tire
technology
INTERNATIONAL

Blast off

CO_2 blasting has had a big impact on tire mold maintenance. Strengths include in-press cleaning and simultaneous microvent clearance.

Molding the final tire shape and polymerizing, or curing, the rubber compounds that make up the compound are usually the final stages of production. By the time the 'green tire' has reached the curing press, most of the cost associated with manufacturing has already been incurred.

Dirty or 'fouled' curing molds introduce imperfections that can cause tires to become scrap at the point of the manufacturing process where the financial impact to the company is greatest. Solid carbon dioxide pellet-blast mold cleaning is arguably the most complete and cost effective method for tire manufacturers to eliminate this expensive problem. First, however, all of the costly problems associated with dirty curing molds must be understood before the benefits of in-the-press carbon dioxide pellet blast cleaning can be discussed and appreciated.

Mold fouling is a residue build-up on the curing surfaces of tire molds caused primarily by chemical reactions of sulfur and zinc oxide under heat and pressure. Excessive fouling in the bead area of a tire mold can cause enough surface irregularity in the finished tire bead surface so the tire will not seal properly on a wheel. Over time, the tire will slowly leak air, resulting in highly dissatisfied customers. The finely sculpted alphanumeric characters of the transportation department information must, by government regulation, remain clear, crisp, and completely legible from cure to cure. The surface of the sidewalls must maintain a uniform texture and gloss level to satisfy the market demands for aesthetics. The tread area must be free of fouling to prevent light cure areas on the tread lugs. Also, the brand logo and lettering must remain very crisp and precise because that is the focus area from which customers develop an initial perception of a tire company's product quality.

These are all excellent and obvious reasons for keeping tire molds clean. However, they are not the only ones. The vast majority of tire molds in use today have vents and/or microvents to expel air trapped between the green tire surface and the mold surface as the bladder expands the green tire into the mold cavity. Typically, the microvents are between 0.020-0.040in (0.5-1mm) in diameter and vents are between 0.040-0.060in (1-2mm) in diameter.

Both types can extend an inch or more in depth into the mold. A typical passenger car tire mold contains thousands of these vents. The bladder expansion pressure, combined with the elevated curing temperature, causes some of the tire surface rubber to 'extrude' into these vents during each cure cycle. When the cure cycle is over and the tire is released from the mold, most of the

the extruded rubber in these vents remains attached to the cured tire and pulls back out to form the familiar rubber 'whiskers' on new tires. However, not all of the microvents release their extruded whiskers. Over time, more and more of the vents become plugged with rubber and cease to function. When this occurs, air trapped in the molds begins to cause surface irregularities (light cures) and other faults on finished tires, which ultimately increases the production scrap rate.

Another area of concern is keeping mold surfaces that mate, or come into intimate contact, during cure, free of residue build-up. For two-piece tire molds, these are the surfaces between the two mold halves that come in contact when the mold is closed and produces a parting line in the mid-cross section of the tread pattern. If too much residue is allowed to build up in this area of the mold, the halves will not mate together completely, even under the extreme press squeeze pressure. The result is a noticeable flash around the circumference in the middle of the tread pattern on the finished tire. An excessive amount results in additional labor costs to remove the flash.

For larger and wider tires, curing is typically done with segmented molds. The fit between adjacent mold segments and the fit between the closed segment 'ring' and the sidewall plates have very tight tolerances. If too much residue builds up on these components, small gaps will develop resulting in flash on the tires. For tires cured in segmented molds, flash can be very noticeable and objectionable because it occurs partly on the sidewalls and across the tread pattern. Also, a build up of residue on the mating mold surfaces can cause high mechanical stresses in the fasteners that attach the segments and sidewall rings to the press. The high mechanical loads can cause fastener failures that typically result in very costly damage to both the mold and press.

It should now be obvious that dirty or fouled curing molds can cause loss of production or expensive damage in many ways. There is, however, a technology available to prevent all of this waste of time and money for the tire industry, and that technology is carbon dioxide pellet-blast mold cleaning.

