BCIRA Broadsheet 38*

Calculation of weights for moulds

Need for adequate mould weights

The upward movement of the top half or cope of a mould, due to the pressure of the molten metal as the mould becomes filled, is a frequent cause of scrap castings in many foundries.

The obvious results of cope lift such as 'run-outs' or an oversize casting with heavy flash are immediately recognizable, but the following additional defects which may lead to the eventual scrapping of a casting are not always fully appreciated.

> The presence of flash can cause chill to strike back into the surface of the casting and give machining difficulties.
>
> Hammering to remove flash can cause cracking.
>
> Lack of ferrostatic head, or further movement of the cope mould during solidification, in effect a 'non-rigid' mould, can cause shrinkage defects.

Cope lift can result from inadequate clamping, the application of insufficient weights, or lack of strength in the cope mould. Distorted moulding boxes, metal on the joint face of the boxes, and badly designed or poorly maintained clamping arrangements can also cause run-outs.

How can the weight required on a mould be calculated?

A reasonably close estimate can be made of the upthrust force exerted on the cope of a mould when the complete mould is filled with molten metal. This upthrust force consists of a combination of *static* and *dynamic* forces.

Static force

Calculating the static force exerted on the cope half-mould by the molten metal, in a vertical-sided flat-topped mould cavity, is by the simple hydraulic formula:

$F = A \times H \times \rho$ (here referred to as Formula A)

where

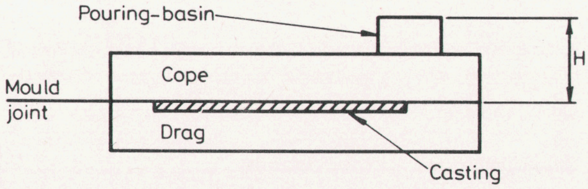
F = force exerted, kg (lb)

A = surface area (plan view) of casting, cm^2 (in^2)

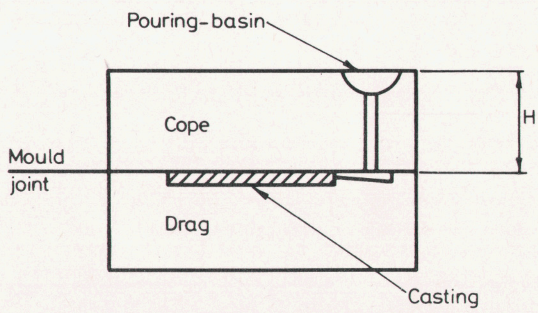
H = height from top of pouring basin to top surface (surfaces) of mould cavity, cm (in)

ρ = density of metal = 0·0072 kg/cm^3 (0·26 lb/in^3) for cast iron.

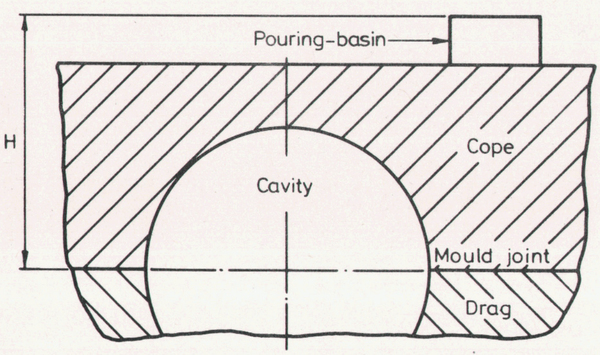
As the force exerted is to be balanced by the use of weights, the formula given above has ignored the SI unit of force, the newton, and is expressed in kg in its metric alternative.



