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# THE THICHNESS OF INTERPENETRATION LAYER AT THE INJECTION MOLDING BI-COMPONENTS PARTS

**Sorin ILIE; Horia UNGUR; Ioan MIHĂILĂ**
S.C. Plastor S.A; S.C. Plastor S.A.; University of Oradea

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**Abstract:** The purpose of this paper-work is to present a theoretical method to calculate the thickness of interpenetration layer at the contact surface between two thermoplastics polyurethanes. Thirst polyurethanes it is a soft plastic material and the second is very rigid or hard polyurethane. The adhesion between these two materials it is very important for the bi-components injection molding parts and she is dependent by the thickness of interpenetration layer at the contact surface between two thermoplastics polyurethanes. These parts obtained with bi-components molding injection technologies are very complex because they combine multi characteristic of the different plastics material like thermoplastics polyurethanes.

## 1. INTRODUCTION

When the melt of the second thermoplastic material arrive in contact with the surface of the first injected material, the molecular chains of the both material interdiffuse. The diffusion process determinate increasing the thickness of interpenetration layer at the contact surface between the two injected components.

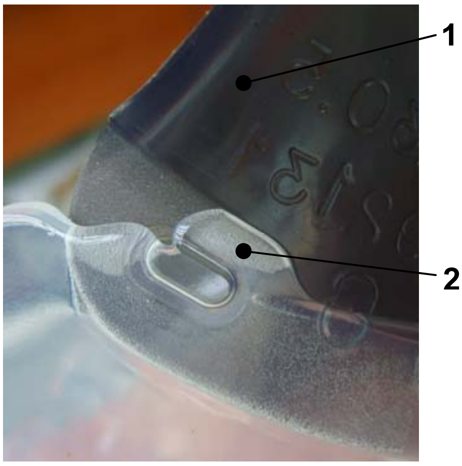


**Fig.1. Example of formation of an interpenetration layer between the two components of an injection bi-components plastic part**
**1-**first component it is a soft polyurethane
**2-**second component it is a hard and transparent polyurethane

The adhesion or the bonding between the two components of a molding bi-material part is proportional with the thickness of interpenetration layer at the contact surface. When the thickness of interpenetration layer at the contact surface increases the adhesion between the two components of a molding bi-material part is much bigger.

## 2. THEORETICAL DETERMINATIONS

Starting from the equation of contact temperature between the two components of a molding bi-material I have determinate the equation for calculate of the thickness of interpenetration layer at the contact surface between the two injected components. [2], [3], [5].

$$T_{cw} = \frac{b_w \times T_w + b_m \times T_m}{b_w + b_m} \quad [°C] \qquad (1)$$

In this equation I have used:

- $T_{cw}$: contact temperature between the melted material and the surface of the cavity;
- $T_w$: temperature at the surface of cavity;
- $T_m$: temperature of of the second melted material;
- $b_w$: thermal permeability of the mold material ;
- $b_m$: thermal permeability of the second melted material.

The contact temperature between the second melted material and the first thermoplastic material (insert) injected before is: [2], [3], [5].

$$T_{ci} = \frac{b_i \times T_i + b_m \times Tm}{b_i + b_m} \quad [°C] \qquad (2.)$$

Where:

- $T_{ci}$: contact temperature between the melted material and the insert injected before with the first thermoplastic material;
- $T_i$: temperature at the surface of the plastic insert;
- $T_m$: temperature of of the second melted material;
- $b_i$: thermal permeability of the insert material ;
- $b_m$: thermal permeability of the second melted material.

Because it is different condition for cooling of the melted material between the cavity surface and the plastic insert we can said we have the situation of asymmetrical cooling. In the case of asymmetrical cooling the fracture of the heat which is transferred at the mould is: [1], [2], [5].

$$g = g_w + g_i \quad [mm] \qquad (3)$$

Where:

- $g$: is the total thickness of the bi-component part [mm];
- $g_w$:is the fraction of the thickness which is in contact with the cavity wall and transfer the heat of the melt (Qw) to the cavity walls [mm];
- $g_i$:is the fraction of the thickness which is in contact insert injected before and transfer the heat of the melt (Qi) to the contact surface of the plastic insert [mm].

