Proper techniques for installing and using UHMW-PE liners

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Lining bulk storage equipment with sheets of ultra-high-molecular-weight polyethylene (UHMW-PE) is, in many instances, an ideal way to improve the flow of bulk solids. The benefits offered by UHMW-PE are becoming more widely recognized and accepted throughout the world. However, further education on the proper use of UHMW-PE is necessary. The technical information needed to predetermine the effectiveness of a liner is seldom sought out; in addition, liners are often installed incorrectly. This article covers the key physical properties of UHMW-PE and how they help solve some bulk solids flow problems. The article also discusses proper installation methods and how they directly relate to the success or failure of the liner.

Ultra-high-molecular-weight polyethylene (UHMW-PE) has certain physical properties that are beneficial for bulk solids handling. As a result, it's often used to line chutes, hoppers, bins, vibratory feeders, drag conveyors, truck beds, ship holds, and bunkers. In many cases, UHMW-PE's properties make it more suitable for an application than steel or other types of liners.

The physical properties of UHMW-PE include:

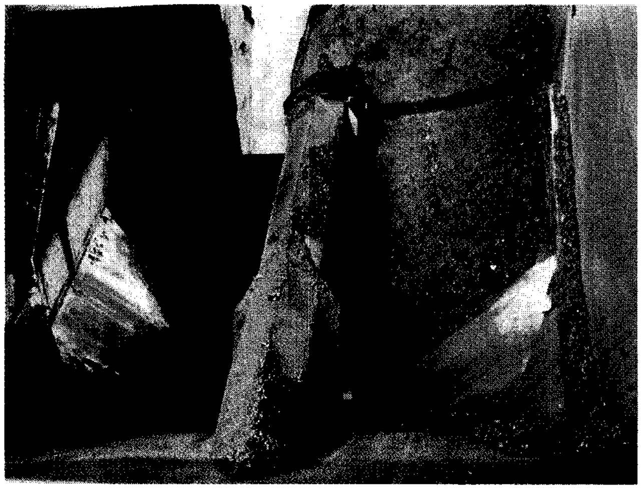
- Low coefficient of friction, which improves the flow of a bulk solid.
- Excellent abrasion resistance from many bulk solids sliding in chutes or hoppers.
- High impact resistance when struck with blunt objects, even at low temperatures; however, low impact abrasion resistance when struck continually with a bulk solid.
- Zero moisture absorption, which keeps bulk solids from freezing to the liner's surface.
- Excellent corrosion resistance.
- Light weight (one-eighth the weight of steel), which makes it easy for workers to handle and install sheets of UHMW-PE.
- Easy fabrication using standard woodworking tools.
- Easy formation into troughs or conical hoppers without the need for special forming equipment.
- Wide temperature range capability from −250°C to 65°C.

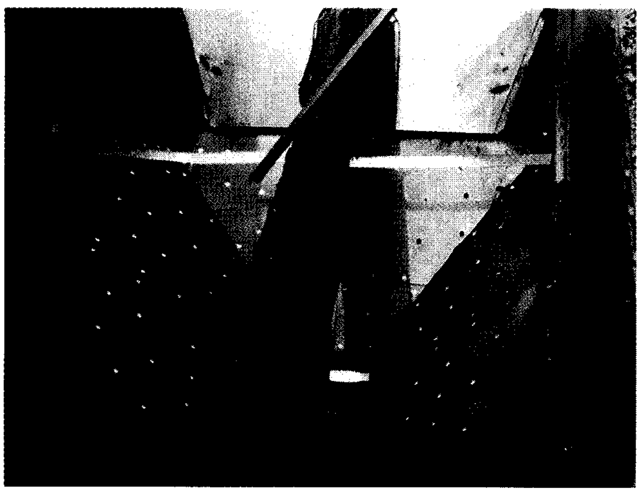
Important physical properties of UHMW-PE

UHMW-PE's low coefficient of friction and high abrasion and impact resistance are the most important properties for handling bulk solids. The following explains how these properties relate to material handling:

Coefficient of friction. UHMW-PE has a very low coefficient of friction; its wax-like surface tends to promote, rather than obstruct, flow. This makes UHMW-PE an ideal liner for handling cohesive bulk solids.

Lining chutes and hoppers with UHMW-PE often allows the structures to be built with shallower slope angles, resulting in





UHMW-PE liners promote material flow and resist abrasion. Top photo shows a steel-lined coal hopper with material sticking to the sides. Bottom photo shows the same hopper with a UHMW-PE liner — note the clean hopper walls.

shorter structures, less reworking (in the case of retrofits), and reduced costs. For example, unlined ship holds usually require that the steel hopper walls be as steep as 55 degrees from the horizontal to get the bulk solid to flow. When UHMW-PE liners are used it's possible to design the hopper walls with a 37-degree slope from the horizontal.

