CONSIDERATIONS FOR MANUAL & AUTOMATIC GREEN SAND EXPANSIONS

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WHITE PAPER TAKEAWAYS

- Jolt Squeeze Machines
- Automation Matchplate Molding
- Gravity-fill machines vs Blow-fill machines
- Horizontal Tight Flask Molding Systems
- In-line vs Cross-Loop vs Pallet Index Lines

Foundries, guiding their business, have to survive through the various economic cycles as well as emerging market pressures, are well aware of the continuous need to reinvest in equipment to increase productivity, and decrease the manual content of casting production, while still producing consistent castings economically in a very demanding market. From their position, the molding machine manufacturers have to provide the properly developed equipment and/or molding process to meet these demands, while at the same time improving casting quality and maintaining a safe working environment.

The continuous evolution of the mechanization of green sand molding has grown from simple jolt table, used to compact sand in the molding box, to the automatic systems of today, producing in excess of 400 molds per hour, with little or no manual involvement. Mold quality which can be achieved on today’s molding machines is such that many of the old defects once associated with green sand have been eliminated or greatly reduced, either by using a simultaneous jolt squeeze action, or high pressure squeeze to minimize mold wall movement during pouring and solidification.
Green sand molding remains an attractive casting production method for two main reasons:

1. Green sand production is and will always be less expensive, as the price of chemical binders continues to rise faster than normal inflation.

2. Green sand foundries are not as labor intensive.

One obstacle preventing foundries from moving into green sand molding is the high capital cost of even a simple mechanized plant. However, foundries should realize that the increased productivity that green sand molding offers will offset these costs over time and have the potential for higher revenues.

However, before embarking on a high cost green sand investment program, certain questions should be asked and answered in order to establish whether it is necessary to invest in some form of mechanized molding equipment.

a. What are current mold production/Future mold production requirements?
b. Is current casting quality consistent and reliable?
c. Is scrap is too high?
d. Are my lead time delivery dates too long for large volumes?

STANDARD MOLDING MACHINE SOLUTIONS
Standard Jolt Squeeze Machines
To minimize the initial green sand investment, standard molding machines offer a major advantage because a foundry can mechanize for green sand molding with reasonable initial expense, and the balance of the mold handling can be built over time. These machines can be the small 212/214 jolt machines, up through the 722 & 730 jolt molding machines. These machines can use almost any standard green sand match plate and cope and drag pattern equipment. A number of flask sizes can be can be employed on the same machine, giving flexibility of production and product range.

A standard molding match plate solution can be found where cope and drag are formed simultaneously. The overall operating efficiency of these machines is very much dependent on the operator’s ability to continually carry out these machines manual functions. By implementing mechanized mold handling systems, as previously stated, the machines can provide more productivity.

Automatic Horizontal Flaskless Molding (Matchplate)
After the development of the jolt, rap, and squeeze molding technology, the focus of the machinery for green sand mold production was put into handling systems designed to reduce the reliance on labor to achieve a more reasonable production rate. Automatic horizontal flaskless molding machines, sometimes known as automatic matchplate molding machines, were designed and first introduced to foundries in the USA in the mid 1960’s. These machines have probably had a more rapid growth in their use than any other innovation to green sand mold production in the last 60 years.

The main reason for this continued success in the US is that many small to medium foundries were of the type known as “Squeezer Shops”, using standard jolt squeeze machines or Roto-lifts with snap flasks and matchplate. With so many matchplate patterns available from the OEM manufacturers, it was quite common for the foundries to install one of these machines and use their customer’s existing patterns.

These automatic horizontal match plate machines are a relatively economic form of molding mechanization. The machine produces a complete mould in one cycle and only requires one machine operator who can set cores as necessary, thus removing some of the reliance on manual labor to make the mold. Production rates can be over 200 molds per hour un-cored. If cored work is required, the foundry is limited to automatic core setting if it wishes to maintain maximum production, although automatic core setting is really a misnomer, since a man is required to put the core or cores into the setting unit.

Two methods of filling are used in flaskless molding:
1. Gravity fill & Squeeze
2. Blow fill & Squeeze
The molding process for both the Gravity and Blow machines is virtually identical. Consequently, for the purpose of this comparison our comments will apply equally to both machines.

With blow machine, the pattern plate is trapped in between the cope and drag flasks which are then tipped up on edge so that the pattern is vertical. Sand is then blown straight down from a pair of blow slots to fill the flasks from above. This means that sand, which is traveling at a very high velocity, must make a right angle change of direction in order to fill deeper green sand pockets or mold cavities. Consequently, there are frequently problems filling and drawing deeper green sand pockets and cavities. Gravity fill & squeeze machines have shown to give more consistent mold quality and are more suited to deep and complicated pattern shapes.

