for smaller canals (slightly greater in case of spreading out the cooling canals). In this case non-removal of excess cooling canals would cause an increase of solidified plastic to 55% (despite the fact that these canals are significantly far removed from the molded piece surface).

In the case of set parameters, it was possible to observe significantly larger differences in the amount of solidified plastic. Increasing the plastic

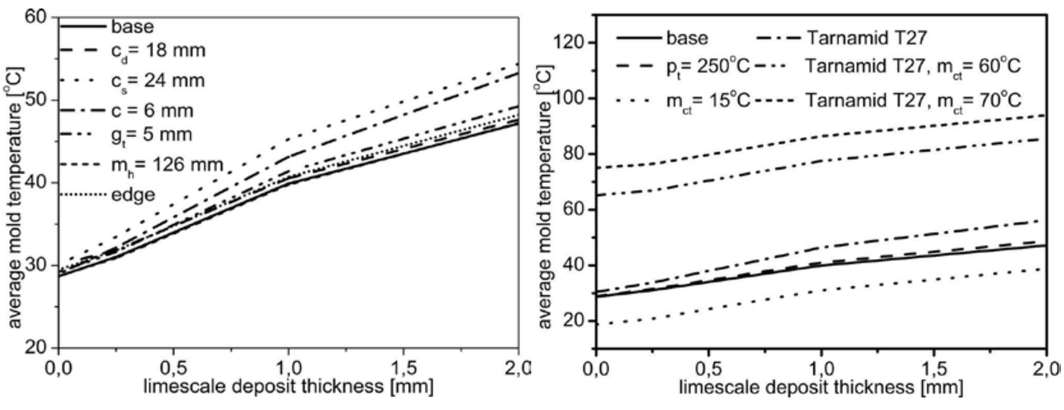

Fig. 6. Graph of the average injection mold temperature

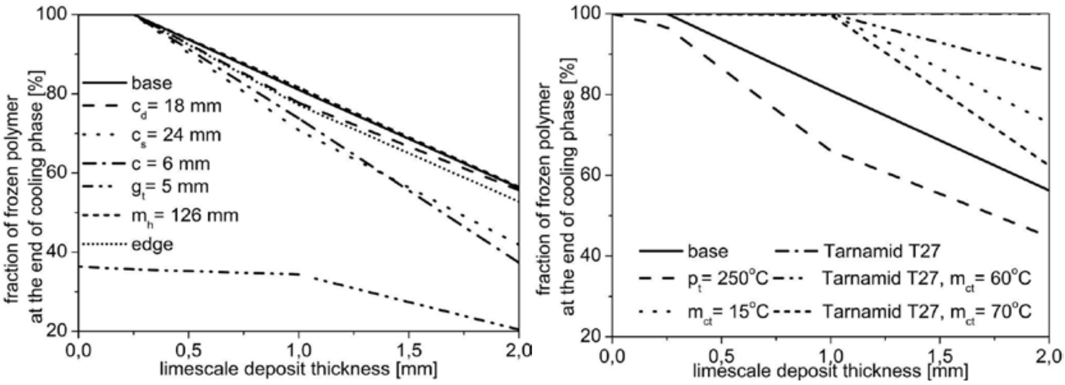

Fig. 7. Graph of the frozen plastic fraction at the end of the cooling phase

material temperature to 250°C resulted in that for even a thin layer of scale equal to 0,25 mm the molded piece is not subject to complete solidification before removal from the mold. The use of a lower coolant liquid temperature resulted in complete solidification of the entire molded piece prior to removal from the injection mold even with a 1 mm layer of scale. In the case of changing the plastic material to Tarnamid, regardless of the scale deposit layer, it was possible to solidify the molded piece within the assumed cooling time (without increasing the coolant liquid temperature). In the case of raising the coolant liquid temperature to 60°C complete solidification of the molded piece was observed with a scale deposit thickness of 1 mm (for a coolant liquid temperature of 70°C 99,71% of the molded piece was solidified).

The final analyzed aspect was the theoretical cooling time needed to solidify the entire molded piece and cool down the mold to the assumed temperature. In the case of geometry changes it was observed that in certain instances the increase in scale deposit thickness over 1 mm does not significantly extend the cooling time. This result occurred in the case of a change in the injection mold thickness, distance from the cooling canals to the molded piece surface and changes to the molded piece geometry. In other cases further scale deposit thickness increases caused significant cooling time extensions.

It should be taken into consideration that such a long cooling time was not a result of issues with plastic material solidification, but with issues connected with cooling the mold to the assumed temperature. The longest time required for molded piece solidification did not exceed 30 seconds, however it assumed appropriate cooling of the injection mold.

