THE MAINTENANCE OF EXTRUSION PRESSES WITH SPECIFIC REFERENCE TO PRESS TOOLING

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ABSTRACT –- The interest on money borrowed to finance the purchase of extrusion presses and their ancillary equipment is paid 24 hour a day, 365 days a year. The performance of the press maintenance activities is measured by the availability of the presses. The benchmark is to have the presses operating all the time. Since the output from the press defines the throughput of the extrusion plant, the cost per operating hour of the presses can be expressed as the total plant operating expense divided by the time the press is producing extrusions. This is also the true cost of unplanned downtime.[1] This paper discusses design, operating and maintenance issues associated with extrusion press tooling.

INTRODUCTION

The downtime of an extrusion press system is dependent on the reliability of each working component and its parts. This comprises log or billet racks, the furnace, the hot shear or saw, the press, the run-out table, pullers, the cooling table, the stretcher, the batching table, feed conveyors, the saw table (with its own feed conveyors), the saw and the stacker. And, whereas a reliability of 99 percent might have been acceptable when presses extruded onto a fixed run-out with little additional handling, it is totally unacceptable today. The reliability of an automated press system is the sum of the reliability of its component parts. If each of the sub-systems listed above were available only 99 percent of the time, the system would be down–inoperable–12 percent of the time![2]

The service failures of a number of critical extrusion press components have been analyzed. Properly design and manufactured dies, stems (fixed dummy blocks), and containers can fail prematurely if they are not installed, operated, and maintained with due regard for the designed loading and the properties of the materials at elevated temperatures.

Since most of these components are manufactured from H13 type hot-work tool steels, preheating is essential. But, sustained heating at high temperatures is to be avoided. Likewise, the components in question are designed to carry loads applied in case-specific directions. And, though proven to perform well in loading conditions that are described as low-cycle fatigue, they are not designed, nor are they capable of withstanding highly eccentric loading or impact loading which may, or may not, be in the direction of the design loads.

On Quality

Although it is often demonstrated that there is a large market of second-hand extrusion presses and ancillary equipment, their quality varies greatly. Older, large extrusion presses, because of their robust construction and relatively short fatigue cycles, often represent a good investment. But old billet furnaces, die ovens, handling systems, saws, and age ovens, have often been misused and abused, and often don't work properly or at a rate consistent with the productivity and quality of today's requirements. Used small and medium size presses are rarely a good investment.

In the last 30 years, the design of extrusion presses and their ancillary equipment has changed dramatically. Press builders, manufacturers of furnaces, ovens, and handling systems have responded to demands for increased productivity and recovery with innovative designs. Efficient log or billet furnaces; the zero-contact induction heater; single cell die ovens; the compact extrusion press; *smart* containers; single, double and multiple pullers; heat-resistant, extrusion-friendly belt handling systems; semi-automatic and automatic stretchers; and saws and stacking systems have replaced many of the older, manually operated equipment. In the intervening years, competitive and economic pressures have resulted in the re-engineering of many features of the equipment, and the resulting changes have not always been to the good of its operation or its economic life.

Manufacturing machinery is purchased on the assumption that it is "fit for purpose," and that it will deliver product at the required output and quality. The specification of any new (or used) piece of equipment will always include the acceptance standards that set out the teats to be met before final payment is made. An analysis of competitive bids will also include a comparison of the weight of proposed equipment

Before any discussion of why tooling fails, it is appropriate to refer to John Ruskin's (1829-1900) often-quoted description of "quality":

> Quality: there is hardly anything in the world that some men cannot make a little worse, and sell a little cheaper; and the people who consider price only are this man's lawful prey. It's unwise to pay too much, but it's worse to pay too little. When you pay too much you lose a little money, that is all. When you pay too little you sometime lose everything, because the thing you bought was incapable of doing the thing you bought it to do. The common law of business balance prohibits paying a little and getting a lot – it can't be done. If you deal with the lowest bidder, it's as well to add something for the risk you take. And if you do that, you will have enough to pay for something better.

