Magnets, Part II

Magnetic Separation Applications

Once users learn the basics of magnet construction, a review of application characteristics - conveyor speed, burden material mix, desired end-product quality, and others - can help buyers choose the proper magnetic separation equipment.

In the first part of this feature, we reviewed magnetic theory and design. We also discussed magnet purchasing considerations an introduced the Force Index, showing how it can be used to determine the most suitable magnet for a particular application.

In this month's installment, we will explore time-tested magnet installations and their typical advantages and problems. These magnets fall into three types of designs: magnetic head pulleys, magnetic drums, and overhead magnets. Finally, we will look at a special subset of magnet applications - the solid waste magnetic system.

Magnetic Head Pulleys

The magnetic head pulley is perhaps the simplest to understand and least expensive of all magnets. It is simply a shell shaped liked a typical conveyor head pulley, filled with magnetic material that exudes a magnetic field, which attracts ferrous materials. Magnetic head pulleys can be specified as direct replacements for standard non-magnetic head pulleys. The same physical dimensions are available, and several types of lagging are commonly specified to reduce the chance of belt slippage.

In a typical installation (Figure 1), the head pulley attracts the ferrous fraction as it passes over the pulley on the conveyor belting. Because the ferrous is attracted to the pulley, it falls from the magnet at a different trajectory than the rest of the material, making separation simple. In fact, if the belt velocity is low enough, the ferrous will stay against the pulley until forced away by the path of the belting on the underside the conveyor.

The designer must carefully consider the materials being conveyed, the belt velocity, and the realistic ability of a magnet, however strong, to remove ferrous objects. For example, material such as plastic trash bags or large chucks of wood will keep the tramp iron from reaching the magnet or even getting close enough to be attracted by it. In head pulley applications, large materials can render the system useless - no reasonable amount of magnetic force can attract tramp iron through, say, a two foot long piece of lumber, nor can any realistic magnetic force change the trajectory of that piece of lumber with a half-inch nut embedded in it.

Typically, head pulleys are used for relatively low-speed conveyor applications, such as less than 250 feet per minute (FPM), and thin burden depths of about three inches or less. To increase separation effectiveness, magnetic head pulleys can be employed at each material-handling step to allow multiple opportunities to remove the ferrous.

Drum Magnets

Drum magnets are big brothers to the magnetic head pulleys. Drum magnets typically range from 24 inches in diameter to about 72 inches in diameter. Drum magnets differ from head pulleys in that they are not an integral part of a conveyor, but rather are driven separately. Usually magnetic material occupies about half of the interior of a drum magnet. In contrast to the head pulley, the magnetic material does not rotate, but is fixed permanently in position (Figure 2). An outside shell, usually powered by a gearhead motor, rotates around the fixed magnetic material to convey the ferrous burden.

The drum magnet rotates at a speed calculated approximately equal to the burden material's velocity as it leaves the conveyor. The magnet is installed so the burden's trajectory is almost tangential to the magnet's surface.

Two common installations illustrate the uses of the drum magnet: low-ferrous-content and high-ferrous-content applications.

In the first task, drums are used to process low-ferrous-content material in which the composition of the general burden material and the ferrous are similarly sized and are conveyed in a homogeneous mixture. In this case (also illustrated by figure 2), top feeding is appropriate, because with the consistent size of the burden material the steel is unlikely to entrap the non-ferrous fraction.

In the second application, the drum lifts the steel up and over the magnet while the non-ferrous material drops off the vibrating feeder before the magnet (Figure 3). In separating a high percentage of ferrous, such as in most automobile shredding systems, the magnet lifts ferrous from the stringy, fibrous, and smaller non-ferrous material, which usually ends up on the bottom of the vibrating feeder. If the material were to be fed to the magnet (as in figure 2), the steel would drag along a larger percentage of the non-ferrous because the steel, being on top, would be attracted to the magnet through the bottom layer of non-ferrous. Thus, as with the magnetic head pulley installation, it is important to know the constituents and the size of material from which you are separating the steel.