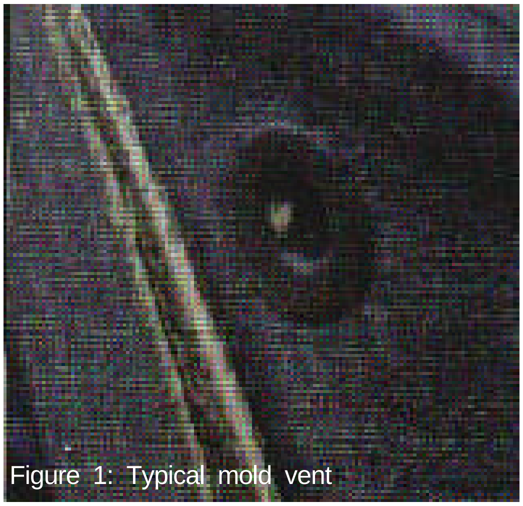


Figure 1: Typical mold vent

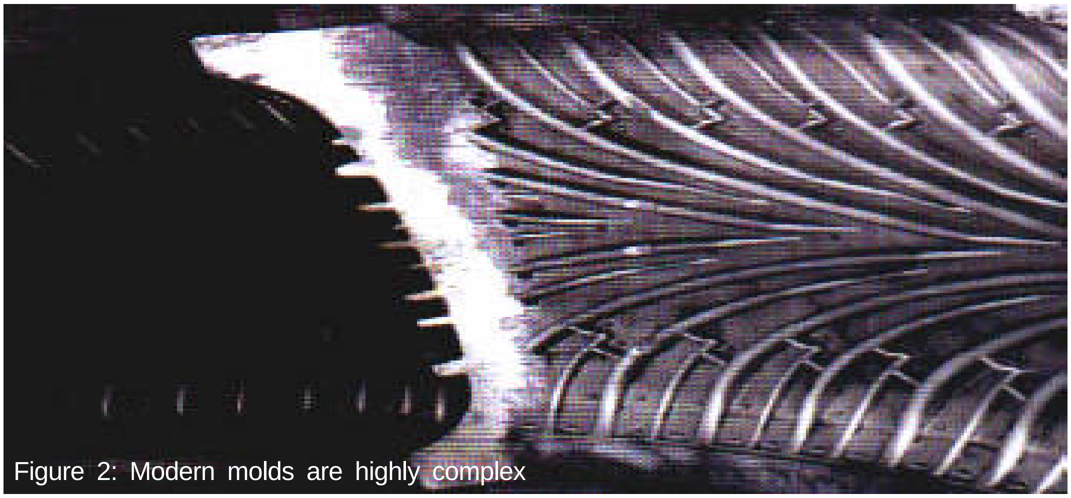
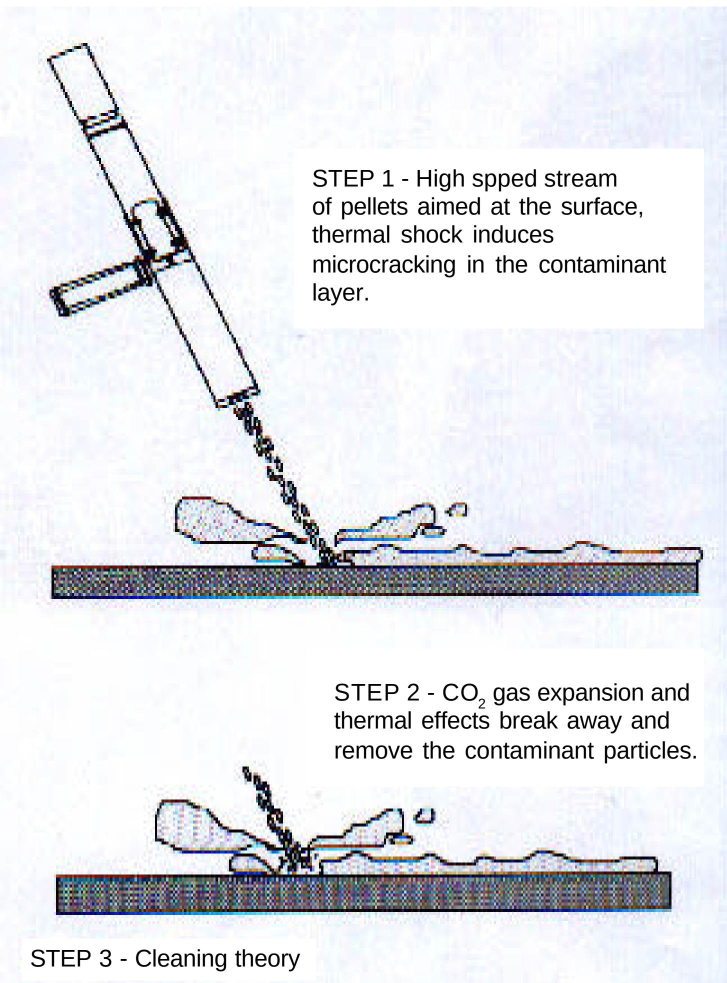