Most 10-meter-long dump trailers with UHMW-PE liners require only a 75 percent scope extension to dump a bulk solid load. In comparison, unlined trailers require a 100 percent scope extension.

Abrasion resistance. It's important to consider abrasive wear of equipment when storing and handling bulk solids. Wear tests show that for many bulk solids the installed cost of a UHMW-PE liner is comparable with that of steel liners with the added advantage of a lower coefficient of friction.[1]

For example, at Kokomo Grain, Kokomo, Ind., stainless steel and abrasion-resistant steel liners in transfer chutes had to be replaced every two years because of abrasive wear. A premium grade UHMW-PE was installed and showed virtually no wear after the same period.

In another example, Hinrichsen Trucking, Alsip, Ill., which hauls coke in aluminum bed trucks, had to replace its truck bed floors four times a year because of abrasive wear. UHMW-PE liners (3/8-inch-thick) were properly fastened to the truck beds and showed no significant wear after more than four years.

Until a few years ago, it wasn't possible to accurately predict the abrasive wear of a liner. However, a wear tester has been developed which simulates the wear caused by a bulk solid sliding on a bin liner, as would occur during flow in a bin.[2,3]

Predicting wear is a two-step process. First, the wear tester is used to determine a wear ratio, which is a function of the pressure placed on the liner surface by the bulk solid. The physical properties of the bulk solid — particle size distribution, moisture content, and temperature — are controlled during the test. Second, the bulk solid velocity and the pressure at the wear surface are determined by applying solids flow theory to the equipment geometry and the measured flow properties of the bulk solid. With this information — wear ratio, bulk solid velocity, and bulk solid pressure — it's possible to quantitatively predict the amount of wear that will occur at any location for a particular application. This testing and analysis procedure is extremely valuable for determining the placement, quantity, type, and service life of wear-resistant liners.

Impact resistance. UHMW-PE has excellent impact resistance. Unlike other polymers, UHMW-PE won't break or shatter when struck with a blunt object, such as a hammer. However, the impact from a blunt object is different from the impact of a bulk solid.

When a blunt object strikes UHMW-PE, its surface is temporarily depressed, but it quickly returns to its original thickness. However, when a bulk solid strikes UHMW-PE, the result is a gouging, glancing impact that actually cuts into the surface and begins to remove it.

Different angles of impact have different effects. For example, say a truck bed is being loaded from an overhead chute. The resulting 90-degree angle of impact against the horizontal liner produces less wear on the UHMW-PE surface because the bulk solid covers the liner surface and provides a cushion for the remaining material to strike. However, say a continuous stream of material is discharging from a horizontal conveyor belt against a vertical liner. This is also a 90-degree angle of impact, but in this case, fresh material continuously strikes the liner. No material cushion forms and the wear is much greater.

A 30- to 45-degree angle of impact is the most damaging to any liner. The characteristics of the bulk solid — such as sharpness, hardness, and velocity — are very important in this situation. Dense, sharp materials gouge or tear the UHMW-PE liner much quicker than soft, lightweight, powdery materials. In general, UHMW-PE performs poorly in applications with this type of impact.

A 5- to 10-degree angle of impact may or may not be suitable for a UHMW-PE liner depending on the material and its velocity. For instance, UHMW-PE has successfully handled bituminous coal with a maximum particle size of 3/8-inch, a high concentration of fines, and a velocity of less than 100 feet per minute. However, as the coal's velocity and particle size increased, the life of the UHMW-PE liner decreased. In another example, UHMW-

PE successfully handled sand discharged from the end of a conveyor moving at 200 feet per minute. However, the UHMW-PE couldn't handle sand discharged from a sand blast nozzle because the increased velocity created high localized pressure.

Determining if a UHMW-PE liner is suitable for your application

All liners in use today have limitations that vary depending on the material being handled. Material characteristics such as hardness, sharpness, angularity, density, particle size, cohesiveness, and moisture content all effect the wear rate of a liner.

For example, consider the various types of coal mined in the US today. Each type exhibits different characteristics and flow patterns; therefore, a UHMW liner will perform differently in each application. Table I illustrates the effectiveness of ½-inch-thick UHMW-PE in 36-inch-wide chutes positioned at a 45-degree angle where only sliding occurs.

Table I Service life of ½-inch UHMW-PE liners handling different coals, operating 16 hours per day.