Drum magnets tend to be very strong, a result of their large diameter and large amount of magnetic material enclosed (picture 1). Typical applications for drum magnets include separation of ferrous from shredded material of all types including automobile scrap, red metals, and aluminum; granular materials in burdens too deep for efficient magnetic head pulley separation; and bulky waste and other miscellaneous applications.

Although drums sometimes separate ferrous material from municipal solid waste, they are a poor choice because they trap large amounts of non-ferrous when used for this kind of application. That's why special magnet systems were developed to handle solid waste; these units will be discussed later in this article.

Overhead Magnets

An overhead magnet is a box magnet placed above the burden path to pull ferrous elements away from the burden. There are two usual overhead installation schemes: crossbelt and inline. In the crossbelt, the magnet is installed directly over and perpendicular to the path of material flow on a conveyor; inline magnets work above the trajectory of the material as it leaves a conveyor.

Many variations of the basic overhead magnet exist. For example, a "self-cleaning" belt can be placed around overhead magnet and driven to discharge attracted material in the desired direction.

Crossbelt magnets are suspended over a conveyor and pick up the ferrous material and discharge it 90 degrees to the non-ferrous material flow (Figure 4). Because the ferrous first has to be attracted to the magnet and then have its direction changed, this magnet usually will be somewhat stronger than the equivalent inline-style magnet. Typical conveyor belt velocities for crossbelt applications range from 100 to 350 FPM.

These magnets typically hang at least three inches over the top of the burden and up to 12 to 15 inches above the top of the belt, depending on burden lump size and conveyor specifications.

The crossbelt magnet also must be suspended over a nonmagnetic section conveyor. This is important, otherwise the conveyor frame and idlers can become magnetized and impede material separation efficiency.

An inline magnet is installed over the material trajectory beyond the conveyor head pulley. As the burden leaves the head pulley, the individual particles tend to spread out, leaving space that gives the ferrous fraction an easier path to the magnet, thus providing more efficient separation.

Typical conveyor velocities for inline installations range from 250 FPM to more than 600 FPM. At the high end of these speeds, though, the piece of ferrous material does not spend enough time under the influence of the magnetic field to be pulled to the magnet and ejected. Therefore, longer or stronger magnets are needed.

Belt speeds much in excess of about 600 FPM are unrealistic from a magnetic separation point of view - the magnet would have to be so physically large and powerful that it would be uneconomic to build one.

Overhead magnet installations also need another important element to function properly - the splitter

(Figures 4 and 5). The splitter separates the ferrous and non-ferrous streams. When installing a splitter, it is important to make sure it is constructed of nonmagnetic materials and placed in the magnet designer's prescribed location. The splitter should be checked regularly for wear and to ensure proper placement is maintained.

Options available for overhead magnet installations include NEMA 9 (explosion-proof) hardware, pulley lagging, belt armor, special motors, and zero speed switches. Overhead magnet manufacturers offer both inline and crossbelt designs with either permanent magnets and electromagnets.

A recent area of concern in magnet applications is the advent of new, flexible conveyor belting. Sometimes this belting has a large cleat which allows the conveyor to be inclined at steep angles and act as a bucket elevator. This can preclude effective separation, especially if the cleat is not perpendicular to the belting.

Solid Waste - the Materials

A change in the conveyed materials can degrade separation efficiency. Solid waste professionals attempting to compost, incinerate, recycle solid waste, or burn it for energy, often don't sufficiently appreciate the extreme variability in waste materials, and the resulting difficulties this presents to processing equipment. For example, some waste materials are so light they float, while a motorcycle frame or steel wheel will definitely have to be considered in equipment design to preclude damage. This variability makes it difficult for the magnet manufacturer to define a fixed burden depth on a conveyor, or to determine a material trajectory over a head pulley at design velocity.

In the early 70's, it was typical for solid waste magnetic separation to be accomplished by means of an ordinary overhead or drum magnet. The approach was doomed to inefficiency, because of the differing material densities and trajectories, as well as the daily changes in waste constituents. Scrutiny of these early systems showed two problems not encountered before in typical magnet applications:

* Solid waste has much larger average volume of tramp iron than previously encountered in other systems.

