Stress analysis during casting and its application to die fatigue prediction.

e-Tips

Nr. 15

During shape casting of metallic components, besides the defects relating to filling behaviour and solidification, another important issue is the stress behaviour of both the casting and die during processing. This behaviour can affect the final integrity of the component, as well as result in defects such as cracks, distortions and die failures. This e-Tip focuses on the stress predictions in die casting and its effect on die life.

Factors which influence the stress behaviour and fatigue life of the die include:

- *thermo-mechanical properties of the die and casting*
- *shape of the cavity*
- *thermal history of the die*
- *external forces and pressures*

Introduction

In order to accurately simulate the stress behaviour in the die, one should consider the full coupling between the thermal, fluid and mechanical stress behaviour of all the relevant materials, including casting, cores and dies. One also needs to take into account the gap formation caused as a result of shrinkage during solidification, as this will affect the heat transfer into the die, see Figures 1 & 2.

In some cases, dies may experience some local plastic deformation and thus one needs to consider both the elastic and plastic behaviour of the die. Any local plastic deformation in the dies would severely limit the die life and should therefore be avoided. Even when dies operate within the elastic region, their life is influenced by the cyclic stresses which occur during processing.

For fatigue life prediction one should then consider the full die cycle where the dies will be influenced by the:

- clamping of the dies
- thermal heat transfer between the casting and the die
- thermal heat transfer from heating and cooling channels
- injection pressures
- part ejection
- spaying on the surface of the die during coating

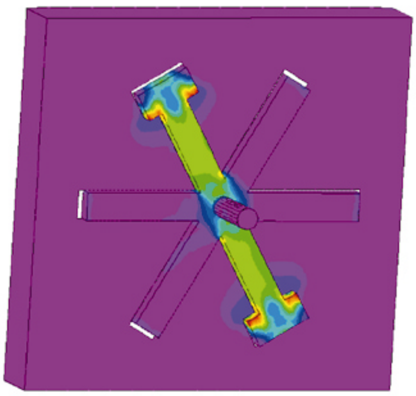


Figure 1: *Effective stress contours in a cast aluminium part showing gap formation during solidification. (ProCAST)*

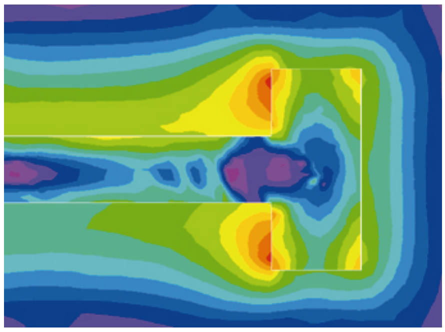


Figure 2: *Heat flux contour influenced by the gap formations. (ProCAST)*

Example

Consider a simple example of a high pressure die cast aluminium alloy component, cast at 720°C, with one die half having a cooling channel positioned at the end of the casting, see Figure 3. The full cycle includes, filling, solidification, ejection and spraying. In the first scenario we consider the cooling channel at 20°C and in the second scenario we remove the cooling channel.

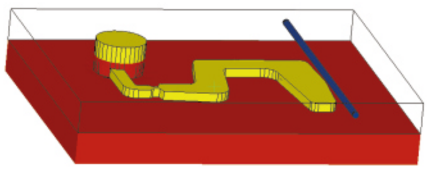
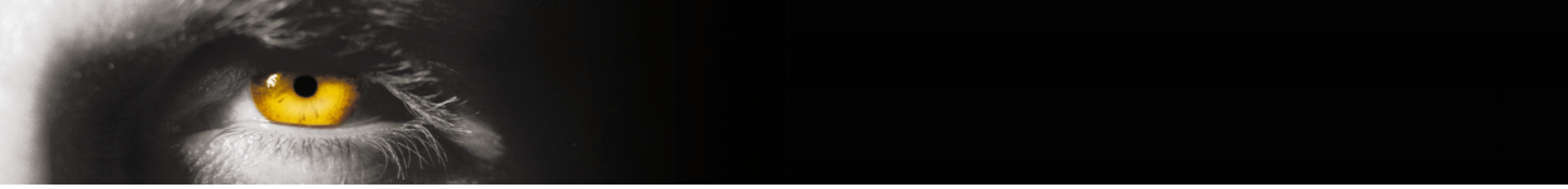