This has been a well known weakness of the side blow machines since were invented 50 years ago. Even though these newer machines tip the flasks and patterns up on edge to blow, it is still essentially a “side-blow” relative to the pattern.

Blowing a mold at the typical 40 or 50 psi pre-compacts the sand before it is squeezed. This makes it necessary for blow-fill machines to squeeze harder in attempt to force the sand into pockets on the pattern. This often results in a mold that is harder than desirable on the flat areas and the parting line, but too soft in deeper pockets and mold cavities. These higher squeeze pressures require thicker and more expensive patterns to avoid pattern flexing and breakage. If a green sand pocket is not completely filled during the blow cycle, it is virtually impossible to squeeze hard enough to correct this problem.

Aluminum foundries do not want to make a mold that is too hard because of gas problems caused by the reduced permeability of harder molds. Blow-fill machines sometimes have problems in this area due to the fact that they must squeeze harder to get an acceptable mold density in deeper pockets. The important point is that mold hardness alone is not necessarily good; uniform density and repeatability is!

Squeezing a mold too hard can cause green sand molds to break off rather than draw properly. Research has proven that any increase in mold hardness at squeeze pressures above 140 psi is almost negligible. Furthermore, higher squeeze pressures cause a phenomenon called spring-back in the sand. Under these conditions the sand actually springs back after the squeeze, and control over the casting dimensional tolerances is lost. Since there is not enough space between the sand grains for normal thermal expansion, there will be expansion defects in the castings and other defects due to cracking of the mold.

There are newer technology improvements of machines that work with gravity to fill the flask. Sand is riddled evenly onto the pattern through an aerator, and the flask & pattern is vibrated during the fill. The mold is then squeezed and drawn according to a computer controlled recipe. Sand in the flask is still highly flowable and can normally be compacted to mold hardness in excess of 90 with a squeeze pressure of only about 100psi.
As previously mentioned, any large projections or obstructions on the pattern plate make it difficult to get an adequately dense fill of the mold on the side of the mold opposite the blow slot. This causes what is commonly known as the “shadow effect” which is a soft spot in the mold. These soft spots prevent the mold from being uniformly dense and are a troublesome source of casting defects and scrap. This is why blow type machines are generally limited to doing smaller castings without any deep or difficult pattern shapes.

Large, deep or asymmetrical castings often require the use of patterns with an offset parting line. This offset parting will create an additional obstacle to the sand being blown in at 90° to the surface of the pattern plate. The obstruction is at least equal to the amount of offset on the parting line of the pattern.

Since anything sticking up from the pattern can exacerbate these problems, the blow process also severely limits where pouring basins, down sprues and risers to feed the casting can be located. This can be a serious problem when large risers are required or the pattern plate is crowded. The pouring cup and down sprue locations are further restricted due to the squeeze cylinder location and other mechanisms on the back side of the squeeze head. This restriction can cause a problem with efficient pattern layout, and the number of parts or pieces you can get per mold. It also dictates which way any given pattern must be oriented when the job is run on the machine which can cause difficulties for efficient core setting or pouring.

Patterns with deeper green sand pockets require venting to run on blow-fill machines. These vents are used in an attempt to get sand to flow into deeper pockets. This increases the cost of the pattern and later becomes a maintenance issue. While vents in the flasks are necessary for venting the mold, they are not very effective for filling pockets. If both halves of the mold are blown simultaneously, the blow pressure on both halves of the mold is equal. Then, how can venting through the pattern to fill a pocket on one side make any difference? Some blow-fill machines have the ability to blow the cope first and then the drag, or the reverse, depending on which side has the deepest pockets. This is called a “staggered-blow”. The theory is that the air will escape through the pattern vents and in the process carry sand with it into the pockets. The realities may be somewhat different.

Accelerated flask and pattern wear is a problem due to the “sand blasting” effect caused by the blowing sand. Any projections on the pattern directly in front of the blow slots will wear the fastest and experience the most severe damage. Also, operating costs and down time will be higher with numerous blow seals and flask and pattern vents to maintain and replace.

Squeezing the mold from both sides requires that both halves of the mold be filled with sand uniformly, and the squeeze pressures on both cylinders be perfectly balanced. Otherwise, the result will be a damaged or broken pattern plate. Users of blow-type machines must be very careful to adjust the machine’s operating program during every pattern change. Attempting to make a mold that is not tall enough for a particular pattern can easily break or damage the pattern plate. High sand compactability when making a mold or a blow that is short of sand can also break the pattern.
In contrast, the gravity filled machine squeezes from the bottom and the pattern and flasks move up against a fixed squeeze head. In this process the pattern essentially floats, so that the squeezing forces on both sides of the pattern are naturally equal. The control system also protects against over squeezing due to short filling of the flasks.