An examination of the failure of returned tooling and ancillary equipment reveals numerous examples where the desire to reduce the up-front cost of tooling has resulted in poor, and, in some cases, plain "wrong" engineering design.

HOW TO MAINTAIN EXTRUSION PRESSES

The press systems described in the introduction are a combination of many components operating in unison. Whereas earlier presses operated with separate, discrete sub-systems including furnaces, run-out, handling, stretcher, and saws thereby allowing for some operation in the case of breakdown or adjustment, the overall reliability of the modern system is no better than the reliability of the weakest link.

In recent years, extrusion press systems have become more reliable through the use of programmable logic controllers and sophisticated diagnostic software programs. Improvements to the engineering of components such as belts, couplings, valves, and micro-switches have increased the mean time between failures (MTBF) of these components. The development of non-contact position sensing devices has removed some components from the system. Understanding of the mechanisms of wear has resulted in the development and use of new lubricants, and increasingly stringent requirements for the control of cleanliness and temperature of hydraulic fluids.

The combination of these developments has improved inherent reliability and has permitted the introduction and development of automated extrusion press systems. The downtime of a system of log or billet racks, furnace, hot shear, press and run out, pullers, cooling table, stretcher, batching table and feed conveyors, saw table (with its feed conveyors), saw and stacker will, as was pointed out earlier, be dependent on the reliability of each of the component working parts.

In planning to improve reliability, the design and maintenance engineers must consider the inherent reliability of each part, the probable mean time between failure of each part, the number of working parts, and the time taken to fix a problem. A problem that only takes a few seconds to correct is not much of a problem if it occurs infrequently. But if it recurs with every billet pushed (as with a billet loader that must be manually assisted, a butt discard that fails to separate from the shear, or spacers that do not feed consistently to the stacker) it will require the undivided attention of an operator at some time during each working cycle. Again, the reliability of the system is a function of the reliability of the sub-systems.

Press Alignment

The alignment of press components must be kept within tight tolerances. Improper alignment is one of the causes of inconsistent die performance; it causes premature failure of fixed dummy blocks and, in extreme cases, damage or breakage to stems, containers, and tie rods.

Modern, self-contained extrusion presses are constructed with a fabricated steel base extending the full length of the press. The rear platen is fixed to the fabricated base. The front platen, connected to the rear platen by the tie rods, is keyed to the base, but free to slide forward and backwards during each stroke of the press. Older presses, which are often constructed without the fabricated base, have separate foundations for rear and front platens.

The base (and foundation) must be level and in good condition, and the stem and container must move parallel to the base throughout the press stroke. Optical (laser) instruments are used for these measurements.

Although it is often assumed that there has been no change to the original symmetry of the columns with respect to the center-lines of the platens, it is believed that alignment should start with confirming the condition of the guide-ways, (including that of the front platen), the stem and die pressure plates; and the relative position of front and rear platens, the stem and the container with the ram in the forward and back positions.

A complete alignment then starts with the platens—with pre-stressing of the tie rods—and proceeds to the main ram, stem, container, die slide, shear, and billet loader.

Alignment can be continuously monitored, but is usually checked by press crew using the impression of the fixed dummy block on card, which is placed between the block and the die face, by checking butt discards, or by the use of an alignment stack.[3]

Inspection

There is no substitute for regular inspection. The press ways must be inspected for signs of uneven wear. The stem, the fixed dummy block, the butt discard, the container faces, and the shear are inspected for evidence of misalignment.

As the press goes through its cycle, the inspector must look for uneven or hesitant motions as they occur and note their possible origins (which could even be a misalignment of the shear blade, pressure plate, or inadequate control of die stack dimensions). Strain gauges that are fixed to the press columns can monitor the loads on the press and provide early warning of uneven loading. In addition, they are sensitive enough to indicate hesitation in the motion of the container, die slide, or shear.