Figure 3: *Geometry showing casting (yellow), cooling channel (Blue) and dies (Red).*



In the first scenario, as shown in Figure 4 & 5, one can clearly see the effect of the cooling channel (indicated by arrow A) on the effective stress contour plot as well as on the die fatigue life plot, respectively. The increased temperature gradient between the casting/die interface and the cooling channel increases cyclic stresses in the die.

In the second scenario, as shown in Figure 6 & 7, the high stress regions have moved away from the cooling channel and thus resulting in an improvement in fatigue life.

The absence of the cooling channel in the second scenario can also have an adverse effect on the die due to the increased temperature of the die.

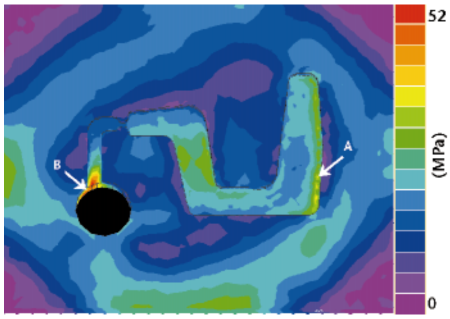


Figure 4: *Results with cooling channel (only bottom die half is shown). Effective stress contour plots showing high stress regions (arrows A & B). These regions are located close to the cooling channel (arrow A). (ProCAST)*

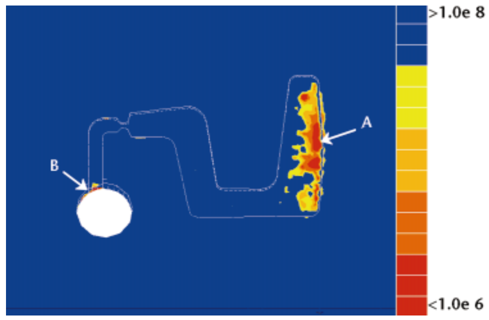


Figure 5: *Results with cooling channel (only bottom die half is shown). The fatigue life contour plot shows the regions with limited fatigue life (arrows A & B). (ProCAST)*

Conclusion

Based on the results of the die stress analysis we can conclude that the close positioning of the cooling channel to the cavity can have a strong influence on the fatigue life of the die.

However, as cooling channels are required for preventing overheating of the die and for controlling solidification, process simulation can be used to find the best compromise early in the design stages of the die.

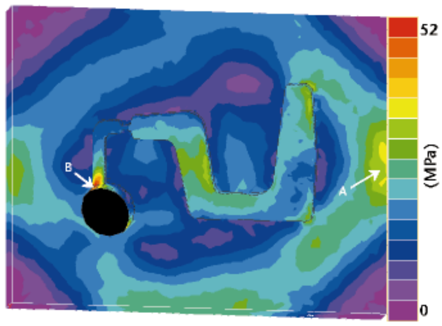


Figure 6: *Results without cooling channel (only bottom die half is shown). Effective stress contour plots showing high stress regions (arrows A & B). (ProCAST)*

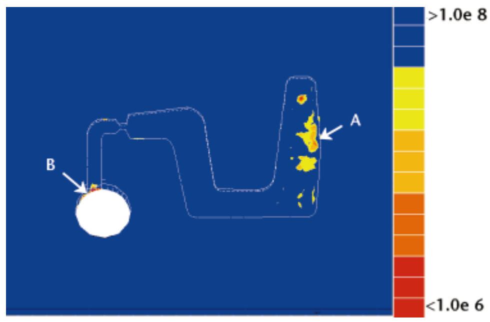


Figure 7: *Results without cooling channel (only bottom die half is shown). The fatigue life contour plot shows the regions with limited fatigue life (arrows A & B). (ProCAST)*

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