Backward extrusion depends upon the active clearance between the dummy block and container under operating conditions of temperature and applied pressure – the active clearance being the real clearance during extrusion, or the effective skin generation thickness on the container liner wall. However, the active clearance is also dependent on the initial cold clearance incorporated into the design, i.e. the difference in diameter of the cold dummy block and the cold container liner under a no-pressure situation.

This initial cold clearance needs to be customised for precision tubing extrusion, and will be different than at a plant extruding their traditional alloys. A typical extrusion ratio in a 5xxx alloy operation is considered to be in the preferred range of 40:1. The plant producing 5xxx or 6xxx alloys for macro-port heat exchanger or automotive A/C applications, typical extrusion ratios can be in the range of 80:1.

Due to the high extrusion ratios, and the desire to extrude with long length billets to optimise cooling, micro-port extrusion cycle times can be lengthy in comparison to traditional 5xxx alloy cycles – 3-5 minutes compared to around 1 minute. The conditions for blow-by over the dummy block, and tighter tendency for the alloy to do so, are therefore quite different in these two situations.

Backward extrusion tends to occur in reducing plastic strain under load is essential, the container in the dummy block and liner container is not precisely controlled, there is backward extrusion occurring in the dummy block.

Backward extrusion

Dummy blocks must expand and retract under controlled conditions to generate a stable yet consistent dummy block pressure and as the dummy block passes through the billet, achieving the heat of deformation during extrusion.

High pressure dummy blocks

Most commercially available dummy blocks operate satisfactorily under applied pressures (or press specific pressures) of 700 MPa (100,000 psi) and cycle times of 2 minutes or less. Under higher applied pressures of 825 MPa (120,000 psi) and longer cycle times, permanent yielding of a standard dummy block can become an issue, and overall performance and function of the dummy block may suffer. Permanent deformation of the dummy block can become excessive at high pressure, resulting in the dummy block failing to retract enough to clear the container skin during withdrawal. Alloy can then be picked up from the container skin after relaxation of the container liner.

The resulting alloy from the container skin collects on the rear of the bearing land, influencing how a dummy performs during the burt cycle, risking more blister on extrusion surfaces, and creating press downtime due to the need to frequently clean or change the dummy block.

High pressure dummy block design

High pressure dummy block design illustrated in Figure 1 has been designed and manufactured for this severe application. Component contact areas are increased to reduce applied stresses, along with other design features to improve pressure and force distribution throughout the dummy block. The effect of the redesign in reducing plastic strain under load is illustrated. The block can cater for pressures up to 825 MPa (120,000 psi) and long cycle times without plastic yield.

Container design

The container undergoes the same stress with PT extrusion in the dummy block. It is also affected by pressure and cycle time.

Three-piece containers are recommended when precise are used to extrude alloys with lower flow stress alloys, i.e. 5xxx and 6xxx alloy groups, at higher extrusion ratios and at higher specific pressures. A 3-piece assembly (i.e. a mantle with sub-liner, often referred to as an outer liner) is used to provide additional support and stiffness, thereby reducing deflection under higher operating pressures. Figure 2 shows equivalent stress is lowered from 600 MPa (90,000 psi) to 560 MPa (85,000 psi) with a 2-piece container. The stress is further reduced to 65,000 psi (450 MPa) with 5-piece container construction.

Calculations show that a 3-piece container is stronger than a 2-piece container. The strength of a 3-piece container is about 20% higher, equivalent to 20% less deflection during extrusion.

It is important to maintain a smaller clearance between the container liner and dummy block, because of the higher sensitivity of these softer, lower flow stress alloys to the gap around the dummy block, and their natural tendency to back extrude over the dummy block. To ensure the gap between container and dummy block is better controlled, a three-piece container has the additional sub-liner support and reduced expansion is required in these situations, along with the use of a high-pressure dummy block.

Container cooling

Due to high extrusion ratios and high strain rates, PT extrusion generates more deformation heat in the container. To attain better process control, there is a need for additional container cooling to avoid both the container and the process overheating, and to avoid the need to slow down. Traditionally when cooling is applied to a container, spiral grooves machined into the container body (mantle) or liner, circulate air around the outside of the liner. While air by nature is a poor conductor of heat, it is the most convenient and safest cooling medium to use.

Figure 3 illustrates a typical heat balance during extrusion. Assuming the container and the die remain at constant heat, the billet heat A increases during deformation by B - the heat of deformation being the area under the force/displacement curve less the energy required to overcome container friction. Heat losses C occur due to heat flow through the container. The sum of these, i.e. (A + B) - C, is the heat transported away in the extrusion. This somewhat simple approach ignores heat generated in the die, which will add to the heat mass in the extrusion, but the important part of this equation in terms of the container, and design of cooling if necessary, is that C must be capable of equalising or exceeding B. In the case of external heating elements, C may be a positive term to optimise the heat flow net effect of increasing the liner temperature.

Recognising high productivity processes with high heat generation, and that cooling is indeed necessary, a container can be designed with external cooling of the body, rather than cooling around the outside of the liner. Cooling the liner disrupts both the radial and longitudinal heat flux through the container body, while cooling the outside of the container complements it. A container design with two-zone external cooling is shown in Figure 4. This type of container design successfully removes additional heat from the high deformation process, and can develop optimum heat flux gradients in the container body by use of both longitudinal and radial offsets, generated by smart selection of container zone temperatures.

Active clearance

Actual extrusion pressure curves were recorded for a 25.5N, 8” front-loading direct extrusion press. The curve was then FEM modelled using a 42” (1,100 mm) long QR container and a new improved high-pressure (HPR) block. The pressure range was within 5% of real press data, and the model was therefore considered acceptable and accurate in predicting pressures on both the dummy block and container during extrusion cycle simulations.

After 5 simulated extrusion cycles, the process was considered stable, allowing both container and dummy block expansion to be predicted with confidence. The findings are shown in Figure 5, where an estimated skin thickness based on the difference between the dynamic container and dummy block expansions, i.e. combined thermal and mechanical expansion under varying extrusion pressures, which correlates in block expansion through the container from start of extrusion to the final position of the burt length. The active clearance for this skin thickness, is around 0.008” (0.2 mm) at all times.

Durable dummy blocks

For many years dummy blocks have been considered to some extent a disposable tooling item to be thrown away after each use. However, under the high requirements of precision tube extrusion with its inherent high extrusion pressures, and the need for active clearance control, a standard dummy block will cease to function properly and may need to be replaced every one to two weeks (or less than 4,000 billets). An optimised dummy block designed to accommodate the specific needs of this specialty market is therefore a critical item of tooling to enable optimal process control to attain high quality and increased productivity.

In addition, only thermally stable and structurally sound containers can meet the specialist needs of the tube extrusion process, producing heat exchanger and automotive climate control tubing in 5xxx and 6xxx alloys. These extremely high productivity processes heat the container to the body temperature to maximise beneficial thermal gradients in the container, and by the use of high pressure, the active clearance must be maintained. The container skin thickness is therefore a critical item of tooling to enable optimal process control to attain high quality and increased productivity.

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