Attention to lubrication of press ways will minimize wear, but lubrication applied elsewhere is detrimental to the extrusion process. Understand that lubrication of the fixed dummy block, the shear blade, the face of the container, and the die stack should be kept to an absolute minimum. Lubricating the face, or worse, the periphery of the fixed dummy block, risks introducing lubricants into the container, with the attendant risk to product quality. Lubricants can be carried through to the longitudinal welds of hollow aluminum sections. They will also be entrained in the transverse welds in solid and hollow sections causing welds to fail during stretching or in service.

Excessive lubrication is sometimes justified as a means of extending the life of the fixed dummy block. The moving surfaces of the fixed dummy should be lubricated with high-pressure lubricant before assembly. But, any lubrication, which is necessary to enable the butt to separate from the face of the dummy block, is best applied to the billet before the billet heater or, in the case of a hot log shear, between the shear and the press.

Excessive lubrication of the shear blade or the face of the container suggests that the blade clearances are not correct; this in turn suggests that the length of the die stack is not precisely controlled or the die stack is not seated properly. “Show the shear blade the lubricant, and wipe it off.”[4]

The development of lubricants that contain no graphite or petroleum-based products has removed many of the risks associated with the use of hydrocarbons in high temperature, high-pressure environments. Furthermore, the use of benign lubricants, such as boron nitride, appears to minimize or eliminate problems that can occur when hydrocarbons or their residues enter the longitudinal welds in hollow sections. Boron nitride (BN) can be applied to the back-end face of the heated billet, to the internals of the fixed dummy block, and to the butt shear.

Extrusion Dies

Extrusion dies, particularly hollow extrusion dies, will fail if they are not properly supported. The platen ring, the sub-bolsters, and bolsters must be flat, round and the faces must be square. Few, if any, first class extruders still use common die backers due to their deleterious effects on the performance of the extrusion die. But bolsters and sub-bolsters are usually common to a number of hollow and solid dies. Support tooling—common backers, bolsters and sub-bolsters, and the pressure ring—will distort with time. The flatness of the working surfaces must be monitored; distorted and dished tooling must be replaced. On presses equipped with in-line quench systems, particular care must be taken to monitor the condition of the pressure ring due to the possibility of corrosion between the ring and the platen.

Extrusion dies can break and fail to run properly if they are not heated to the correct operating temperature. The die should be heated as quickly as possible, without overheating the surface, and held at temperature no longer than is necessary to accommodate the production schedule. Properly designed and constructed single cell die ovens ensure that extrusion dies reach the correct, uniform, temperature in minimum time. Visual management systems will ensure that the correct die is delivered to the extrusion press just in time.

Figure 1. Die oven development, showing an instrumented die being monitored to ensure that overheating cannot occur in service

The merits of heating support tooling are well understood, but, although some extruders pre-heat the bolster, few extruders use bolsters with integral heating systems. In most applications, preheating the bolster will improve the performance of the extrusion die. However, electrically heated bolsters, die slides, and ram-noses (for indirect extrusion) are increasingly being used to maintain the correct thermal gradients during extrusion operations.

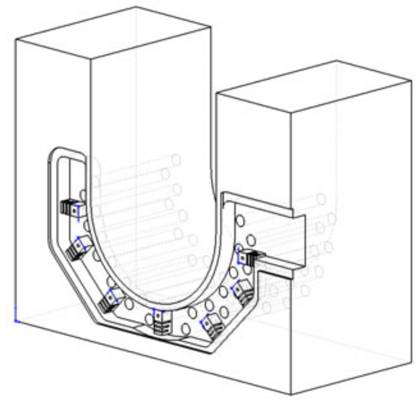

Figure 2. The heated die slide

The electrical heating systems must be properly controlled and sustained. Maintenance of the correct operating temperature for all die stack components ensures that dies run properly from the first billet and that productivity and recovery is maximized.

Press Container

The press container is the most expensive item of press tooling, and its design has evolved with time. However, it is evident that some designs, presumably to reduce the cost of manufacture, have introduced features that weaken the mechanical structure and promote premature failure.