Large asymmetrical castings such as cooking pots or brake drums inherently cause the biggest problems for these machines. One side with a large cavity will require significantly more sand and a longer stroke to squeeze. The other side with a large flat surface on the projection will require less sand and only permit a short squeeze stroke. This is very difficult to balance and control with the blow-fill machines limited ability to consistently fill and squeeze deep pockets to an adequate and consistent mold density.

Blow-fill machines permit only small variations in sand properties, especially moisture and compactability. Wet sand and/or higher clay levels will quickly plug up the machine’s blow head.

**Sand Segregation**

Most foundry workers are aware of sand segregation problems that occur when sand is transported pneumatically. There are indications that this occurs to a degree during the blow-fill molding process and that finer material ends up at the mold interface on the joint line of the mold. This further reduces the mold permeability and can contribute to gas problems in the mold. In contrast, gravity-fill machines do not fluidize sand, so this is not an issue. Gravity machines can easily adjust squeeze pressures and vibration to produce a mold of optimum and uniform hardness for even the most difficult pattern configurations.

Operating blow-fill machines in warm or tropical climates can be difficult. A surge tank is required near the machine to supply a large quantity of air on demand. The air must be dry and there can be no fluctuations in the air pressure at the machine. They use large amounts of compressed air to blow the sand. In general they will consume 3 to 4 times as much compressed air as a gravity fill machine.

Warm or hot sand combined with compressed air can cause condensation in the blow chamber. This in turn can cause sand to partially clog or plug up the blow chamber. A batch of sand that is too wet or too dry is very difficult to dispose of once it enters the blow chamber of the machine.

On the gravity filled machine the operator can easily inspect both sides of the pattern and the finished surface of the cope or drag molds before closing. With the blow machines, the operator never sees the drag side of the pattern or the cope mold. This means that the machine could be producing molds with a defect in the cope mold and the operator would never know about it.

Anything that is set on the pattern and/or invested in the mold is a problem for the blow machines. This includes ram-up cores, chills, filters, chaplets, facing sand, exothermic sleeves, insulated or even open risers, etc. The blow fill process precludes all of these operations, since the sand rushing in and pattern tipping up vertically during the molding process would dislodge anything placed on the pattern.

As always it should be kept in mind that green sand mold quality is a function of pattern and sand quality with the third essential ingredient being high density and uniform compaction of the mold.
HORIZONTAL TIGHT FLASK MOLDING SYSTEMS

The development of high pressure molding using flasks, took place in the USA in the mid 1950's. These handling systems were a natural progression away from heavy manual labor, and the reliance on labor to meet production targets.

The IN-LINE arrangement is a single line arrangement, which runs parallel to a mould conveyor. It takes in all stages of mold manufacture from mold pick off, through punch out, flask separation, molding, core placing closing, and placing the completed mold back onto the mold conveyor. This system is designed to accept flask sizes in the range 20” x 16” up to 36” x 24”, with production rates of between 300 to 400 moulds per hour.

The CROSS-LOOP arrangement has two moulding lines, one to produce the drag and the other to produce the cope, as they span the mold conveyor loop. This arrangement is normally used for flask sizes above 36” x 24”, and/or where heavy cores are placed in the drag, as in a cylinder block, for example. Production rates on the CROSS-LOOP are slower than the IN-LINE, normally between 260/300 molds per hour.

The benefits which these two systems offer are the infinite flexibility in use, high productivity and adaptation to all types of castings, especially those requiring cores where the tight flask system is found to be more efficient and economical. This is because more castings can be produced within the same given mold area when compared to flaskless molds.

Core placing does not slow production, since the coring zone is designed to give maximum flexibility, whether two or ten cores need to be placed.

Mold pouring can be automatic, but a pouring zone is always designed into the system to retain flexibility and allow for manual pouring as necessary. The extra cost of labor required for manual coring and pouring is insignificant, because the system is kept running at its maximum output, 300 to 400 moulds per hour, which assists the profitability of the entire foundry.

To further improve the flexibility of these systems, the molding machines can be equipped with a pattern shuttle change unit, so that pattern changes can be made within the automatic cycle without loss of production. Two patterns can be run at the same time or varied to suit conditions and even out core demand, and/or metal availability.

The IN-LINE and CROSS-LOOP systems offer the foundry the most productive and flexible approach to mechanized molding for castings requiring cores at a high production rate of +250 mph. The cost per mould is less than with any other system, calculating initial capital cost, against productivity and running costs.
For lower or more versatile production requirements of today’s jobbing foundry, many of these continuous mold line conveyor loops have been replaced with index pallet systems. Pallet index systems offer the flexibility of parking lines for extended cooling times and can also take up less floor space due to closer line proximity and the elimination of the mold conveyor radius.

