ABRASIVE MATERIALS AND SURFACE PROFILE

There are many different abrasive materials used in dry blasting systems and to a lesser extent in slurry blasting systems, which clean surfaces in different ways. Softer materials break down on impact and tend to clean by scouring the surface, while harder materials will clean by impact damage, or by cutting the surface. The size and shape also affects the surface texture. Large and rounded shot will produce a flat shallow profile, where as angular grit will produce a more jagged profile.

The choice of an abrasive will depend upon the surface profile and cleaning requirements, as well as its cost, availability and health and safety considerations. In this section, we will look at the characteristics of the different types of abrasive that are commonly used in the marine industry.

1. TYPES OF ABRASIVE MATERIALS

Abrasives are generally classified as metallic or non-metallic. Metallic abrasives are expensive to buy, but the do not readily break down on impact and can be re-used many times. They are therefore used in closed wheelabrator, or vacuum blasting systems, where recovery is easy. Non-metallic abrasives are much cheaper to buy, but they break down on impact and are normally used only once or twice. They are classed as expendable and are used in open blasting operations where recovery and recycling is much more difficult.

Specifications for metallic abrasives are given in ISO 11124 parts 1-4, and for non-metallic abrasives in ISO 11126 arts 1-10.

Test methods for metallic abrasives are given in ISO 11125 parts 1-7, and for non-metallic abrasives in ISO 11127 parts 1-7.

1.1 NON-METALLIC ABRASIVES

Non-metallic abrasives can be put into three groups, as follows:

1 Naturally occurring abrasives.
2 Bi-product abrasives
3 Manufactured abrasives

1.1.1 Naturally Occurring Abrasives

Silica Sand

Naturally occurring silica sands are widely used, because they are inexpensive and readily available. They come from a variety of sources, including quarries, river beds, beaches and deserts. These sands generally consist of a mixture of different materials, but the main one is silica in the form of quartz crystals.

The crystals can be sharply angular, or almost spherical, depending on their source, but they are all effective at blast cleaning, although they generally produce a fine profile. Unfortunately, there are two problems with natural sands. Firstly, there may be other materials mixed with the silica, such as organic matter, clays and salts, which not only produce dust, but contaminate the surface which is being blasted. Secondly, dust from silica sand can cause the lung disease silicosis. This health hazard has stopped the use of silica sands for dry blasting in many parts of the world.

Olivine Sand

Prohibition has led to the increasing use of silica free sands. The ones in most common use include olivine and garnet, both of which are considerably more expensive than silica sand. Olivine is a heavy mineral which usually come in a fine grain size. It is good at cleaning, but it will not produce much of a profile, which is advantageous in some applications. For example, you may see olivine sands used for cleaning stainless steel cargo tanks prior to acid pacification. A profile on stainless steel cargo tanks is unacceptable, because it makes cleaning between cargoes difficult and can lead to cargo contamination. Olivine sand can also be used to remove impinged abrasive from a surface which has already been blasted. For example, zinc silicate tank coatings require an Sa2½–3 blast standard, with a surface profile of 70 microns. The larger grain size of copper slag often used to achieve this can impinge grit into the surface, which cannot be removed by vacuum cleaning. A slight sweep blast with fine olivine sand is an excellent method of removing it.

Garnet

Garnet is a very hard, heavy, angular abrasive which is expensive to buy (2–3 times the cost of copper slag) but which is becoming increasingly popular for several reasons. Garnet has low dust emissions compared to other abrasives, so it can be used for dry blasting in some dust sensitive locations. It also has excellent cleaning properties. Its small grain size produces a scouring effect whilst its hardness and specific gravity can produce a good surface profile and can reduce the amount of abrasive needed for blasting. (Typical hardness on the Mohs scale is 7 to 8 and the specific gravity, or SG, is about 4.5*). In addition, it is possible to recycle garnet several times before it breaks down.

*Comment The Mohs scale measures the hardness of minerals on a scale between 1–10 with talc being 1 and diamond being 10. Hard minerals are able to scratch soft minerals. SG, or specific gravity, is the ratio of the density of a substance to that of water.