Figure 2: Modern molds are highly complex

How and why it works

Carbon dioxide pellet blasting uses compressed air to accelerate frozen carbon dioxide (CO_2) ‘dry ice’ pellets to a high velocity. A compressed air supply between 60psi (4 bar) and 90psi (6 bar) is required. Dry ice pellets can be made on-site or supplied. The pellets are made from liquid carbon dioxide which is a naturally occurring compound that is non-toxic, non-flammable and chemically inert. CO_2 is inexpensive and easily stored at work sites.



CO_2 works because of two factors: pellet kinetic energy (velocity) and thermal shock (temperature). The performance of solid CO_2 blasting for tire mold cleaning is optimized by combining these forces and tuning the parameters of the system specifically for the application. These parameters are compressed air pressure, type of blast nozzle, CO_2 pellet size and density and the pellet flow rate.

High pellet kinetic energy is achieved by using high velocity supersonic nozzles that are sized properly to fit easily into tire mold details. The ‘single-hose – direct acceleration’ type of CO_2 pellet- blasting system provides the high kinetic energy required to clean fouling residue from tire molds. However, even at high impact velocities and head-on impact angles, the kinetic effect of CO_2 pellet-blasting is minimal when compared to other kinds of blast media (sand, glass beads, plastic beads, etc). This is due to the relative softness of solid CO_2. Also, the pellets change phase instantly from solid to vapor when they impact the surface, so there is essentially no coefficient of restitution for the impact. This means that very little energy is transferred into the mold surface after the thin fouling coating is removed.

The instantaneous phase change from solid to vapor at the point of impact absorbs many BTUs of thermal energy. The maximum amount of heat is absorbed from the very thin layer of surface contaminant, and the extreme temperature gradient between the contaminant and the substrate causes microcracks to rapidly form in the contaminant layer. The contaminant layer literally flakes off the surface of the mold.

The rapid conversion of the solid pellet to gas at the point of impact provides a ‘microexplosion’ of rapidly expanding CO_2 gas which helps flush the particles of contaminant from the surface of the mold.