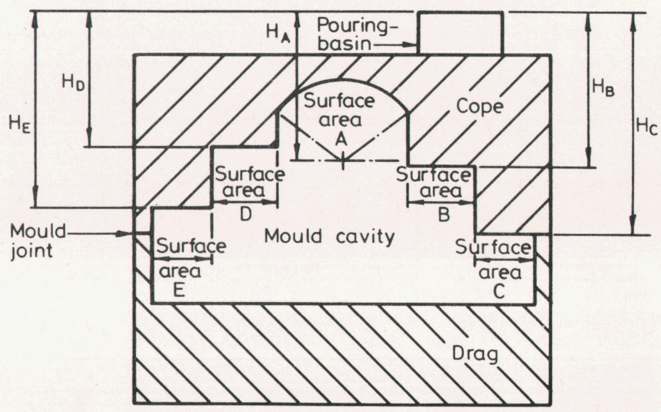
Section through mould showing head height (H)



Section through mould showing head height (H)



Section through mould showing circular cavity



Section through mould showing irregularly shaped cavity

• Revised Jan 82 to include metric units, to take into account the weight of the core in Formula C, and to include Recommended Further Reading.

The calculation of the static upthrust in mould cavities having curved ceilings requires a different formula. For example, the formula used for horizontal cylindrical cavities is as follows:

$$F = \rho D \left(H - \frac{\pi D}{8}\right) \text{per unit}$$

(here referred to as Formula B)

where:
F = force exerted, i.e. upthrust.
D = diameter of mould cavity.
H = height from top of pouring-basin to centre line of cavity.
ρ = density of metal.

In the case of an irregularly shaped cavity, with the mould ceiling at different levels, the total static upthrust on the cope mould is the summation of the upthrusts present at each level, i.e.

Upthrust on area A + upthrust on area B + upthrust on area C + upthrust on area D + upthrust on area E = $F_A + F_B + F_C + F_D + F_E$

When the ceiling of a mould has significant areas of both flat and curved surfaces, Formula A is used for the flat surfaces and Formula B for the curved surfaces.

The effect of a core is to transmit a lifting force on the cope half mould via the core prints. This force is equal to the weight of metal displaced by the volume of the core less the weight of the core. This is called the buoyancy effect. Therefore to calculate the effect of inserting cores into moulds on the total upthrust when the mould becomes filled with molten metal, the extra upthrust due to the core is equal to:

(Volume of the core which is surrounded by metal) × (the density of the metal) — (the core weight)

(referred to here as Formula C).

Dynamic force

The additional lifting force which has to be considered is that which can be developed at the moment when the rising metal reaches the ceiling of the mould. This is a short-lived dynamic force and in simple terms can be regarded as the thrust imposed on the cope when the rising liquid metal collides with the ceiling of the mould cavity.

This dynamic force, contributing to upthrust, depends on the rate at which metal is being poured into the mould. This, in turn, is related to the height of the pouring-basin above the ingate level and the general dimensions of the gating system as a whole. From the practical point of view, the dynamic force developed increases with increasing plan-view surface area, particularly on castings of the flat plate type. This is because the larger and thinner the casting, the more it is necessary to increase the number and/or size of ingates to achieve a reasonable pouring time and a fully run casting.

The dynamic upthrust force on a mould cope can be calculated, but these calculations become quite involved. Since this force is in addition to the static forces exerted, it is best to design the running system to avoid excessive mould filling rates and sudden stoppages of metal flow.

In this respect risers or flow-offs can be most valuable, and the relieving effect of these additions to the gating system can often be observed; as the mould cavity becomes filled, the level of metal in the riser suddenly increases, often reaching a point above that at which it eventually comes to rest.

How much weight should be employed?

Making use of the information given above, a calculation can be made for each design of casting to determine the upthrust on the cope mould during pouring. It is necessary to select from the following conditions those which apply, and then calculate each contributing static upthrust force.

Static forces

For vertically-sided mould cavities with flat-topped ceilings use Formula A.

For mould cavities with curved ceilings use Formula B.

For mould cavities with both flat-topped and curved ceilings use both Formula A and Formula B where appropriate.

Where cores contribute to upthrust include Formula C. Add together those of the static forces which apply to the particular casting under consideration to obtain the total static upthrust on the cope.

Dynamic upthrust

Minimize this as far as is practicable by effective design of a running and risering system, as suggested above.

The calculated total static upthrust should be increased by 50 per cent to give a practical safety margin, which will also accommodate the minimized dynamic upthrust.

Recommended further reading

Brown, D. Prevention of cope-mould lift during casting. *BCIRA Journal*, 1966, vol.14 No. 6, 753–760. BCIRA report 853.