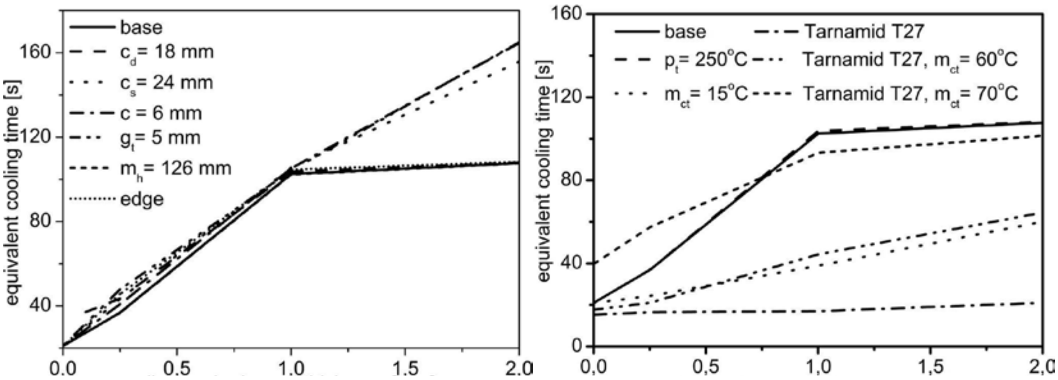

Fig. 8. Graph of the equivalent cooling time, in which the entire plastic material becomes solidified and the mold achieves the assumed cavity temperature.

Changing the plastic material temperature to 250°C gave results similar to the base model. Reducing the temperature of the coolant liquid to 15°C allowed to cool the injection mold down to the assumed temperature much faster (a nearly 50% cooling time reduction). When using Tarnamid, setting the coolant liquid temperature to 70°C resulted in a correlation between the cooling time and lime scale deposit layer thickness more similar to the correlation for Moplen at 25°C. The use of liquid with a temperature 10°C lower resulted in a correlation similar to using Moplen with a temperature of 15°C. This means that it is not the coolant liquid temperature, but relative difference between the assumed mold temperature and liquid temperature which has a significant impact on the required cooling time. The use of a cooling liquid of 25°C for Tarnamid resulted in the cooling time of slightly over 13 seconds (with approx. 19,5 s for Moplen), which is connected with the solidification temperature of Tarnamid. Even with a 2 mm layer of lime scale, the require cooling time was slightly over 20 s (while the molded piece solidification time was approx. 19,2 s).

4. Conclusion

The conducted analyses have shown a significant impact of lime scale deposited in the cooling system on the injection mold's utilization. Due to its low conductivity, the deposited scale causes issues with proper heat dissipation from the injection mold.

In the case of a thicker layer of lime scale (1 mm), its very significant impact on all studied aspects was observed. From the perspective of utility and reliability of the injection mold, the most important factor is the temperature of the mold, which is subject to expansion as a result of temperature increases. This may lead to issues with the fitting of moving elements, leading to reduction of the mold's longevity as a tool. On the other hand, the distribution of temperatures on the cavity surface and cooling efficiency had a very significant impact on the reliability of the injection mold as a tool, which is intended to mold the product within a specified time and with specified parameters. A non-uniform temperature distribution on the mold's surface may lead to increased molded piece deformations and resulting problems with maintaining tolerances. An inefficient cooling system extends the process duration and results in the molded piece not solidifying correctly after removal from the mold, which also causes further deformations. Changes to the mold's dimensions as a result of increasing its average temperature will impact individual dimensions, which ma cause failure to maintain the previously assumed tolerances.

Calculations have shown that the plastic material temperature, distance of the canals to the mold surface, as well as size of the mold have a minor impact on the course of the cooling process. This means that the use of an excessively large injection mold will result in additional issues with dimensional tolerance. A larger impact was recorded for the molded piece thickness due to the fact of a larger amount of heat needing to be dissipated from the plastic material, which has insulating properties. A very large impact, on the other hand, was shown for the diameter of cooling canals, especially in conditions of hindered heat dissipation, similarly as for the number of cooling canals. In the conducted analysis spreading out the cooling canals resulted in some of them being located in a large distance from the molded piece, therefore, in term of industrial practice, they would not be drilled. Their absence together with the increase of the lime scale deposit thickness, caused a much larger increase in the average injection mold temperature, in comparison to instances in which such cooling canals had been drilled. This shows that the introduction of additional cooling canals in areas which would normally not take part in heat dissipation, in the case of the appearance of lime scale may reduce its negative impact on the injection mold's utilization.

The analysis takes into consideration two types of plastic materials in order to compare their influence in connection with different coolant liquid temperatures. For a material requiring a high mold temperature there is a theoretical possibility of applying a much colder cooling liquid compared to the assumed mold temperature, which results in significant reduction of the cooling time, reduction of the average mold temperature, but would introduce non-uniformity in temperature distribution in the molding cavity, which in the case of more complex molded pieces would result in deformations. In the case of a plastic material requiring lower mold temperatures, reduction of the coolant liquid temperature is problematic due to the increased cost of the cooling process of the medium itself.

It is necessary to be aware that analyses have been conducted for a very simple molded piece geometry, which is a base and edge. Currently elements manufactured using the injection mold method are very complex, often featuring thick walls (especially in the automotive industry), due to which in an actual situation of average mold temperature increases may reach even several dozen degrees. In certain circumstances a complex system of ejectors makes it impossible to use an efficient cooling system, due to the fact that cooling canals would intersect with the ejector locations. This means that the magnitude of linear dimension changes may reach up to 0,5 mm, which would have a significant negative impact on the utility of the injection mold, which is characterized by very narrow dimensional tolerances.

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