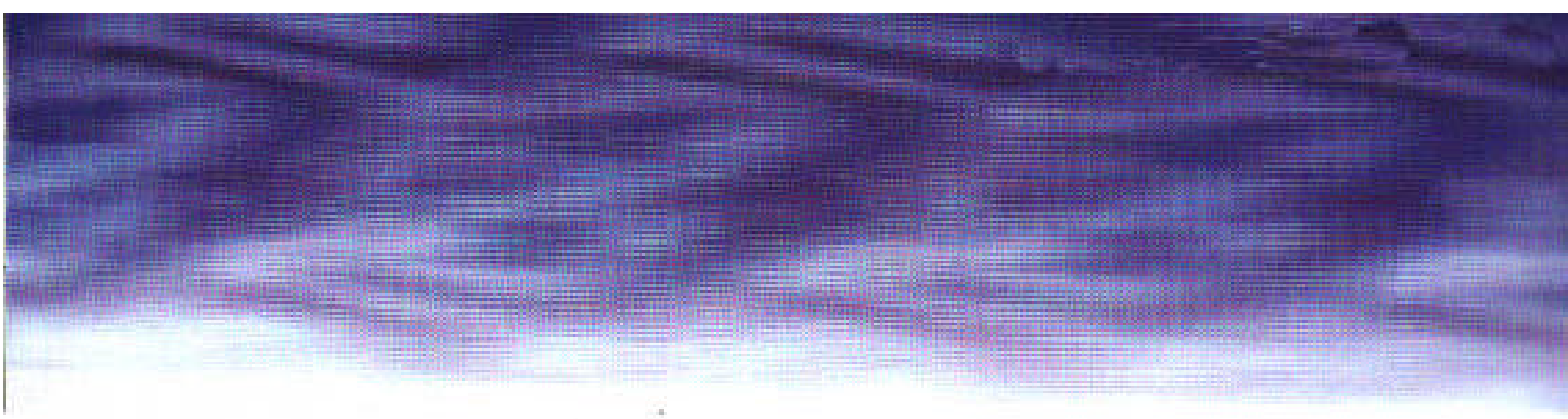


Figure 4: In-press cleaning

The process happens so rapidly that it appears to be a continuous path of cleaning under the tip of the blasting nozzle as the nozzle is moved across the mold surface.

Cleaning in the press

Hot molds are best

Data gathered over the past decade, since the emergence of CO_2 particle blast cleaning as a useful method for the tire industry, supports the fact that tire molds between 300°F and 350°F, can be cleaned three to four times faster than the same molds at ambient temperature. The more reactive chemicals present in the base polymer, the chemicals in cure accelerators and inhibitors, and the chemicals in many mold release agents combine at the curing temperatures to form an almost glass-like material at the product-mold interface.

This glass-like material is different from the polymer material (rubber) of the cured product. The glass-like property of this fouling residue at elevated temperatures allows it to be easily removed from the mold surface and fractured into small particles by inducing high levels of thermal stress, or ‘thermal shock’ with CO_2 pellets. Since the temperature of solid CO_2 is –109°F, the pellet blast stream is an ideal source for inducing thermal shock in the residue layer. At lower temperatures (below 150°F), the fouling residue becomes much more difficult to remove from the mold surface because it resembles a very hard viscoelastic material which absorbs the impact energy of the CO_2 pellets. The thermal shock mechanism ceases to function because there is very little temperature differential between the material and the mold surface. The overall result is very difficult residue removal from room temperature, or ‘cold’, tire molds, and sometimes the residue will not respond to the CO_2 particle blasting at all.

Rough molds are tough

Abrasive blast media, like plastic or glass beads, typically leaves a ‘bare metal’ appearance after residue removal, even on steel tire molds. This ‘like new’ appearance is deceiving because it is achieved at the expense of removing a