The molding machines used in any of the IN-LINE, CROSS-LOOP or even more common today the Pallet Index systems are typically of the high pressure squeeze type.

Investigation using a wide range of squeeze pressures has shown that a casting produced in a mold which has been compacted to a squeeze pressure of 100/110 pounds per square inch, is as accurate as one produced using a squeeze pressure of 200 to 220 pounds per square inch. Therefore today it is generally accepted that the degree of mold compaction increase is very small above a pressure of 140 pounds per square inch in relation to the extra pressure applied. Therefore, molds can be produced which will make castings of consistent accuracy and soundness to meet the technical and dimensional requirements of today’s casting users, by using much lower squeeze forces than was previously thought necessary.

The only advantage to be had by increasing the squeeze force above this pressure is to decrease the time taken to make a mold, since the higher the initial squeeze force, the less time this force has to be applied to the mold in order to achieve optimum compaction. That is, the greater the squeeze force above 100 pounds per square inch, the higher the production rate, until a maximum is achieved around 200/220 pounds per square inch. Above this figure, there is no gain in mould production, or casting quality.

Using this information, some machine manufacturers have developed various means of compacting the mold inside the flask. That is Blow Squeeze, IMPACT molding with squeeze, vacuum molding, or even squeeze (top and bottom in some cases) with compensating peen feet, all in order to reduce the operating noise of the machine by eliminating the proven jolt and rap molding methodology. In practice however, all of these machines have limitations, as to what type of castings they can produce and they are extremely susceptible to varying sand conditions. Inconsistent mold hardness is also common.

In addition, improved hardness distribution is also achieved by jolting or rapping for some seconds to uniformly compact the sand against the pattern face. Then to jolt and squeeze simultaneously to compact the top of the mold preferably against a compensating squeeze surface to sufficiently support the mold face. Some type of pre-jolt is necessary to evenly compact the sand where is is most important to form a rigid mold, at the pattern face and joint line.

Since these types of high pressure automatic production systems require the foundry to use flasks, there are costs and maintenance to consider. Flasks for high pressure automatic molding are expensive, as are pallets/mold cars. Flasks require maintenance cleaning and routine planned pin and bushing replacement. However, they should last at least ten to fifteen years, so cost is expensed over a long period.
These systems require handling equipment through the various stages of mold and casting production. The most important job they do is to ensure parting line accuracy. They support the mold through its various stages of movement and assist in resisting the metal head pressure, allowing a softer mold to be made than is necessary for a flaskless one. Because the green strength requirement is less, so is the clay content. This reduces the cost of sand preparation and increases mould permeability. They also allow at least 80% of the mould area to be used, where only 60% can be used effectively without flasks.

The higher capital cost of a high pressure IN-LINE, CROSS-LOOP or PALLET INDEX system does to some extent limit their market, however with life spans over 25 years, this investment needs to be weighed against the demand and productivity capacity these systems create.

The heart of the high speed systems and the part which keeps it producing moulds in excess of 300 per hour, is the molding machine. Being high pressure jolt squeeze units, powered hydraulically, they can be costly, but from experience and knowledge built up over many years, certain criteria are necessary to include in a four post molding machine to produce molds of consistent high quality.

a. Rigid structure to withstand the forces developed by the machine.
b. Sand hopper to evenly distribute the correct amount of sand into the flask.
c. Aerator to fluff the sand as it falls into the flask.
d. Upset frame to give a head of sand above the flask for squeezing.
e. Pre-jolt action to compact the sand before squeezing.
f. Option of simultaneous jolting with squeezing to improve effective squeeze forces.

A high pressure molding machine will possess all of these features.

Referring back to investigation of the effects of jolting and squeezing, the jolt was found to be very important whereas squeeze assisted in improving mold rigidity, but also decreased the production cycle as the pressure increased. This has led to the development of a range of systems that can utilize one molding machine rather than having to use two machines, with the utilization of a pattern shuttle to make the cope and the other to make the drag.

As most four post molding machines incorporate a pattern shuttle for rapid change of pattern, this unit can be used also for producing cope and drag half molds alternatively, making it possible to have only one molding machine in the system. This immediately cuts the production capacity in half, but also reduces the capital cost significantly. It is possible to achieve up to 100/120 molds per hour using a single machine within an IN-LINE arrangement.

Referring back to information that the jolt is more important than the squeeze for hard rigid molds, it was thought possible to obtain this, with a flat squeeze head, leading to the design of a four post machine without the expensive squeeze feature.
CONCLUSION

It is fairly reasonable to forecast that green sand will continue to be the most important medium for making molds, well into the foreseeable future. The demand for castings in the developed countries will decrease further, and alternative methods and materials will be adopted. The foundries which survive the market changes that will take place during this transition will have to mechanize more effectively and economically as basic labor, will either be too expensive or unobtainable.

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