4.4.4 Water-Cooling at Die Casting

Several measures have to be taken to design a die casting equipment in an optimal way. Vents and draw pockets are necessary to prevent air inclusions at the filling of the mould, for example.

The irregular shapes of many castings require special precautions to maintain the temperature at an even and optimal level in all parts of the casting. Some sections, for example gating points where the speed of the injected metal raises the temperature, must be cooled with water to keep the correct temperature.

The water runs in special water tubes, which are drilled in the die block. In some cases they are drilled through the whole block. In other cases the cooling is selective. The water may enter through one short pipe, circulate around the regions to be cooled and leave through another short pipe or nipple.

The design of proper water-cooling will be extensively discussed in section 5.4 in chapter 5. It is a common matter for all casting methods with water-cooling.

4.4.5 Nussel´s Number. Temperature Profile of Mould and Metal at Low Values of Nussel´s Number

On page 32 we found that the heat transfer across the interface metal/mould drastically decreases when the solid metal looses the contact with the mould wall. The solidification process was analysed, which among other things, resulted in an expression for the temperature of the metal at the interface as function of *h*, *k* and the distance y_L of the solidification front from the interface. The expression is equation (45) on page 34:

$$T_{\text{i metal}} = \frac{T_L - T_o}{1 + \frac{h}{k} y_L(t)} + T_o \qquad (45)$$

We will analyse this relation more closely here. If the heat transfer at the interface between metal and mould is very slow (*h* very small) and/or the thermal conductivity of the solid cast metal is large (k very large) then the second term in the denominator will be small.

At complete solidification y_L has reached its maximum value, which we will call s. At constant values of the temperatures of the melt and the surroundings in equation (45) the temperature profile is obviously determined by the so-called Nussel´s number. It is defined by aid of the relation

$$\mathrm{Nu} = \frac{hs}{k} \tag{84}$$

where

h = heat transfer number for the interface between the mould and the metal
s = value of y_L at complete solidification
k = thermal conductivity of the metal.

Nussel´s number is frequently used as a criterion on the choice of temperature distribution model. If Nu << 1 the simple temperature distribution, illustrated in figure 27, is valid and can safely be used.

If Nu << 1 equation (48) on page 34 can be simplified to

$$t = \frac{\rho(-\Delta H)}{T_L - T_o} \cdot \frac{y_L}{h} \tag{85}$$

The total solidification time is obtained if y_L in equation (85) is replaced by the thickness of the casting at unidirectional cooling. Equation (85) can also be applied on bilateral cooling of castings. In this case s means *half* the thickness of the casting.

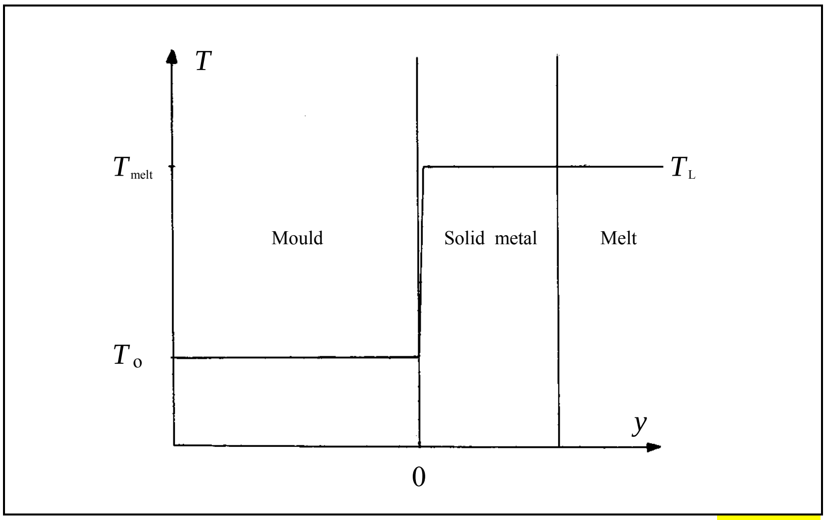

Figure 27.
Temperature distrib
mould and metal fo
lues of Nussel´s nu

The solidification process described above is valid for thin component casting in permanent moulds, i. e. when Nu << 1.

Example 6.

You will produce a thin article for the car industry by pressure die casting. To make the production cheap the article should be cast as rapidly as possible. You can either cast the article in a magnesium alloy or an aluminium alloy. Which one should you use? The heat transfer constant can be regarded as equal in both cases.

Solution:

In order to apply equation (85) and calculate the solidification time in the two cases we have to use the material constants for Mg and Al, taken from tables:

$-\Delta H_{Al} = 3.54 \cdot 10^3 \ \text{J / kg}$ $\quad -\Delta H_{Mg} = 208 \cdot 10^3 \ \text{J / kg}$

$\rho_{Al} = 2.69 \cdot 10^3 \ \text{kg/m}^3$ $\quad \rho_{Mg} = 1.74 \cdot 10^3 \ \text{kg/m}^3$

Field Code Changed

Field Code Changed

The temperature of the melt is approximately equal to the melting point temperature of the metal.

$T_M^{Al} \approx 658 \ ^oC$ $\quad T_M^{Mg} \approx 651 \ ^oC.$

y_L is the same in both cases. The values above and $T_o = 20 \ ^oC$ are inserted into equation (85), which gives

$$\frac{t_{\text{Al}}}{t_{\text{Mg}}} = \frac{\left(\dfrac{\rho_{\text{metal}}\left(-H\right)}{T_{\text{M}} - T_{\text{o}}}\right)_{\text{Al}}}{\left(\dfrac{\rho_{\text{metal}}\left(-\Delta H\right)}{T_{\text{M}} - T_{\text{o}}}\right)_{\text{Mg}}} = \frac{2.69 \cdot 10^3 \cdot 354 \cdot 10^3}{658 - 20} \cdot \frac{651 - 20}{1.74 \cdot 10^3 \cdot 208 \cdot 10^3} = 2.6$$

Answer: The Mg alloy should be chosen. It has the shortest solidification time.