Coal type	Maximum particle size (inches)	Capacity (tons per hour)	Average moisture content (percent)	Liner service life (years)
Anthracite	2	150	10	1 to 2
Bituminous	2	400	15	2 to 3
Sub-bituminous	2	500	30	2 to 3
Lignite	2	1,200	38	2 to 3
Low-volatile lignite*	2	2,500	38	2 to 4

*High clay content

Note the drastic differences in characteristics and liner service life between the anthracite and the lignite with the high clay content. The anthracite, which is hard, brittle, and angular, tends to bounce or tumble down the chute. The lignite, which is soft and cohesive, slides or rolls, creating a more uniform and predictable wear pattern.

In addition to material characteristics, other wear factors include: flow patterns, pressure exerted on the liner by the bulk solid, and velocity of the bulk solid. All help determine the severity of the application and whether a particular liner will be acceptable.

Flow property tests are useful for specifying bins and indicating the conditions in which bulk solids are suitable for storage. Moisture content, temperature, and storage time at rest are the principal factors that affect the flow of solids.

To quantify the bulk solids properties required for design, run flow property tests on a representative sample of the bulk solid to determine its cohesive strength (arching, ratholing dimensions), internal friction characteristics, and the coefficient of sliding friction between the bulk solid and liner surface. One common device for measuring these properties is the Jenike shear tester.[4,5]

Mass flow in bins (a first-in, first-out pattern in which all of the bulk solid in the bin moves whenever some discharges) may cause unusually high localized loads at the transition between the bin's vertical section and the mass flow hopper. These high loads increase the pressure on the liner and cause increased wear.

Lining a funnel-flow bin with UHMW-PE will, in some instances, produce or promote mass flow. However, the bin structure must be checked to make sure it can withstand the high localized loads produced by mass flow conditions.

The velocity of the bulk solid also affects liner wear. As you'd expect, the faster the material moves, the more severe the wear.

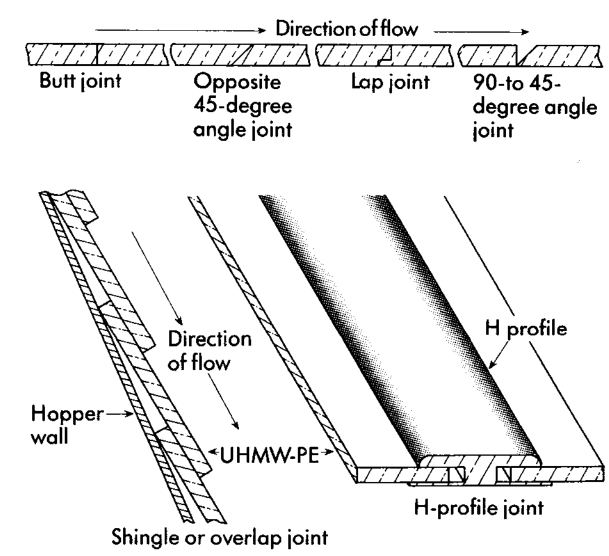
Choosing a suitable installation method

Every bulk solids handling application demands different performance levels from the liner. The liner installation method must be compatible with the demands of the application. To decide on a suitable installation method you need to define what the liner is to accomplish and how the flow pattern will affect it. This information will help you analyze critical installation factors, such as:

Temperature. Like most materials, UHMW-PE expands and contracts with changes in temperature. The mean linear thermal expansion of UHMW is 1.4×10^{-4} in the temperature range from $-30°C$ to 30°C. This expansion/contraction creates a force which moves the UHMW-PE sheets. This movement must be compensated for or the sheets will buckle or pull away from each other at the seams. The expansion of the sheets is proportionately lower when the sheets are cut down in size.

Seams. Sheets of UHMW-PE can be joined in several ways (Fig. 1). Each method has advantages and disadvantages and may or may not be suitable depending on the demands of the application. Some proven joint methods include:

Fig. 1 Methods for joining UHMW-PE sheets



• Butt joints and opposite 45-degree angle joints, which are satisfactory for 85 percent of lining applications.

• Lap joints, which prevent powders and other products from getting under the liner.

• 90-degree to 45-degree angle joints, which are used mainly in drag conveyors. This seam works well where the solids flow is relatively slow and smooth and expansion is expected. As the first sheet expands toward the second sheet, it pushes out any bulk solid caught in the seam.

• Shingle or overlap joints, which are used only in hoppers on horizontal seams where velocity is slow and the pressures acting against the hopper wall reduce turbulence.