Because of the asymmetrical cooling of the injected melt of the second component the fraction of the thickness is: [5]

$$g_i = \frac{g}{1 + \frac{T_m - T_{ci}}{T_m - T_{cw}}} \quad [mm] \qquad (4)$$

$$g_i = \alpha_i \text{ x } g \quad [mm] \qquad (5)$$

Where we have defined the coefficient ( $\alpha_i$)

$$\alpha_i = \frac{1}{1 + \frac{T_m - T_{ci}}{T_m - T_{cw}}} \qquad [\,] \qquad (6)$$

The fraction of the heat of the melt of the second component (Qi) is transferred in totality to the insert injected before from the first plastic material. At the contact surface between the two components these heat is use to partial melt the insert injected before and at the contact surface that's results an interpenetration layer between the two melts of the two components. That's think can be results in the equations below: [1], [2], [5].

$$Q_u = Q_i = \alpha_i x Q_m \qquad [KJ] \qquad (7)$$

$$\rho_i \times V_i \times c_i \times \Delta T_i = \alpha_i \times \rho_m \times V_m \times c_m \times \Delta T_m \qquad (8)$$

Where:

- Qu=the heat used to melt the contact surface layer of the insert injected before from the first component [KJ];
- ρi= the density of the first component material [kg/m$^3$];
- ci= the specific heat of the insert material;
- Vi= Si xAi= the volume of the melt material at the contact surface Ai;
- ΔTi =$T_{ki}$-$T_i$ = the variations of the temperature of the insert [°C];
- ΔTm =$T_m$-$T_k$ the variations of the melt temperature from the second component material[°C];

Using the equation above, result the most important theoretical equation of the thickness of the interpenetration layer between the two plastic components used to inject a bi-component molded part.

$$s_i = \alpha_i \times \frac{\rho_m \times c_m \times (T_m - T_k)}{\rho_i \times c_i \times (T_k - T_i)} \times g \qquad [mm] \qquad (9)$$

Where:: [1], [2], [5].

- $S_i$ is the thickness of the interpenetration layer at the contact surface between two injected components [mm];
- $\rho_i$ is the density of the plastic material of the insert injected first [kg/m$^3$];
- $c_i$ is the specific heat for the plastic material of the insert [J/kg x °C];
- $T_k$ the crystallization temperature for the melted component [°C];
- $T_m$ is the melted temperature for the second component injected on the insert [°C];
- $T_i$ is the temperature of the insert at the contact surface [°C];
- $\rho_m$: is the density of the melt of the second component [kg/m$^3$];
- $c_m$: is the specific heat of the melt of the second component [J/kg x °C];
- g the thickness of the bi-component part at the contact zone [mm].

## 3. CONCLUSIONS

From the equation of the thickness of the interpenetration layer at the injection molding bi-components parts we can see the following:

- The thickness is direct proportional with the fraction of asymmetrical cooling ($\alpha_i$);
- The thickness is influenced by the melt temperature of the second component which is injected after the first component ($T_m$);
- The thickness is influenced by the crystallization temperature of the second component which is injected after the first component ($T_K$);
- The thickness is direct proportional with the thickness of the bi-component part at the contact zone (g).

These conclusions are very important because all these factors which has a big influence of the thickness of the interpenetration layer at the injection molding bi-components parts can be modified adjusting the parameters of the injection molding bi-component machines and also the temperature of the cooling system of the mold. Also this result can be used for the determinations of the roughness of the contact surface between the two components because they must be related. The roughness of the contact surface of the insert must not to have a value bigger than the thickness of the interpenetration layer because can results a non melt layer and a isolated of air layer which can determinate a important reducing of the adhesion between the two components. On the other hand, if the roughness of the contact surface of the insert is too much little than the thickness of the interpenetration layer, this can reduced the influence of the roughness and decrease the interpenetration layer which can also reduce the adhesion between the two injected components.

To obtain a maxim adhesion between the two injected components of a bi-material part it is very important to calculate the thickness of the interpenetration layer using the equation determinate before and than correlated with the roughness of the contact surface between the two components.

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