The Systems Approach to Aluminum Extrusion, and How to Evaluate a Production System

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Introduction

The global market for light metal extrusions is changing. Major users are becoming more knowledgeable about the real capability of world-class extruders. Accordingly, they are more demanding. They specify profiles that have never been made before, tolerances that are uncommonly tight, and surface finishes that have previously required a secondary operation.

To remain competitive in this increasingly difficult market, many extruders must change their basic approach to productivity.

Too often, parts of the extrusion process are considered individually, without regard for the influence of other components, or the ultimate goal of all parts of the process working collectively as coordinated system.

No single part of the production process operates in isolation. All components must function together as a system, and at a high level of efficiency, if synergy is to be created.

The extrusion production process is best considered as a succession of mini-systems, each comprising 2 or 3 parts that most closely affect the performance of each other. In product research and development over a number of years, Castool has found that this is the only way to achieve maximum productivity and recovery.

To Rate Your Production Process

In evaluating any part of an extrusion production system, there are really only two questions to ask:

1. How does the **performance** of the component affect productivity? How does it affect press speed, number of billets per shift, amount of downtime, scrap, percentage of recovery, and so on?
2. What is its **operating life**? How long will it last before it needs replacement? This is of course critical when calculating the real value of any new product.

The Dummy Block and the Container

An example of a mini-system in the extrusion production process is the relationship between the dummy block and the container, and their dependence on each other.

The operation of neither the dummy block nor the container can be usefully studied individually. They should always be considered as a small system, working closely together. The effective functioning of the dummy block depends on the condition and the temperature of the container. If the container has lost its hardness and has become bellied, or distorted in any way, the operation of dummy block will be negatively affected immediately.

Consider the critical gap between the dummy block and the container liner.

It is impossible for the dummy block to work well unless temperature of the container is stabilized, and the diameter of the liner remains virtually unchanged from end to end. For this to happen, and for the gap to remain constant, the temperature of the container must be carefully controlled throughout the extrusion cycle.

For the dummy block to work properly, a thin film of alloy must, of course, remain between the block and the container liner at all times during the extrusion process. Its thickness must be uniform. With a soft alloy, the clearance that creates this film will be only about six thousandths of an inch, (0.015cm). If it is more, the alloy will penetrate the gap in the first push. If less, the film of alloy will be stripped.

Stripping the film of aluminum off the liner results in scrap due to blisters, and also to inferior alloy being carried into the product instead of being discarded in the butt.

A problem, of course is that when it is heated, the dummy block expands. During extrusion, the dummy block operates at the same temperature as the billet and the container. Care must be taken, therefore, to preheat the block to operating temperature before it enters the hot container. For every 200°F (93°C) difference between initial block temperature and operating temperature, an 8-inch (20cm) dummy block will expand by about 0.010 in. (0.025cm). Most of this expansion will occur during the first push.

The Castool Dummy Block

The dummy block is a critical element of the aluminum extrusion press. It is a component on which both quality and productivity depend. It has evolved from a simple yet effective basic tool, to a high-tech device that incorporates the results of extensive research and development to perfect its function.

Castool pioneered the development of the modern fixed dummy block, and has remained at the forefront of dummy block technology ever since. The move from loose to fixed dummy blocks has won universal acceptance, and has significantly increased the productivity of light metal extruders throughout the industry.

Castool product development engineers, however, continued their effort to improve the conventional fixed dummy block. Their innovative work resulted in the introduction and success of the proprietary replaceable expanding wear ring. This was another milestone in the continuing evolution of dummy block technology.