• H-profile joints, which protect seams and allow the UHMW-PE sheets to expand and contract. They are used primarily in hoppers to protect vertical seams when shingle or overlap joints are used. However, they are also used in chutes when a vertical seam is undesirable.

Surface continuity of the liner is extremely important. Any disruption in the liner's surface creates excessive turbulence in the material flow. This turbulence results in a type of high-pressure abrasion and creates accelerated wear in those areas (Fig. 2). The rate at which this accelerated wear occurs depends on the abrasiveness and the velocity of the material being handled.

The seams should not allow the bulk solid to filter under the liner. This can lift the liner sheets away from the substrate, or structure. In some applications, material trapped under the liner will degrade or spoil. Also, the seams should not cause turbulence in the material flow.

Fasteners. Sheets of UHMW-PE can be attached to the substrate (structure) in several ways.[6] Factors in fastener selection include: the existence of corrosion, expansion and contraction of the UHMW-PE liner (dependent on temperature and size), the type of liner substrate, the amount of shear force or pressure exerted on the liner, the type of flow pattern expected, and material velocity. The fastening system should hold the liner securely against the substrate while still allowing the liner to expand and contract.

Some fasteners, when properly installed, maintain a smooth, continuous surface. If a fastener protrudes above the liner surface three problems are likely to occur: bolt heads will wear prematurely, material flow will be obstructed, and a different type of wear pattern will develop on the liner (Fig. 3). Types of fasteners include (Fig. 4):

• UHMW-PE capped bolts,[7] which provide a smooth, wear-resistant surface. The substrate mounting hole is drilled ¼-inch larger than the bolt to allow for expansion and contraction. This fastener is available for liners ¼- to 1-inch thick.

Fig. 3 Wear pattern caused by protruding bolt head

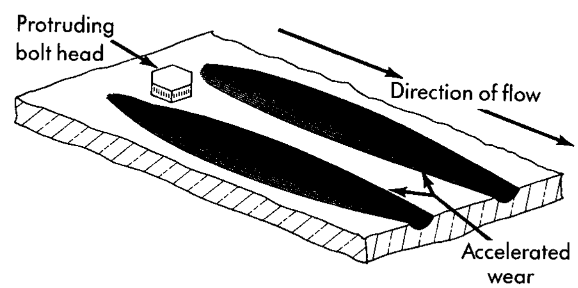
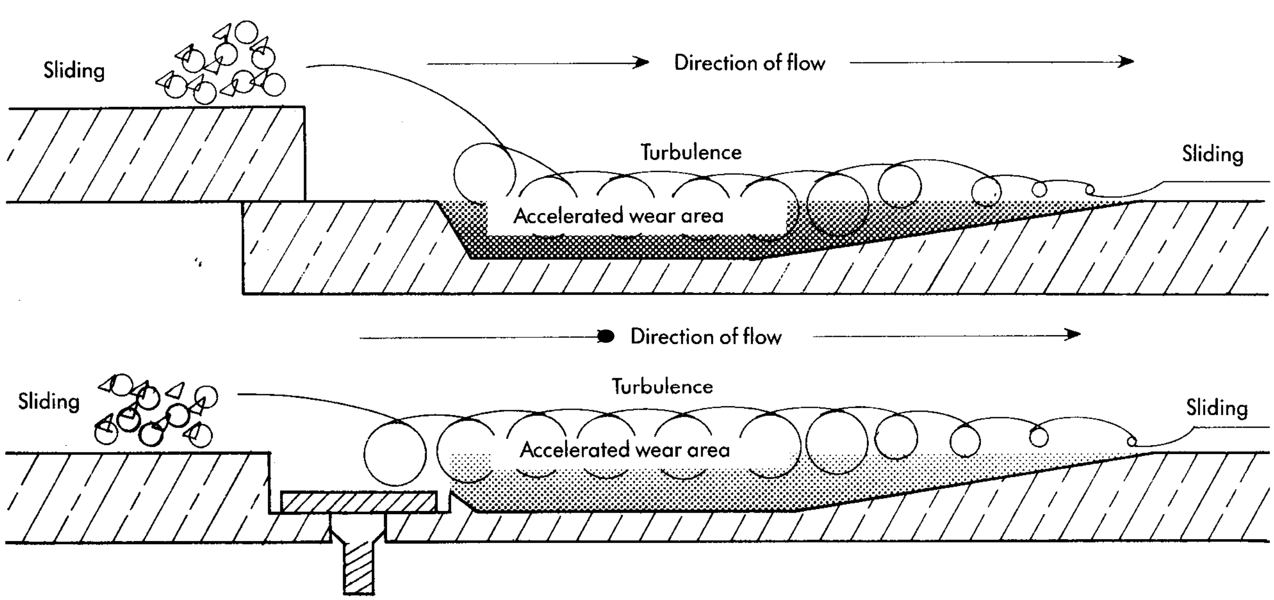


Fig. 2 Accelerated wear areas caused by uneven liner surfaces



• Weld washers, which are welded to the substrate with the liner in place. A compression-fit plug made of UHMW-PE is then driven into the hole over the washer, resulting in a smooth, wear-resistant surface.

