bulk solids handling Volume 3, Number 1, March 1983

UHMW Polymer: A Successful Approach to Lining Bulk Handling Equipment

Michael J. Pratko, USA

Summary

Ultra-High Molecular Weight (UHMW) polymer sheets are made from resins manufactured by Hercules Inc. under the trademark Dyna-Flo® UHMW sheet.

This material has unique friction and abrasion properties and is therefore used successfully as a liner material. The advantages and fastening procedures are described for self-unloading ships, dragline buckets, rail cars, dump trucks, screw augers, large hoppers etc.

1. Introduction

Innovative techniques are improving bulk handling efficiency in a large number of important areas — cargo unloading, dragline buckets, chute liners, railcars, dump trucks, screw augers, coal reclaimer buckets, and breaker chutes. One of the cost-saving methods that all have in common is the liner involved.

Often for different reasons — energy costs, labor savings, operational speedups — the liners have benefited from the innovative approaches suggested by Mentor Dynamics Ltd., of Waterloo, Ontario and its U.S. headquarters in Glen Burnie, Maryland.

The liner Mentor Dynamics chose for selling its unique concepts to bulk handlers — from shippers to truckers to mine operators — is an ultra-high molecular weight (UHMW) polymer sheet made from resins manufactured by Hercules Incorporated, Wilmington, Delaware, USA. This family of resins, designated Hercules 1900® polymer, has a molecular weight ranging from three to six million. UHMW polymers exhibit a unique combination of properties which include: low coefficient of friction; the highest abrasion resistance of any thermo-plastic polymer; exceptional impact resistance even at cryogenic temperatures; non-stick surfaces; good chemical and crack resistance; cyclical fatigue resistance; noise dampening properties; and FDA and USDA sanction for use in food, meat, and poultry applications.

As the molecular weight increases, technical properties are also increased, such as, notched impact strength, energy absorption capacity at high loading rates, ultimate tensile strength at elevated temperatures, and resistance to stress cracking. Like all other polymers, UHMW polymer is water repellent and does not swell. This makes it ideal for handling moisture laden materials in below freezing temperatures.

2. The Sticking Problem

Sticking is the most common and most recurring of the situations that affect bulk materials; it is the major cause of lost production. Temperature changes in the product, duration of storage, increases in moisture content, and the innate stickiness of the product all compound the problem on a minute by minute basis. Simply stated, the product is not available when needed because it is stuck inside the ship, truck, hopper, bin, chute. The engineer must increase the angle of slope in an attempt to get the product moving. In winter he must add insulation or apply heat to the exterior of the container to keep the product from freezing to the sides. Most times these solutions are to no avail. In such difficult situations, where moisture content of the product is 5% or higher, the need for a low coefficient of friction liner is paramount.

The majority of bulk containers are constructed of steel. Since steel absorbs moisture, the winter months are the most critical. When the steel surface is below freezing, the surface quickly absorbs the moisture that is present in the product, causing the material to freeze to the steel. The situation created — material flowing on to material — produces the highest coefficient of friction and the poorest flow characteristics.

Our solution to this problem is to line all sloping surfaces with Hercules UHMW polymer. The resulting liner, trademarked Dyna-Flo® UHMW sheet, does not absorb moisture; thus, it immediately corrects the problem of a wet product sticking to frozen steel. The liner also allows the product to "mass flow" without the tendency to rathole. With the use of the MDL-weld washer fastener, installation takes place from only one side and the Dyna-Flo UHMW cap completely covers and seals the fastener. This eliminates any steel being exposed to the product and the possibility for abrasion or sticking on the fastener is eliminated.