Calcium Carbonate

Calcium carbonate or limestone is another naturally occurring mineral which has found a limited use in certain slurry blasting operations, but it is unlikely to be used for dry blasting. It is relatively soft. This means that its cleaning rates will be low, it

will not produce much of a profile and it will create lots of dust. In addition it is not an inert material. It will dissolve in slightly acidic conditions and may affect coating adhesion if it is left on the surface as a contaminant.

1.1.2 By-product Abrasives

These abrasives are furnace slags and are by-products of the metal smelting and electric power generating industries. They are relatively inexpensive, widely available, and are generally silica-free, or have a very low silica content, i.e. below 1%.

Metal Slags

The metal smelting slags include iron, nickel and copper slags. Copper slag is harder and heavier than the other two, which means that it produces less dust and has better cleaning characteristics.

Copper slag is the most widely used expendable abrasive in the Marine industry. It is generally available in a range of sizes from coarse (8 sieve) to fine (100 sieve) for different types of application. It is good at cleaning new steel, painted steel and badly corroded and pitted steel. It is black in colour and is a sharply angular, glossy, homogeneous mix of various oxides. However, it does not, or should not, contain free copper. Traces of free copper left on a substrate after blasting could cause disastrous bi-metallic corrosion in aqueous environment. Fortunately, trace elements of copper, zinc and other metals found in slags are tightly bound in a silicate matrix and cannot cause galvanic corrosion. A typical chemical composition for copper slag is as follows:-

Iron Oxide (FeO) 10-55%
Silica (SiO_2) 20-55%
Aluminum Oxide (Al_2O_3) 8-25%
Calcium Oxide (CaO) 1-15%
Zinc Oxide (ZnO) 0-12%
Others <1%
Free Silica <1%

You should note that good quality copper slags are almost a pure compound of aluminum silicate and iron silicate. This means that the large percentage of silica shown in the table above does not constitute a health hazard. It is the free silica which is not bound into a compound that can cause problems.

Typical hardness for copper slag as measured on the Mohs Scale is 8 and the specific gravity is about 3.3.

You should also be aware that copper and other mineral slags may contain traces of toxic heavy metals, such as arsenic and lead. This obviously depends upon the source of the material, but it has caused some health and safety concerns in recent years.

Coal Slags

Coal, or bottom ash slag abrasives are produced when the material is taken from the bottom of the furnace, dried, crushed and graded to the appropriate size. They are very similar in appearance to copper slags, being black, angular and glossy and they have similar cleaning characteristics. Chemically they are similar to copper slags and consist of various oxides including silica, aluminum and ferric oxide. However, their hardness on the Mohs scale is only about 7 and their SG is about 2.8, so they are slightly less efficient at cleaning than copper slags.

You should remember that the cleaning rate of an abrasive is dependent upon its impact energy E via the formula $E=\frac{1}{2}mv^2$. Abrasives with a higher SG (mass per unit volume) will be more effective than the same size of abrasive with a lower SG.

Both metal and coal slags are chemically inert, so they will not react with treated surfaces and they are not hygroscopic, so they will not absorb water. This does not mean that they can be stored in an open environment, because they will still become contaminated. The topic of abrasive contamination and acceptable soluble salt levels will be discussed in Part 4 of this section and in much greater detail in Module No. 8, which gives detailed procedures for measuring abrasive salt contamination.

1.1.3 Manufactured Abrasives

Manufactured abrasives are generally produced for specific applications and they tend to be very expensive, perhaps 10–15 times the cost of mineral slags. Some of them are very hard and tough and can be recycled many times, whilst others are 'environmentally friendly' and are used only once. We will briefly describe some of the manufactured abrasives you may encounter.

Silicon Carbide

This is an extremely hard angular material (Mohs scale 9.0, SG 3.2) that can be used for etching very hard surfaces in open blasting systems, although you are more likely to have come across it on abrasive discs used for angle grinding.

Aluminum Oxide

Again this is a hard angular material (Mohs scale 8.0, SG 4.0) which is used for blast cleaning materials such as stainless steel and aluminum. It is used in situations where it is essential to avoid contamination of substrates with free metals. (Remember that some mineral slags may contain trace quantities of free metals).

Glass Beads

Glass beads are used for peening and cleaning small delicate parts where damage to the substrate has to be avoided. You may also see them used for cleaning contaminants from stainless steel or machined surfaces in some situations.