• Countersunk fasteners, which provide a smooth surface but expose the bolt head to wear. The bolt-head diameter should be a minimum of ¼-inch larger than the shank diameter to provide adequate holding strength for the liner. The substrate mounting hole is drilled oversize to allow for expansion and contraction. This fastener is available for liners up to ⅜-inch thick.

• Spanner nuts, which require that 3/8-inch-diameter threaded studs be welded to the substrate. A stepped hole is then bored in the UHMW-PE liner, and the spanner nut is threaded onto the stud. This fastener is available for liners with a minimum thickness of ⅜-inch.

Leading edge protectors. Many UHMW-PE installations require a steel leading edge protector to prevent material from getting under the sheet and lifting it. Some proven methods are shown in Fig. 5. These leading edge protectors are welded or mechanically fastened to the substrate.

Corrosion of the substrate. You can protect the substrate from corrosion by sealing all lap joints with a corrosion-resistant sealant such as silicone. Apply an abrasion-resistant sealant under and on top of the fastener heads to protect the fasteners from corrosion. Another protection method is to use UHMW-PE-capped bolts or weld washers covered with UHMW-PE plugs. For added protection, apply a corrosion-resistant coating to the substrate before attaching the liner.

Fig. 5 Leading edge protectors

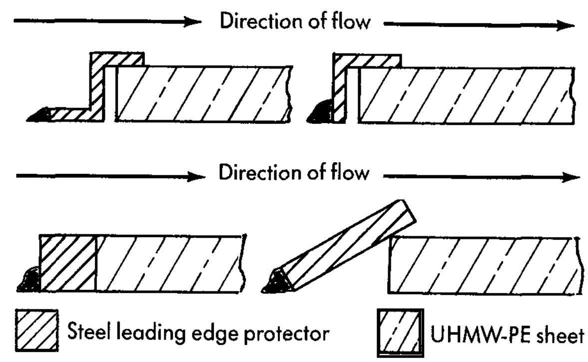
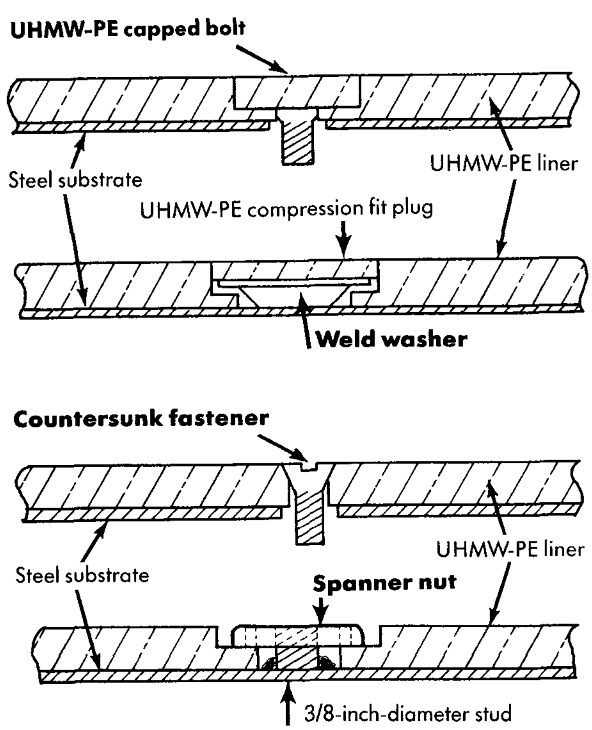


Fig. 4 Methods for fastening UHMW-PE liner sheets to substrate



Conclusions

UHMW-PE liners, when properly applied and installed, are a long-lasting way to help solve many bulk solids flow problems. These liners are often an excellent choice for new or existing hoppers handling varying types of bulk solids. The UHMW-PE liners require flatter wall angles, reducing the height of the bin, the amount of reworking required, and consequently, the cost.

However, don't fall into the trap of concluding that UHMW-PE is a cure-all for all flow problems. Consult with a UHMW-PE manufacturer to determine if the liner is suitable for a specific application. In some cases the bulk solid may have to be analyzed to ensure a reliable system. **PBE**

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