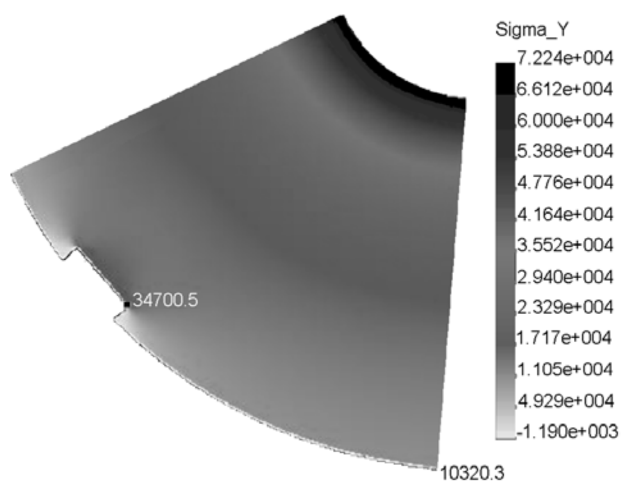

Figure 3. Introduction of a keyway, as opposed to the use of an external bolt-on key, introduces a stress raiser and, in effect, makes the outer surface of the container a redundant structural element

The basic principles of designing thick-walled cylinders subjected to internal pressure are set out in many texts. For example, *Extrusion*[5], by Laue and Stenger, explains how using multiple layers consisting of a liner, sub-liner, and mantle can strengthen the container structure. It also explains how the resulting assembly is weakened by the improper placement of heating elements.

The press container has to be preheated prior to extrusion. However, poorly controlled wrap-around heating systems are known to be the cause of premature failure since they can soften the outer mantle.

The wrap-around heaters are being replaced by multi-functional heating elements inserted in holes in the container. In addition, can heaters, which are inserted into the bore of the container, are used for preheating and maintaining the temperature gradients.

Containers and their thermal control systems must be inspected to ensure that the liner remains in good condition, that the mantle is strong enough to support the liner under pressure, and that the heaters and thermocouples are working as designed.

Figure 4. A container that has been overheated

The Press Stem

The press stem (ram) must be properly installed on an inspected and maintained pressure ring. The stem should be heated prior to use by advancing it into the hot container.

The alignment should be periodically checked to ensure that the stem is concentric to the container bore throughout its stroke. The diameter of the stem is smaller than the container bore, and the face of the stem is usually designed to carry a fixed dummy block, so that the maximum unit pressure on the stem is higher than that on the face of the dummy block. The stem is designed to be uniformly loaded. Eccentric loading, which can occur for a number of reasons, may result in the stem bending or breaking. Improper press alignment (the result of inadequate inspection and maintenance procedures), a hanging butt preventing proper sealing of the container, or, for example, poorly cut billet can result in eccentric loading.

Because it is highly stressed, the surface of the stem must be kept free of surface defects. Improper handling of the stem, accidental mechanical damage or rapid heating or cooling of the surface from direct flame impingement or stray water must be avoided. The surface of the stem must be free of stress-raisers; the stem should periodically be stress-relieved.

Table 1. Recommended Practices for Stress Relieving Stems

Compressive Stress Range during Operation	Recommended Interval for Stress Relieving
180 – 200,000 psi	20 – 30,000 cycles
160 – 180,000 psi	30 – 40,000 cycles
130 – 160,000 psi	40 – 50,000 cycles
100 – 130,000 psi	50 – 60,000 cycles
below 100,000 psi	100,000 cycles

The Fixed Dummy Block

Fixed dummy blocks must be properly sized for the press and aluminum alloy being extruded, and they should expand and contract a fixed amount on each pressure stroke. Single cell ovens should be used to preheat the fixed dummy block, and, while in service, the dummy block can be kept at temperature by advancing the press ram to bring the dummy block into the container whenever the press is stopped.

The fixed dummy block should be inspected daily. It should be visually checked for aluminum build up on the face and the land. The land should also be checked for evidence of explosions. The mandrel should be free and forward from the face of the dummy block.