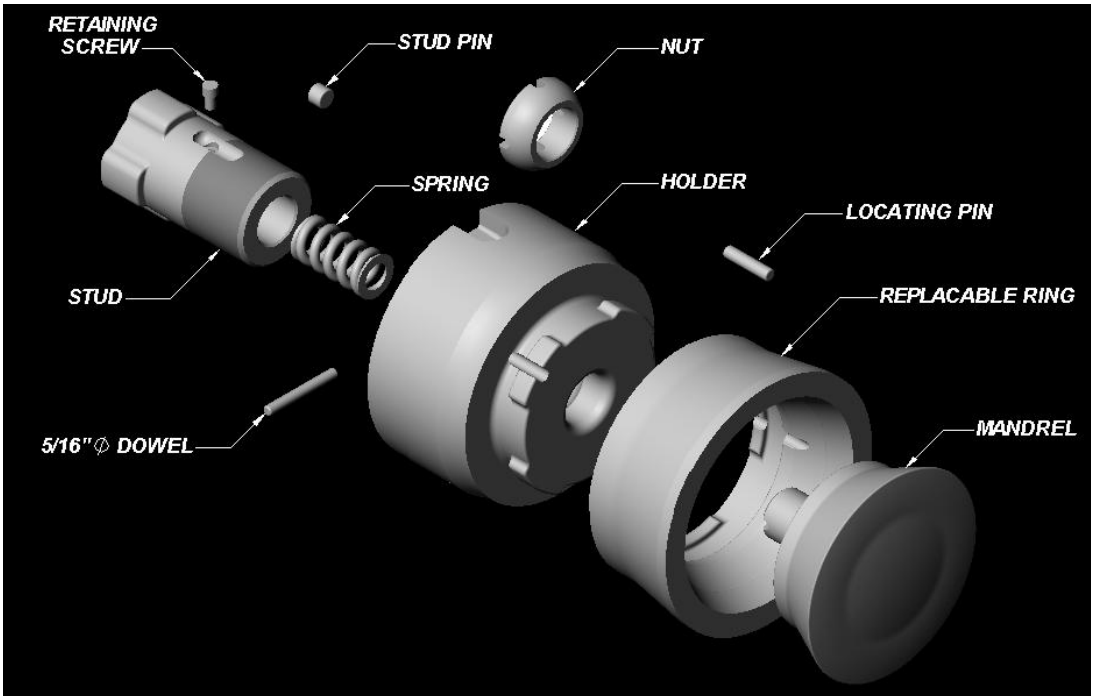

FIGURE 1 – Exploded View of Castool Dummy Block

Function

The function of the dummy block appears quite straightforward. It is the extension of the ram and stem which actually pushes the softened alloy through the die. This is, of course its main purpose. If the extruder is aiming for maximum productivity, however, there are a number of functions that must be satisfied by an effective dummy block.

- To transmit the force of the ram, at high temperature, to the alloy.
- To expand quickly under load and maintain a secure seal with the container wall, leaving only a thin film of alloy on the liner.
- To separate cleanly from the billet at the end of the stroke.
- To contract immediately, and return through the container without stripping the film of alloy from the liner.
- To cause no gas entrapment that can result in blistering, or damage the face of the container and/or dummy block.
- To compensate for minor press misalignment.
- To be quickly and easily removed and replaced.

Operation

When extrusion begins, the ram and stem push the dummy block slowly through the container. This forces the softened alloy through the die. Initially, the face of the block is about 0.035”-0.060” (0.89mm-1.52mm) less than the internal diameter of the container. The expanded fixed dummy block must permit a thin film of alloy to remain on the container liner. The front of the shell of the dummy block must therefore expand to increase the diameter by about 0.030” (0.75mm) during the forward or extrusion stroke of the press. At the end of the stroke, on the separating from the billet, the dummy block must immediately collapse to its original diameter. As it returns through the container, it will therefore not strip the liner, but will leave a thin coating of alloy.

The expansion of the front of the dummy block is achieved by means of a tapered mandrel that is forced back into the block as it moves against the billet. The exact amount of expansion is, of course, critical. Expansion is, however, positively controlled by limiting the extent that the tapered mandrel can penetrate the block.

The rate of expansion is also critical. The dummy block should reach maximum expansion just prior to the billet being upset, so that most of the trapped air will be evacuated. The friction between the tapered mandrel and the lip of the shell also has considerable effect on the rate of expansion. Adequate lubrication of these two surfaces is therefore essential.

The length of the billet and the type of alloy also affect this process. They should always be discussed prior to making decisions on the type and dimensions of the dummy block to be used.

At the end of the extrusion when the face of the block separates from the billet, the mandrel is released and the shell contracts. This allows it to return through the container without stripping the film of alloy.