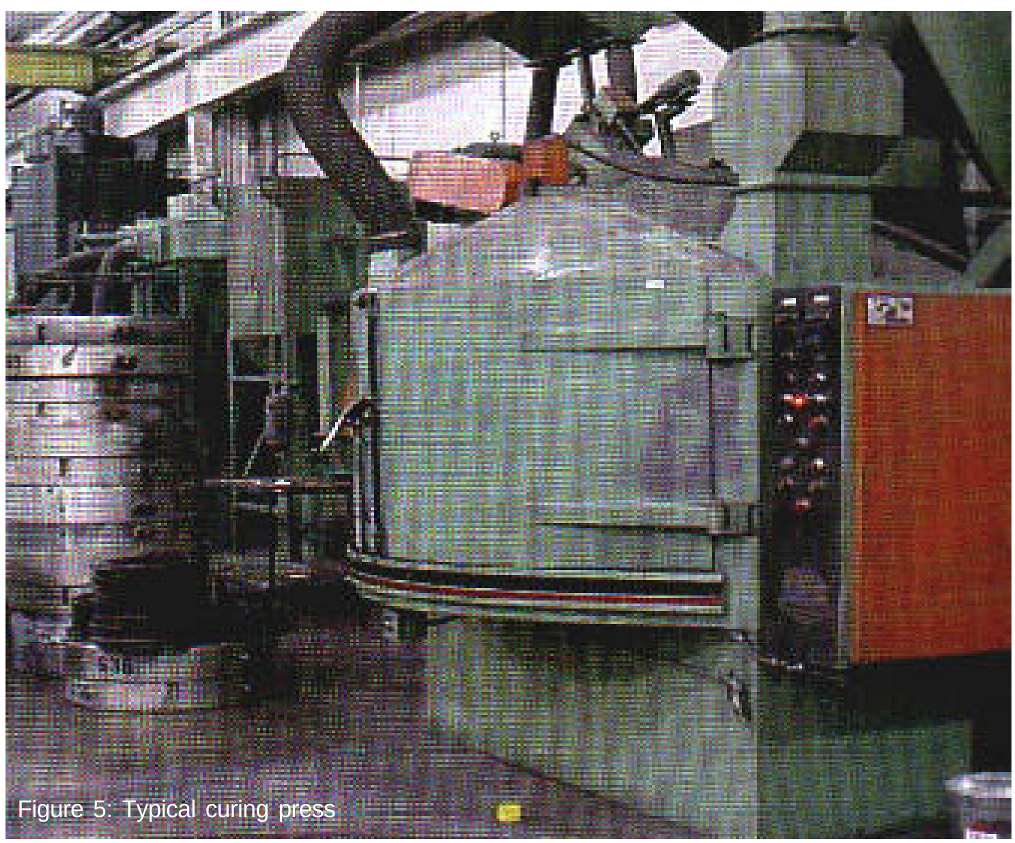
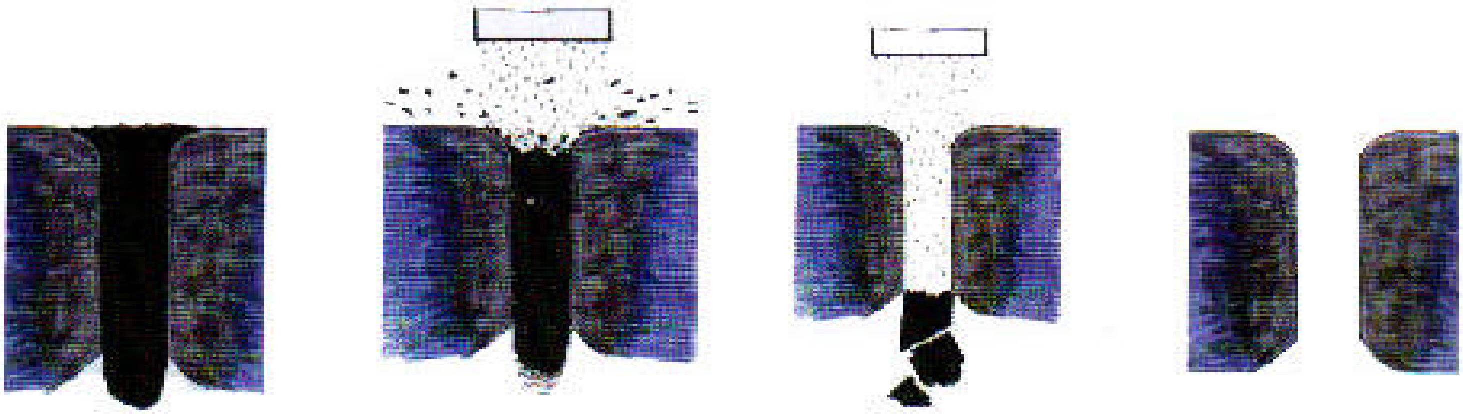


Figure 5: Typical curing press



small amount of metal from the mold surface, and by imparting a much 'rougher' (more micropeaks and valleys) surface finish into the mold from the chiseling effect of thousands of abrasive impacts. The rough surface creates an 'anchor pattern' that was not present in the original mold surface.

This causes fouling residue to adhere and accumulate at an even faster rate than it did on the original mold surface. This mold surface 'erosion' will be discussed below in more detail, but it is evident that what appears to be a 'clean mold' surface is a step toward decreasing the useful life of a very expensive production tool.