3. Growth of UHMW Liners

The use of UHMW liners for self-unloading cargo ships, now spreading around the world, began in an experimental application in 1975. Mentor Dynamics Ltd. of Waterloo, Ontario has since then provided hopper linings for some 30 or more self-unloaders built in the Lakes (Figs. 1 and 2). So successful has been the application of this new plastics technology that Mentor Dynamics has been able to export its expertise,

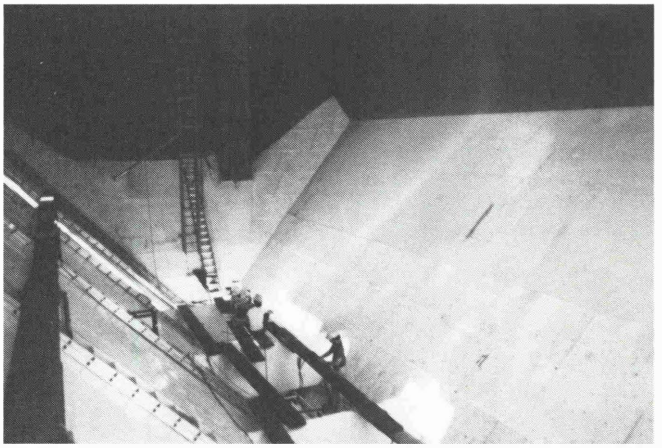

Fig. 1: Mentor Dynamics Ltd. personnel installing a Dyna Flo UHMW polyethylene liner in a self-unloading barge

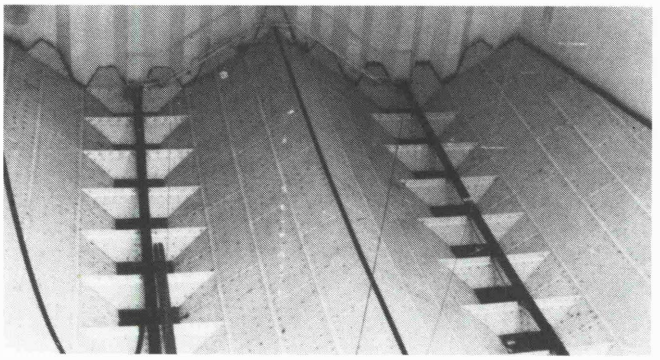

Fig. 2: View of a self-unloading ships' cargo hold after the installation of the Dyna Flo liner

notably to Korea where a 71,000 DWT self-unloading bulk carrier was built by Hyundai for Upper Lakes Shipping Ltd.

The initial test application was made in a Canada Steamship Lines self-unloading vessel in advance of this ship owner commencing a contract for the carriage of western Canadian lignite on the Lakes. Previously, most notable as a problem cargo for the gravity discharge self-unloaders, because of a tendency for high moisture content in the lignite, unloading operations often took as long as two days to evacuate a total 30,000 tons from the ship's holds. Following successful application of the ultra high molecular weight (UHMW) polymer linings to the angled slopes of a ship's hold hoppers, average discharge times with lignite cargos could be reduced by up to six times or down to just eight hours.

Algoma Central Railway's Marine Division was the first line to receive a brand new ship, the 27,600 DWT ALGOLAKE built in 1977, fully fitted out with the hopper linings specifically for the carriage of western Canadian brown coal, and now several of the larger lines, including Canada Steamship Lines, American Steamship Lines, Upper Lakes Shipping, St. Lawrence Cement Company, Hanna Mining, and others, operate vessels having the same beneficial linings.

4. Fitting the Materials

Fitting of the material, which has a 4.5 million molecular weight, is achieved by a special fastening system developed by Mentor Dynamics that utilizes minimum labor involvement and yet provides fitness for purpose. Typically, the sheets of UHMW polymer are of 4 x 8 ft in size and vary in thickness — generally according to the nature of the bulk cargos to be carried — from 7 mm to 20 mm. The linings are fastened to the steel hoppers by electrically welded button-head steel fasteners, and the fasteners are designed to allow for some slight thermal movement in the polymer since the coefficient of linear expansion is greater than that of the steel substrate.

A corrosive resistant method of fastening using countersunk stainless steel fasteners capped with 1900 UHMW polymer has also been developed by Mentor Dynamics to allow self-unloaders fitted with the hopper linings to transport corrosive cargos. Additionally, when joining sheets of the material together in the hold, a special profile extrusion seam seals the joint which, while still allowing for expansion and contraction of the material due to temperature changes, prevents the possibility of residual cargo remaining behind after discharge. Thus, it is perfectly safe for a vessel to carry dissimilar cargos on consecutive voyages without danger of cross-contamination.