Replaceable Expanding Wear Ring

Most wear naturally occurs at the front of the dummy block, on the outer lip of the shell. The block is then usually replaced, or returned to the supplier to be re-shelled. Castool provides an efficient and cost-effective alternative, by replacing the front lip of the shell with a high-strength steel expanding wear ring that is easily and quickly replaced.

The economy of the replaceable wear ring is soon apparent.

Coupling

There are several methods of attaching the fixed dummy block to the stem. The coupling used must, of course, be strong enough to withstand the repeated cyclic loading when the block is pulled back through the container.

The traditional method of attaching the block is with a stud. If a stud is used, however, care must be taken to ensure that the block always remains tight to the stem. If a gap develops between the block and the stem, the stud will then bear the full pressure of the ram, and will almost certainly fail.

Castool uses a unique bayonet-type coupling which locks the dummy block quickly and securely to the stem. This makes it much easier and faster to replace the block than with a conventional screw type coupling. In addition, the block can easily be rotated a quarter turn at regular intervals to equalize wear. This block is also designed to allow some lateral movement that reduces excessive wear that can be caused by press misalignment.

Mandrel Spring

A common problem with conventional dummy blocks is that the lip of the shell eventually loses its spring-back. The mandrel fails to eject, and the shell remains expanded. Castool solves this problem by installing a strong spring behind the mandrel solves this problem. The spring overcomes the friction between the mandrel and the shell, or wear ring. Under pressure the mandrel will compress the spring. The spring will then eject the mandrel as soon as pressure is released.

Rating a Dummy Block

Performance:

Scrap is primarily reduced in two ways; by reducing or eliminating gas entrapment which causes blisters in the extruded product, and by maintaining a consistent film of alloy in the container liner, thus preventing impurities from the billet skin from entering the extrusion.

Operating Life:

The operating life of a dummy block depends entirely on the length of time the shell retains its ability to expand and contract effectively. This should be regularly monitored, by comparing the diameter of the lip of the shell while cold with its original diameter. Incomplete contraction will have an immediate negative effect on performance.

Alignment of the Extrusion System

The basics of extrusion haven’t changed, but the technology has improved. For example, until recently, the need for die trials was taken for granted by most extruders. Now both die design and manufacture are sufficiently advanced that if an extruder has a competent diemaker, and can’t get good product from the first push every time, he has a problem. His problem is usually alignment.

One of the first principles of extrusion is the fundamental essential of alignment, thermal as well as physical.

Consider the importance of exact alignment during the entire extrusion process.

1. The alloy should remain at the optimum extrusion temperature at all times.
2. The die should be positioned exactly in the centre of the container.
3. The die should be completely at the same temperature as the alloy.
4. The temperature of the container liner should remain uniform.
5. The temperature of the alloy in the container should remain uniform, top to bottom, as well as back to front.

At each stage of production, alignment is critical. Zero tolerance must be the goal.

Physical Press Alignment

The importance of the absolute physical alignment of the extrusion press cannot be overstated. For example, if the die is not mounted exactly in the centre of the container, the flow of alloy into the die will be uneven, and the profile will be distorted. Also, the ram and the dummy block must pass through the container smoothly, straight and true. For this to happen, the press itself must always be kept in complete alignment.

Press misalignment is a major cause of dummy block wear. Accordingly, uneven wear on the front edge or land of the dummy block is usually the first indication of misalignment. This can be easily seen. Unfortunately, once a press becomes badly worn, absolute alignment is often impossible. It is important, therefore, that wear on bushings and seals, particularly the ways and the main ram bushing, be checked regularly.

Press misalignment is insidious, because it can result from so many different factors such as the press foundation, tie rods, stem, billet loader, die changer, and so on. None of these alone may appear too significant, but combined they can result in one of the most common problems in extrusion.

The key to maintaining good press alignment is regular, detailed and diligent inspection. Alignment can, of course, only be accurately measured when the press is at operating temperature.

Emphasis must always be on prevention, not on correction.

Thermal Alignment

Good thermal alignment, as well as mechanical alignment, is vital to successful light metal extrusion.

The need for the mechanical alignment of all parts of the extrusion process is obvious. Mechanical misalignment can be determined and corrected fairly easily. No deviation is acceptable. Absolute thermal alignment, however, is a fundamental goal for extruders to strive for. It has yet to be achieved.