CO_2 particle blasting does not abrade or erode the surface of most common mold materials. Since CO_2 particle blasting only removes the residue on the mold's surface and not any surface metal, any dark stains from cured tire compounds will remain on the mold's surface. Following CO_2 particle blasting, a functionally clean, residue free tire mold may not at first appear clean by the old standard of a bright, bare metal surface. The proof of the mold's cleanliness will be seen when the first tires are cured and inspected for the sharpness of the tread, lettering, and logo details, and sidewall surface gloss level.

Clear without drilling

Vents and microvents present a unique cleaning and maintenance problem for the tire industry. During the cure cycle, as the green tire expands and air is evacuated through the vent system, each vent acts like a small extrusion die hole that allows some uncured rubber at the green tire surface to flow into the hole.

Most of the rubber whiskers pull out of the vent holes and remain attached to the new tire upon removal from the mold, but several may mechanically adhere to the vent hole interior bore and separate from the tire. This process repeats to clog a few more vents on cycle. Eventually, so many vents become clogged they have to be cleared to allow enough air to escape when the green tire expands.

The traditional vent clearing method has been to remove the mold from the press, grit blast the sidewall and tread surfaces, then drill the cured rubber out of each vent hole with very small drill bits and air tools. A subset of the clogged vent problem occurs when these very fragile drill bits break off to permanently plug the vents. Then the vent must be removed and replaced with a vent insert. Typical passenger car and light truck tire molds contain thousands of vents or microvents. The labor to drill out clogged vents and to repair vents when drill bits break off in them, plus the cost of hundreds of drill bits consumed per month, adds up to a very significant yearly cost for most tire manufacturers.

In recent years it has been discovered that CO_2 pellet blasting is effective in removing almost 100 per cent of the rubber whiskers and other residue from even the smallest diameter microvents in tire molds. Furthermore, the vent clearing can take place in the press at the same time as fouling residue is being removed, so genuine one-step cleaning can be accomplished. This is the result of the state-of-the-art in single hose CO_2 particle-blasting nozzle design which can deliver very high surface impact energy and thermal energy at very low air pressure and volume.

Most of the mechanical adhesion of the extruded rubber whisker in a clogged vent occurs at the entrance 'lip' of the vent hole where the 'squeeze' pressure on the rubber is high and the extrusion flow velocity of the uncured rubber is low. The remaining majority of the whisker extending into the vent hole has very little adhesion to the walls of the hole. CO_2 pellet blasting delivers enough energy to quickly remove the small amount of tightly adhered rubber at the base of the whisker. The high velocity stream of particles and air immediately after the initial pellets impact, simply blow the unanchored whisker out of the hole, through the vent passages, and completely out of the tire mold. The ability of CO_2 pellet blasting to accomplish this type of clearing in one step represents a revolutionary productivity gain for the tire industry.

Figure 6 shows how CO_2 pellet blasting effectively clears tire mold microvents. From left to right, the rubber plug is in the vent and the CO_2 pellet blast stream initially removes the firmly adhered rubber 'cap' from the plug. The flow of air and cold pellets pushes the plug the rest of the way through the vent and out of the mold.

CO_2 pellet-blast mold cleaning is steadily becoming the method of choice for the world's leading tire manufacturers. When it was being commercialized 15 or more years ago, the pelletized form of dry ice was not available everywhere. Today, the infrastructure for providing palletized dry ice has been established in every major part of the industrialized world. It is now easy for tire manufacturers to implement this technology with an inexpensive supply of dry ice blast media readily available to be delivered to any tire facility in the world. If the pellets are not available, they can be manufactured on-site with relatively inexpensive and easy to use machines called dry ice extruders, and only a source of high purity liquid CO_2 is required. Although curing mold cleaning is the primary quality and cost justification for dry ice blasting, there are several other proven applications in the tire manufacturing plant as well. Dry ice blasting is very effective for cleaning mixer heads, calendering rolls and uncured rubber build-up from tire building machines. The technology is also ideal for removing rubber build-up from traction surfaces of tire test load wheels, for quickly removing dust off the finished tire surface deposited during white sidewall feature grinding operations and general machinery degreasing and cleaning for maintenance cycles. Dry ice blasting truly represents a wonderful new capability for the world of tire manufacturing and should be, at the very least, investigated by any tire maker that considers itself to be world-class.

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