Sodium Bicarbonate

Sodium Bicarbonate is used in some low pressure, pressurized water abrasive blasting systems. It is effective in removing coatings, but is too slow and expensive for most marine applications. It does, however, have some advantages. It will not damage or profile underlying substrates and can therefore be used in critical applications such as the removal of paint from aluminum aircraft. The spent abrasive will eventually dissolve in water and it is not classed as a pollutant in most cases. (Sodium bicarbonate is in fact baking soda). Sodium bicarbonate also has an alkaline pH value and will act as a corrosion inhibitor on slurry blasted surfaces inhibiting flash rusting. However, it must be washed off with fresh water prior to the application of coatings.

Frozen CO_2 Pellets

Cryogenic blasting, using frozen CO2 pellets has been under development for some time. The idea is that the pellets simply evaporate after doing their work, so that there are no disposal or pollution problems. Success to date in marine applications seems to have been limited. There are several problems. The process and equipment are expensive. The CO2 pellets clean by thermal shock and will not remove tightly adherent coatings such as epoxies. The temperature of the CO2 pellets also reduces the temperature of the substrate below the dew point. This means that the substrate will get wet and if it is mild steel, it will flash rust.

1.2 METALLIC ABRASIVES

Metallic abrasives are available in a variety of materials. The three types in most common use are:-

1. Cast steel
2. Malleable iron
3. Chilled cast iron

Chilled cast iron is extremely hard giving it fast cleaning rates, but it quickly breaks down and consumption of the abrasive is high. It also produces rapid wear of wheelabrator impeller wheels.

Malleable iron has about half the hardness of chilled cast iron, which gives it double the life with lesser wear of impeller wheels, but it has a reduced cleaning rate and it can contaminate substrates with graphitic carbon. Cast steel is the most commonly used metallic abrasive because it can be produced in various hardnesses depending upon the application, and will give a long, useful life.

All of the three materials mentioned above can be produced as both shot or grit. Shot is generally manufactured by pouring streams of molten metal onto jets of pressurized water which ‘atomises’ the molten metal into random sizes of shot. The shot is then

quenched and graded to size. Grit is simply produced by crushing the shot in roller crushers or ball mills. The grit is also graded for size.

Cut wire is another form of metallic abrasive which can be made from various metals including steel, aluminium, copper and brass, but it is not widely used and will not be discussed further.

1.2.1 Abrasive Work Mix

All metallic abrasives will eventually break down in use into smaller and smaller particles, which are then removed through the plant exhaust system. The rate of consumption depends upon the abrasive hardness. However, new abrasives must be added to the system to balance this loss, (normally at the end, or beginning of each shift). This means that Wheelabrator and vacuum recovery plants normally operate with a range of abrasive particle sizes, known as the abrasive work mix.

As mentioned above, the kinetic energy, E, of an abrasive particle is proportional to its mass, M, and velocity, V, via the formula $E = \frac{1}{2}MV^2$. In Wheelabrator plants the velocity is for all intents and purposes fixed, so **it is the mass of the particle that is the significant variable affecting cleaning rate**. Large abrasive particles (with lots of mass) tend to break or fracture contaminants such as scale or millscale and produce a large surface profile. Medium and smaller particles (with less mass) will scour or clean the surface and produce a smaller profile. Controlling the mix size is therefore vital for controlling the rate of cleaning and the size of the profile. Effective blasting is best carried out with a well graded mix of particle sizes.

1.2.2 Advantages of Metallic Abrasives

1 They have a very long useful life, 50–200 times that of sand or mineral slags.
2 They have a higher specific gravity, or greater mass for a given size than other abrasives. This gives them a faster cleaning rate.
3 They produce less dust than other abrasives.
4 There is less impingement of metallic abrasive into the substrate. However, you should be aware that when impingement of metallic abrasive does occur it can lead to serious coating breakdown and corrosion problems.

1.2.3 Disadvantages of Metallic Abrasives

1 Their high cost means that they must be recycled to be economic.
2 They produce increased wear on blasting plants, which requires more maintenance. If they are not completely removed from staging or scaffolding during tank coating work, they will rust and stain the finished coating. You will then have the problem of persuading the owner that it is the abrasive and not his tank that is corroding.