Isothermal extrusion is usually considered to be the maintaining at all times of the optimum extrusion temperature of the alloy, as it passes through the die. For this, the billet is usually taper-heated or quenched, and the speed of the press gradually reduced, to offset the heat generated by the friction of the die bearings. Absolute thermal alignment, however, also requires that the alloy being used remains completely and uniformly at optimum extrusion temperature from the time the billet is heated until the alloy enters the die. To approach thermal alignment, the temperature of the container must be closely controlled at all times.

Effective temperature control of the container is absolutely essential to maximize productivity.

Container Temperature Control

People are often unaware of the high level of technological sophistication that is required in a container to allow the extruder to operate his press confidently and consistently at maximum speeds.

For example, the extrusion die designer must assume that the die will remain completely and uniformly at operating temperature at all times during extrusion. And he must also assume that the rate of flow of alloy from all parts of the container into the die will remain uniform as long as the press is operating. The size and shape of the die bearings, pockets, ports, etc. are all based on these two assumptions.

The total rate of flow of alloy from the container depends, of course, solely on the movement of the ram. If the temperature near the top of the container is greater than at the bottom, however, the rate of flow of metal from the top of the exit aperture will increase, and the flow may in fact enter the die at a different angle than from the bottom. To extrude an accurate and consistent contour, the temperature of the container must remain constant, top to bottom as well as back to front, at all times during the extrusion cycle.

Both the performance, and to a much lesser extent the useful life of a container, are affected by the billet temperature during extrusion. They are also affected to a considerable extent by the configuration of the container heating system, the location of the heat source, and of the thermocouples which control it.

Ideally, the heat source will be close to the need. That is, close to the liner. Also, the heat source should be close to the thermocouple that controls it, so that response to the demand will be more immediate.

Since the container is designed to extrude aluminum, the temperature of the billet in the liner is usually at or about 800-900°F (425-480°C) The liner is normally of H13 or 1.2344 tool steel that anneals at 1085°F (585°C). In North America, the mantle is usually of 4340 steel that has an annealing temperature of about 1000°F (540°).

It is obvious, therefore, that while extruding, the temperature of the billet cannot come close to softening either the mantle or the liner, and so when the press is running 24/7 there should be no problem.

Preheating the Container

If the press has been stopped, the container must be preheated to minimize “chilling”, or thermal shock to the billet on start-up. Preheating the container in a manner that is both quick and efficient, as well as maintaining operating temperature during brief stops, can be difficult.

Ideally, each time production stops, the extruder would insert some type of heating unit into the bore of the container to hold it at temperature. This is, of course, impractical.

The real danger comes when we are not extruding, and we try to maintain operating temperature at the liner by introducing a remote heat source that is actually outside the mantle.

Container Thermal Control Systems

There are just now three principal methods of managing container temperature. They can be differentiated by the location of their heating units.

The Container Housing Method heats the container by placing heating elements in the container housing. The container is surrounded by elements that have a sheath temperature of about 1300-1400°F (700-760°C) and controlled by thermocouples near the liner. In a large container, the thermocouple may be more than a foot from the heat source. To maintain 800-900°F (425-480°) at the liner, the temperature near the surface of the mantle can reach more than 1300°F (705°C). If this occurs, the mantle will anneal and soften. The liner will then "belly", or expand in the centre. This will adversely affect performance by allowing a build-up of impurities. Also, the mantle may crack.

And if the outside of the container is allowed to become considerably hotter than the liner, the difference in the amount of thermal expansion can eliminate the interference between the liner and the mantle. This will cause the liner to loosen and slip.

With this type of blanket heater, since the sensors are usually some distance from the heat source, the response time is unavoidably slow. In addition, it is impossible to achieve zone control to compensate for the variations in the rate of heat loss from different parts of the container i.e. top to bottom, and back to front.

The Container Mantle Method for heating containers positions the heat source inside the mantle itself. This method is much better than the first, and with a thermal control system that monitors temperatures in more than one zone, the possibility of overheating the mantle is considerably reduced.

By strategically placing specially designed electrical resistance heating elements within the body of the container in only the zones where heat is needed, and with thermocouples on the liner, control over the changing temperatures during the extrusion process is much enhanced.