Once each week, the dummy block should be removed from the press and cleaned in caustic. It should be visually inspected for signs of wear, and measured accurately across the face. The dimension should be recorded and compared to the diameter of the block when it was new, since the dummy block will eventually grow to take up a permanent set.

As the diameter of the dummy block increases, blisters will form on the extrusion. Machining the land to the original diameter can prevent these blisters and extend the dummy block's life.

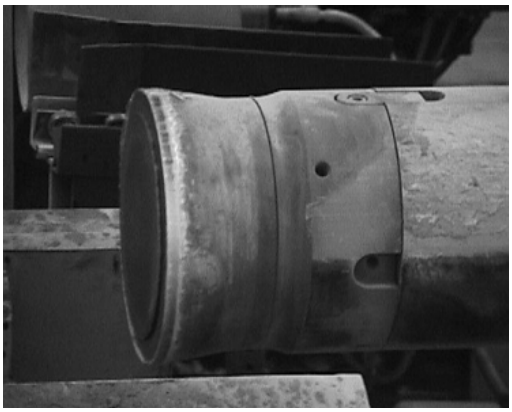

Figure 5. Fixed dummy block in good condition on a 2500 ton press

All the components mentioned above must be mechanically and thermally aligned at all times.

The Butt Shear

The butt contains the surface skin of the billet that has flowed inwards and across the face of an advancing dummy block. At the end of each press stroke the butt must be discarded. With the container open, and the stem and dummy block inside the container, the butt, which is still attached to the back of the die, is exposed, ready for removal.

Modern extrusion presses are equipped to position the butt so there is about a 0.020-inch (0.51mm) gap between the die face and the path of the shear blade. Older presses must be maintained so that the relative position of die face and shear blade retain this clearance.

The design of the shear blade varies with the size of the extrusion press and the alloy being sheared. Common alloys, with smooth as-cast surfaces and little shell zone, can be extruded down to a very thin butt. This butt must literally be peeled from the extrusion die face. Hard alloys are typically sheared using a blunt or block shear.

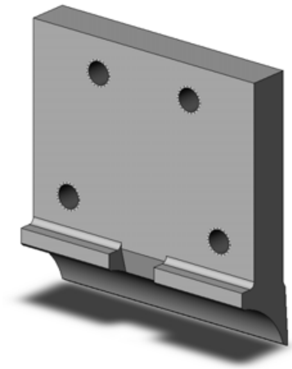

Figure 6. The butt shear

Press Maintenance

The press system must be maintained to meet its performance capability. The billet furnace must deliver the billet at the specified temperatures. The press must be correctly aligned. Pressures, speeds, and clearances must be maintained to eliminate the creation of mushrooms and flashes, and to ensure that the butt shear cuts cleanly, and the fixed dummy block operates properly. The equipment must be available for operation at all times.

Making equipment available for use requires an understanding of why it breaks down. Understanding why machinery does not work comes from taking appropriate measurements and an intimate knowledge of machine design.

SUMMARY

Extrusion dies–hollow and solid–break when the load, and hence the stress in the H13 tool steel, exceeds its ultimate strength. Although thousands of extrusion dies are put into use every working day, die breakage is extremely rare. Breakages are usually limited to details that are difficult to support. However, H13 is a hot-work tool steel and must be preheated prior to its use. Improper preheating in traditional chest ovens, where continual loading and unloading of dies disrupts the intended heating cycle resulting in cold dies being loaded into the extrusion press, has been shown to be one of the causes of premature failure. Whereas too low a temperature can result in breakage, die temperature that is too high can result in premature failure because of excessive wear.

The press stem, although not in the true sense of the term structural column, has to withstand high compressive stresses. Although on many extrusion presses, the unit pressure will not exceed 80,000 pounds per square inch, modern high-performance presses consistently operate with a unit pressure in excess of 110,000 pounds per square inch. The fixed dummy block is designed to ensure that the loads are not concentrated.

Because of the high unit pressure, the static alignment of the press stem, container, and the die stack must be maintained within close tolerance during the operation of the extrusion press. This ensures that the load on the stem remains axial to the stem.

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