Q&A: Utilizing Dry Ice for Decontamination of Rubber Parts and Tooling

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When it comes to the important process of removing contaminants from rubber molds and the molded rubber parts themselves, there are a variety of different methods available. However, as more focus is placed on employee safety, environmental protections and sustainable practices, it's worth exploring those processes that do not make use of chemicals or abrasive materials. One such process utilizes dry ice, which can be used to remove contaminants from a variety of surfaces and substrates.

How does the dry ice cleaning process remove contaminants from molds and molded rubber parts?

There are three principals involved in the process of cleaning with dry ice. The acronym I.C.E. helps to explain the process.

1. Impact – While dry ice particles have little hardness – around 1.5 to 2.0 on the Mohs Scale of Hardness. Dry ice is frangible, so it cannot be measured on a Rockwell scale of hardness. When accelerated, dry ice particles create what is called the Kinetic Energy Effect (impact). The level of this mechanical impact, which micro cracks the contaminant, is controlled by the user. Kinetic energy is calculated one-half mass times velocity squared. Both of these variables (mass/dry ice particle size and blast velocity) are process settable machine parameters, depending on the nature and amount of contaminant, as well as the hardness of substrate being cleaned. Independent studies have shown dry ice cleaning to be nonabrasive on numerous substrates. Generally, the process does not profile surfaces harder than the dry ice itself.

Dry ice particle sizes are selected via the machine controller and can vary from nearly snow (micro particles at 0.3mm) up to 3.0 mm in diameter, but generally do not exceed 1.0 mm in most surface preparation solutions. The velocity of the dry ice particles is created via the dry ice cleaning system's nozzle and is controlled by an adjustable blast pressure chosen by the user. Stand-off distance and angle of impingement can also have an influence on kinetic energy and, when critical, can be controlled via a programmed robot path.

2. Cold – Dry ice is very cold: -109°F. Unique to dry ice cleaning, the cold particles create a Thermal Effect, causing the various contaminants to embrittle (shrink) and to lose their bond strength with the various substrates. Essentially, it's the coefficient of expansion and contraction principle between the two different materials (substrate and contaminant). When cleaning a hot substrate, the contribution of this principle is increased to nearly 50% of the cleaning effect. Anecdotally, users will see contaminants removing faster from hot substrates. Independent studies have shown no thermal shock or stress to various substrates.

3. Expansion – The last contribution to the cleaning process is another unique principle of dry ice cleaning. Upon impact the dry ice particles will phase from a solid back to its natural state as a gas (sublimate), expanding volumetrically upwards of 700-800 times in size. These multiple micro explosions on the surface lift the contaminants from the substrate.

In summary, I.C.E.: Micro crack the contaminant with controlled impact, embrittle the contaminant with cold and blow it off with the expansion of the dry ice particles.

Is the dry ice method limited to certain applications?

By adjusting the Impact (Kinetic Energy Effect), the dry ice cleaning process is very adaptable to a variety of different applications. Generally, it is used by those who want the cleaning process to be dry, non-abrasive and having no secondary waste. Contaminant types and levels come in many varieties, such as fingerprints, dust, and mold release agents, etc. The dry ice cleaning process is adapted to each level of cleaning requirement needed and the nature of the contaminant and substrate itself.

For example, contaminants, i.e. finger prints, have a very weak bond strength, while some substrates have a lower Rockwell or Shore (durometer) hardness than others. In such an application, reducing the Kinetic Energy by using smaller dry ice particle sizes (i.e. 0.3mm particles), at lower blast pressures (i.e. 20 psi), will be utilized. When contaminants are stubborn, the dry ice cleaning process can be adapted to meet those requirements, up to 3.0mm particles sizes and 240 psi. Cleaning parameters can be stored in the machine controller for various applications. Generally speaking (rule-of-thumb), dry ice cleaning will remove contaminants that are "on" a surface, but not "in" a surface (i.e. pitting from rust which requires the ability to profile).

What are the advantages of using dry ice over other process to remove contaminants?

The biggest advantage of using dry ice is the fact that it is dry. It eliminates aqueous and solvent-based methods and the associated costs that go along with those other methods – reclamation, scrap from incomplete parts drying, etc. The user no longer needs that large dryer, which consumes lots of plant footprint and energy to operate. The operating cost of a dry ice cleaning system is generally around 50% of traditional aqueous systems. The fact that dry ice sublimates also means that it leaves no secondary waste.

Another advantage of the process is the ability for the user to integrate dry ice systems into existing fully automated, 24/7 system. Dry ice particles can be manufactured on-site, just in time, from a closed-loop CO2 system. Dry ice production (pelletizers) and dry ice delivery systems (blasters) are available as an integrated system solution. There is no longer the need for storing dry ice in portable totes and traditional manual loading of the dry ice particles into the blaster. Instead of purchasing dry ice from a local gas company, manufacturers simply have a local gas company install a bulk liquid CO2 tank at their facility and automatically produce their own dry ice particles as needed. These dry ice cleaning systems also are Industry 4.0 ready with Cold Jet CONNECT™ capability, to connect into existing plant monitoring systems and for remote predictive maintenance.

Improving quality is another advantage of dry ice cleaning over traditional methods. CO2 has a lower surface tension than many aqueous fluids, so it can clean very small and complex geometries of various parts resulting in a better clean. When dry ice sublimates, it leaves no solvent residue behind which often requires a secondary cleaning. The process can also reduce scrap that can occur is surface preparation applications when parts are to not get fully dried prior to coating. When working with a new part design, parts no longer require weep holes needed with aqueous cleaning methods.

Dry ice cleaning often helps companies improve productivity because it is significantly faster than traditional cleaning methods. Rubber molds can be cleaned at operating temperature and in-situ, minimizing downtime and improving OEE Availability Scores.
Lastly, the dry ice itself is often a less expensive alternative to other chemical cleaning methods, thus helping manufacturers to lower costs. Many traditional cleaning chemicals contain VOC's which are harmful to employees, so using dry ice can also improve worker safety and factory environments.

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