5. Changing Slope Angles

The plan to use UHMW polymer in lining their vessels led these ship owners to take the bold and creative stroke of changing from standard hopper slope designs of 57° to angles of less than 35°.

Doing these modifications without the aid of a low-coefficient-of-friction cargo hold liner could have created insurmountable flow problems. Dyna-Flo UHMW sheet has a friction coefficient less than one half that of steel. Its wax-like surface permits the flow of even wet, sticky cargos such as coal, gypsum, iron ore and cement.

Without the use of this liner and with a considerable disadvantage to the cubic capacity and stability of the vessel, naval architects would have been forced to design steep hopper slopes in order that sticky or wet products would flow.

The liner permits the cargo to flow by gravity through the open gates and onto the conveyor belts. The flow rate is then controllable without surges or interruptions. Also lined with the Dyna-Flo are the transverse conveyor belt skirtboards and the boom skirtboards. This liner helps to dramatically reduce the friction between the cargo, which flows at rates as high as 10,000 tons per hour and velocities of 3.304 m/s, and the steel skirtboard. In fact, a 20 % reduction on power requirements was obtained on a 37.285 kW conveyor belt drive motor.

Following are some of the advantages that ship owners have been able to achieve by lining their cargo holds with Dyna-Flo UHMW polymer:

- With a lower slope angle (57° to 35°) a greater volume (cubic capacity) of materials is stored below the ship's center of gravity, adding greater stability for navigation.
- A lower slope angle resulted in increased cubic capacity for carrying cargos of low density such as grain.
- The Dyna-Flo liner reduced the unloading time substantially, resulting in increased profitability; this also benefits the receivers, whose dock facilities can service a greater number of ships.
- The slickness of the Dyna-Flo liner eliminated the need to send men into the cargo holds to free stuck material — reduced liability.

- The clean-up time is extremely fast and results in no cross-contamination of cargos as a result of residual cargos remaining in the hold.
- The liner is unaffected by sea water, salts, or corrosive cargos and will not swell when it comes in contact with moisture.
- Because of the light weight of the Dyna-Flo liner there is a minimal effect on the carrying capacity of the vessel.

6. Dragline Buckets

Downtime and material buildup in dragline bucket operations can, and do, cost companies thousands of dollars yearly. The dragline is hampered, particularly in cold weather, by residual material sticking to the inner sides of the wear plate of the metal bucket. This causes a strangling effect on the efficiency of the strip mine operation.

Our successful solution to this problem was to thermally form 18 mm Dyna-Flo UHMW polymer to the contour of the drag bucket. The Dyna-Flo sheets were attached to the walls of the bucket with MDL-weld washer fasteners. The weld washers were welded to the steel bucket and then Dyna-Flo UHMW polymer caps were used to seal the counterbored holes. The final result, in this most difficult application, was that even at temperatures as low as —30 °C, the clay overburden was able to slide out.

7. Rail Cars

Bottom dump, rotary dump, and side dump rail cars used by the majority of the utilities and mines to transport coal and fly ash present unique unloading problems. Demurrage charges mount quickly when the cars will not discharge their payloads.

To relieve the problems associated with discharging, various types of rail cars have been lined with 6 mm Dyna-Flo UHMW polymers utilizing the MDL-annular ring fastener with 'F' cap. To keep material out of the seams, the MDL-'H' profile was used. Many satisfied customers attest to the efficacy of the solution.

8. Dump Truck Liners

Owners and operators of dump trucks and dump trailers have been plagued by unloading problems, and these problems exist equally in both steel and aluminium bodied trucks. The typical wet cargo of coal, sewage sludge, ore and other waste products does not flow. Since trucks travel on the open road, the wind chill factor must be considered in the winter months.

The solution we selected was the Dyna-Flo UHMW polymer liner in 6 mm and 10 mm thicknesses with the MDL-button head weld stud for steel trucks and the MDL-aluminium drive rivet for aluminium dump bodies. In both types the MDL-'H' profile was used to seal the joints or seams. Since the Dyna-Flo liner weighs only 6.10 kg/m², it has minimal effect on the carrying capacity of the vehicle.