* Due to material turbulence as the ferrous fraction is pulled from the waste stream, more than 25 percent of the nonmagnetic material was being discharged with the ferrous metal. This entrapment phenomenon happened with all magnet designs common to the industry at that time.

In retrospect, these early installations provided the necessity for the invention of the modern solid waste magnet, which has been designed to work with distinctly heterogenous and constantly varying materials. Magnet manufacturers had previously designed all common magnetic separators primarily to separate materials from nonvarying, homogeneous burdens. The result of this misapplication was poor metal removal and a nonclean product.

Solid Waste Magnets

In researching solid waste magnets, designers discovered that a long distance between the pickup and discharge points was necessary to allow time for removal of trapped nonmagnetics. This led to the development of the first true solid waste magnet - The Dings Co.'s Solid Waste Magnetic System (SWMS). The SWMS (sometimes called the "hockey stick magnet" due to its shape - see picture 2) originally was designed to separate tin cans for resale to detinners. This magnet was proved in early solid waste installations, and became a standard design for those facilities requiring removal of ferrous clean enough to command a premium price without further handling.

The design of the SWMS employs a novel multiple-action concept: mechanical, gravitational, and magnetic forces all provide the cleaning power of the magnet. In figure 6 you can see that the material is lifted, conveyed, agitated by the transfer magnet, realigned, reconveyed, and then discharged as cleaned product. The agitation/drop/reattract cycle causes ferrous objects to spin in mid-air, releasing entrapped paper, cloth, plastic, etc. The distance between the magnets - the points at which the ferrous falls away - can be adjusted, as can the belt speed. This allows the operator to compensate for the typical variability in the waste stream.

This magnet is used widely today, with the production of clean steel from MSW shreds still the most common application. The SWMS is designed to lift only light objects (up to about 5 pounds).

A variant of this basic design is used primarily in refuse-derived fuel application in which producers simply want to remove all the steel, not necessarily produce clean, salable steel. Machinery used to process combustible wastes in RDF can be severely damaged by heavy steel objects in the waste stream, so a powerful and effective magnetic system is needed to remove the entire ferrous fraction, including very large objects such as motorcycles, car parts, etc., prior to processing.

The single-stage, heavy ferrous SMWS is approximately 10 feet long and incorporates a magnet having an extremely large Force Index rating (the Force Index is described in the first half of this article; see Recycling Today, August 1988). The design of this magnet system is such that material is attracted and conveyed away - no attempt is made to clean the material.

Another variant, the two-stage heavy ferrous SWMS performs some cleaning by incorporating a transfer conveyor to drop the ferrous material after the first attraction. This releases many of the trapped nonmagnetics from these large pieces. The second-stage magnet then reattracts the ferrous, which is conveyed to the disposal site.

The design of both of these heavy-ferrous magnets incorporates massive wear plates and armor-plated belt materials to withstand the large pounding forces inflicted on this equipment by heavy ferrous objects.

Solid Waste Magnet Applications

All magnetic systems require that the incoming solid waste be shredded or at least have the plastic bags opened in a flail mill or similar processing equipment. Typically, magnets are positioned in the processing line to follow primary shredding, but prior to further processing.

In summary, the solid waste processor has the following choices in magnetic separation: he can utilize inexpensive drum magnets to remove some (approximately 65 percent) of the ferrous fraction, but the penalty will be missed steel and entrapped nonmagnetics in the ferrous fraction.

Alternately, he can choose the three-stage SWMS, which will provide clean metal and remove all light ferrous up to approximately five pounds from the waste stream. Or he can choose the one- or two-stage heavy-ferrous SWMS's, which will remove approximately 90 to 95 percent of all ferrous from industrial and household waste, but will not provide clean steel comparable to the three-stage SWMS.

For RDF applications where "all metal" removal is mandatory, the heavy-ferrous magnets should be used. If salable ferrous material is the goal, the three-stage SWMS should be specified.

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