Although this method is certainly an improvement on having the heat source outside the actual body of the container, heat is still being applied to the core of the mantle, with the controlling sensors on the liner. Depending on the location of the heating elements in the container, the time taken for the temperature of the mantle to react effectively to temperature changes in the liner can be far from immediate.

The objective of any container thermal control system is not to maintain a uniform temperature throughout the container, it is to maintain a uniform temperature at all points in the liner. . . top to bottom, and front to back. The further the source of heat is from the liner, the more difficult this task becomes.

<u>The Castool Sub-Liner Container Method</u>, a recently developed solution to the need for close thermal control of the container, places internal heating elements as well as heat sensors within a sub-liner, between the container liner and the mantle.

This sub-liner method makes it possible to closely monitor the temperature around the heating elements, and to compare it with the temperature of the liner. It heats the liner quickly, while preventing it from overheating. The temperature gradient within the container during preheating closely resembles that of the profile during the extrusion process. The possibility of the mantle overheating, annealing, and cracking, is virtually eliminated. The shrink fit stress that secures the liner remains stable. The mantle now simply supports the liner and sub-liner, and acts as a heat sink, dissipating excess thermal energy from its surface.

The new sub-liner control system reacts quickly to changes in demand for heating. Since the heat source is right next to the liner, elements are positioned just in areas where heat is required. Only small amounts of thermal energy are therefore necessary to effectively control the rate of flow of aluminum into the extrusion die. Once the extrusion process begins, the thermal profile of the container will remain almost uniform.

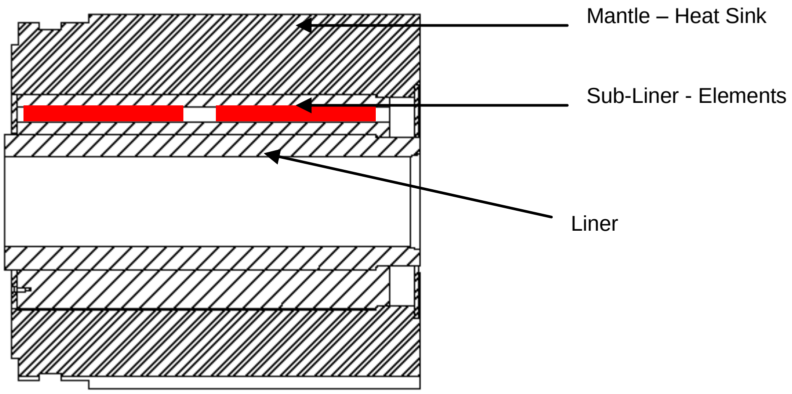

FIGURE 2 – Section View of Castool Sub-Liner Container

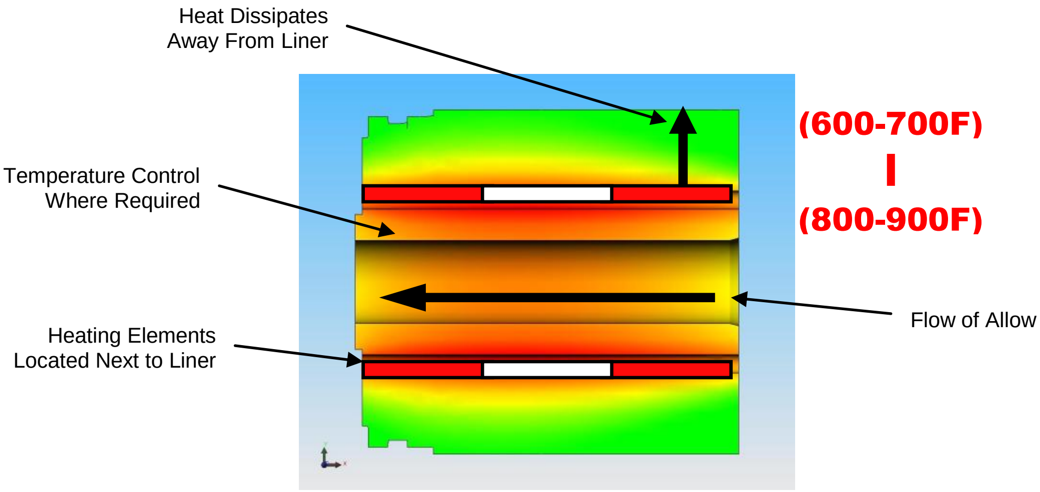

FIGURE 3 – Thermal FEA of Castool Sub-Liner Container

Rating a Container

Performance:

The performance of a container depends on its temperature control system being able to constantly maintain a uniform alloy temperature from top to bottom during the extrusion stroke so that the flow of metal into the die will also be uniform.