The immediate advantage to owners was the ability of the cargo to release and slide out. Also, the dump body did not have to be fully extended in order for the cargo to start sliding out. Corrosion and abrasion caused by the different cargos had no effect on the liner.

9. Screw Augers

At a major gypsum manufacturing plant, screw augers were the means of conveying the product from one area of the plant to another. High corrosion and wear were the concern of the plant operator. As the corrosion increased in the screw auger troughs, the horsepower requirements also increased because of the friction between the product and the corroded trough walls.

To reduce surface friction, 6 mm and 10 mm Dyna-Flo UHMW polymer was installed in the screw auger troughs. Because of the high amount of corrosion and perforation of the bare metal, elevator bolts were used to fasten the liner in place.

The results of a typical 10 m long installation was a drop of 35 % to 45 % in amperes required to drive the motors and the hang up of material was eliminated.

10. Coal Reclaimer Bucket

A large utility was confronted with high down-time costs and decreases in the available coal to fire its boilers. The reclaimer buckets were clogging with coal during the winter months. The coal would freeze to the bucket walls and the reclaim system would have to be stopped and lowered to the ground. At this level, men would enter with air hammers to dislodge the frozen coal.

Mentor Dynamics Ltd.'s personnel installed 6 mm thick Dyna-Flo UHMW polymer to the bottom, sides and back of the bucket. The results were immediate: no sticking or freezing of the coal to the bucket, and a liner life of two years before replacement.

11. Bradford Breaker Chutes

Coal entering the power plant must be sized in the Bradford breaker before being stored. The chutes leading into the breaker present unique flow problems. The coal, at one power plant, drops 13 m onto a chute leading into the Bradford breaker at the rate of 875 t/h. The coal creates impact, abrasion and sticking conditions (Fig. 3).

Fig. 3: The installation of a Dyna Flo liner in a large coal hopper

Our solution was to isolate the impact area and install 50 mm thick polyurethane to absorb the impact from the falling coal. At the perimeter of the urethane lining 18 mm Dyna-Flo UHMW polymer was installed to handle the abrasion and sticking.

After three years of operation, the plant has had no sticking or abrasion problems to disrupt the flow of coal.

12. Fastening Systems

The key factor in the successful installation of any lining material is the selection of a fastening system. The fastening system should be economical to use and yet keep the liner in place throughout its life. Failure of the fastening system will immediately result in the failure of the liner.

Mentor Dynamics Ltd. has developed a number of different fastening systems. The common element is that they consist basically of studs that are electrically welded to the cargo hold of the ship or the steel substrate of the hopper, bin or chute. Fasteners are also available for concrete and wood substrates. To meet the special demands of owners and operators who handle corrosive cargos and products, a corrosive-resistant method of fastening was developed which utilizes a stainless annular ring fastener and a UHMW polymer cap that seals the sheet in place.

Another type of fastening system utilized for attaching UHMW polymer is the weld washer fastener. It employs the use of a stamped and formed washer that is welded to the steel substrate by an electric arc welder. The hole left in the polymer is then plugged with a polyethylene cap that helps to keep out corrosive product and eliminate fastener head wear. It also reduces turbulence in the bulk material flow caused by countersunk bolts. Since the counter-bored hole is plugged, material hangup is also eliminated. In all installations the fasteners are installed from the inside.

Nuts and bolts can be used for installing a lining material but are extremely time consuming and costly. They require men working on the inside of a hopper or bin and men working on the exterior to hold and tighten the fasteners. As indicated, this can overburden an installation budget quickly.

In all fastening systems, allowances for the thermal expansion and contraction of the lining material must be taken into account. This is especially true with UHMW polymer, which has an expansion rate five times that of steel. Without allowance for the expansion, sheets will bubble, lift and even tear off. Ultimately, the end result will be the premature, if not immediate, failure of the liner.

Conclusions

Although we are able to solve many of the problems associated with the flow of bulk solids, some situations require that the chosen liner be modified or adjusted after the system is in operation. This is because bin and chute volumes and velocities can change with the liners installation. However, no matter the size or shape of the bulk vessel, a lining material can be installed to improve the flow.