Operating Life:

The life of a container depends to some extent on preventing excessive temperature variation between the ID and OD of the mantle.

Lubrication

At the end of each extrusion cycle, the dummy block must separate cleanly from the butt, without removing the section from the die, and without breaking the mandrel cone in the dummy block. Sticking can be a serious problem, especially when using the softer alloys, and with larger billets. It is absolutely essential, therefore, to lubricate both the billet and the dummy block to make separation easier.

Every technology improves over time, and becomes increasingly effective. In light metal extrusion, lubrication is no exception to this rule. What began many years ago as an oily rag on the end of a stick, has evolved into acetylene sooters which, although fairly effective, are often difficult to control. They also produce toxic fumes.

After an extended period of testing and comparison, the product Castool has chosen as its preferred tool release lubricant, is Liquid Boron Nitride. This was developed specifically for use by aluminum extruders.

Just now, boron nitride is universally considered to be the ultimate lubricant for extruders. It is easily applied in precisely calculated amounts to the billet, log or butt shear blade, or container seal face.

The lubricity of liquid boron nitride is unmatched. Experience has shown that usually boron nitride need only be applied to every 3 – 5 billets. The quantity used is easily controlled, and the billet usually transfers enough to the dummy block that no further lubricant is required.

As well as facilitating the separation of block and butt, boron nitride lubrication is helpful to reduce wear at the area of contact between the tapered mandrel in the dummy block, and the lip of the shell that it expands.

Castool's Liquid Boron Nitride Lubrication System

Water based Boron Nitride Tool Release, along with Castool's Liquid Applicator, has a number of significant benefits. The applicator design incorporates a control panel, hopper and pump, and nozzle system.

TOOLRELEASE™

FIGURE 4 – Castool's Liquid BN Applicator

The lubrication system has been designed to adapt to almost any required configuration. The closed loop system, combined with Gerlieva technology allows Castool to manage multiple nozzles at one time. With one system it can lubricate the log and butt shear, as well as the billet end.

Gerlieva nozzle technology effectively atomizes the liquid Boron Nitride to reduce overall consumption. Atomization takes place outside the nozzle cap. This ensures that there is no product buildup within the nozzle tube. Nozzles can be quickly interchanged to provide different spray patterns needed to achieve proper coverage.

The Castool multi-zone nozzle system provides separate spray control for each nozzle head, thus allowing for multiple targets. The nozzles work within the closed loop system, utilizing the closed loop pressure to aid in the atomization process.

Spray pressure and duration are both adjustable to ensure complete coverage without costly overspray.

Rating a Lubrication System

Performance:

An effective lubrication system should . . .

- Ensure instant and clean separation of the dummy block from the butt.
- Ensure the butt release from shear.
- Keep the container seal face clean and free of aluminum.
- Create no graphite or oil contamination.
- Produce no toxic fumes.

Operating Life:

The life of a lubrication system is reflected in the operating life of the equipment it lubricates.

Conclusion

The global market for light metal extrusion is expanding. Large multi-national extruders are increasing their market share. They are bringing extrusion technology, product complexity and quality, and productivity to new levels.

Extrusion is a holistic process. All parts must work together. Production should be considered as a cohesive system comprising a series of mini-systems, all working together. No single component operates alone.

Good alignment, thermal as well as physical, is essential to successful extrusion.

In evaluating any part of an extrusion system, there are only two measures . . How will it affect production of the product? How long will it last?

Considering extrusion as a system, and constantly measuring the real worth of all parts of it, is a proven formula for better productivity. In an increasingly competitive market, improvement is essential to success. Extrusion is no exception to the rule that anything that can be measured can be improved.