

Markel ARTM Abrasion Resistant Control Cable Liner

Introduction

The control cable industry in the United States experienced a serious demand for performance enhancement in the mid 1970's. Markel responded then and continues to provide the industry globally with liners that eliminate the seize and stick-slip problem while dramatically increasing efficiency and cycle life. Complex routings, downsized engine compartments and higher temperatures under the hood caused by the introduction of anti-pollution and fuel saving systems rendered direct linkage systems and cable constructions based on traditional thermoplastic (i.e. nylons, polyethylene and acetal) liners inadequate and even obsolete for some applications. PTFE, the material with the lowest coefficient of friction of any solid, proved to offer the basis for an acceptable solution. Markel discovered that natural PTFE with fillers added offered the much needed performance enhancement of life up to 3,000,000 cycles while maintaining high efficiency and withstanding the required high temperature environments in difficult routings. Markel ARTM filled PTFE liners are specified by the major US automobile manufacturers for use in throttle, detent, speed control and automatic shift cables. Demand has now spread to manufacturers in Europe and Asia.

physical properties. Properly filled PTFE liners exhibit several orders of magnitude better wear resistance than unfilled natural PTFE. Fine powder grades of PTFE used in paste extrusion of thin wall tubing are much more sensitive to shearing forces encountered during blending of fillers compared to granular grades commonly used in molding applications. Due to this fragile shear-sensitive nature of unsintered (uncured) fine powder, PTFE processors are limited to the types and percentages of filler that can be used as well as the techniques employed for blending. Care must be taken not to shear individual PTFE particles as they would later



Markel ARTM Liner Development

PTFE (polytetrafluoroethylene), $[-CF_2-CF_2-]_n$, is the polymer with the lowest coefficient of friction, both dynamic and static, of any solid. In addition to its high lubricity, PTFE exhibits excellent thermal stability at temperatures in excess of 250°C and also superior chemical resistance. However, it has relatively poor mechanical properties; particularly abrasion resistance and deformation under load. In order for PTFE to exhibit acceptable performance characteristics as an abrasion resistant / anti-friction liner, it must be modified with reinforcing fillers to significantly improve its

Blender Particle size is an important filler criterion for fine powder PTFE. Fillers that are too large can cause discontinuities in the filler / PTFE blend which prevent the PTFE from properly knitting together during the delicate extrusion process. The fillers which are traditionally used with PTFE are glass, graphite, molybdenum disulfide, certain metals, and certain ploymeric materials, in particular ployphenylene sulfide (PPS) and polyoxybenzoate. Any filler used must be thermally stable at the sintering temperature of PTFE; 342 °C. That is why inorganic oxides and metals are selected. Even so, the morphology of fillers is critical to optimum wear performance. It is known that “plate-like” fillers such as graphite

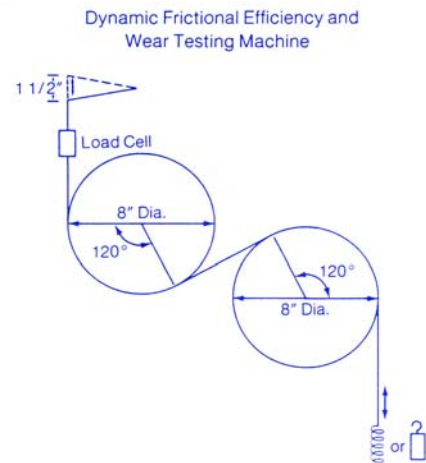
and molybdenum do not make acceptable choices. The introduction of fillers into PTFE does not significantly alter its low coefficient of friction, so the composites are as lubricious as natural PTFE. Fillers are only mechanically held in place as there is no wetting by the PTFE resin.

For abrasion resistant tubing, microcrystalites or small spheres of glass were originally selected because they are inexpensive and do improve the abrasion resistance and creep of PTFE. However, if filler particles become dislodged from the composite matrix, they act as abrasants and can, in a short time, have a deleterious effect on liner performance. This effect is magnified with the use of a lubricant as a highly abrasive slurry is created which results in a drastic erosion of performance and eventually to wear through. If a lubricant is needed in high load and / or complex cable routings, liners containing polymeric fillers give excellent performance and life. These fillers are more expensive and introduce additional complexities in the extrusion process. They are however, very effective in upgrading the performance of natural PTFE. Markel patented a composite containing a filler which, at the sintering temperature of PTFE, cross-links to form a distinct polymer network within the PTFE matrix. The nature of this "alloy" is such that it must be used with a lubricant to realize superior performance. This revolutionary product is designated Markel AR-500™ Liner. Markel has continued to introduce patented liners with additional specific characteristics such as higher load capacity (AR-650™), higher initial efficiency (AR-900™ and WAVE™ Liner) and reduced noise transmission (Quiet™ Liner).

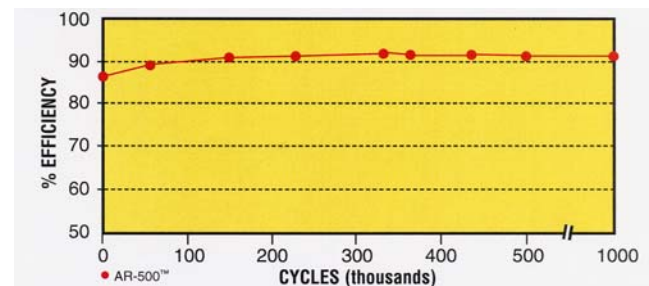
Evaluating Liner Grades

In order to evaluate relative performance characteristics of various liners some standard test methods had to be developed. This was accomplished between Markel and the major auto manufacturers nearly 30 years ago.

A schematic of the test rig is shown below.



The standard configuration is an "S" routing over two 8" diameter mandrels with a bend angle of 120°. The total cable length is 29". The liners are evaluated as extruded without flat wrap armor applied. The inner member is a .062" dia 7 strand stainless steel cable. A load cell is utilized to measure efficiencies with a 5 lb. weight applied. The applied load can be applied with springs with ratings of 0-6 lbs and 6-18 lbs. The test rig cycles at 60 cpm with a traverse of 1 1/2". Efficiency measurements are taken at the start and at intervals during the test procedure. A typical performance chart for Markel AR-500™ liner is shown below.



AR-500™ Liner has been the premier liner in terms of efficiency, load bearing capability and life cycle expectation in the auto industry since its introduction in 1980. It is designed for use with a silicone lubricant to yield efficiency and cycle life not normally attainable with liner of any type. As previously stated, the composite alloy nature of this product eliminates the

problem of premature failure when used with a lubricant. The filler provides reinforcement to the PTFE through formation of a dual polymer network without acting as a potential abrader. When used with a properly cleaned and lubricated inner member, AR-500TM Liner routinely exhibits efficiencies >90% even after 1,000,000 cycles. AR-500TM Liner is specified by the three major US manufacturers(1) and by an increasing number of auto manufacturers in Europe and Asia.

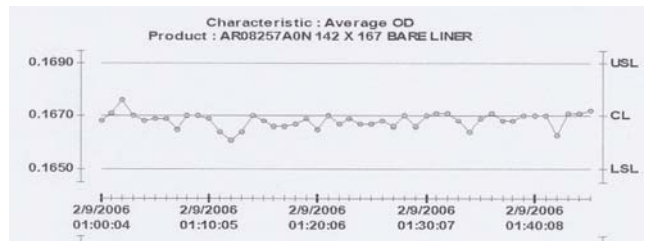


Liner OD Control and Recording.

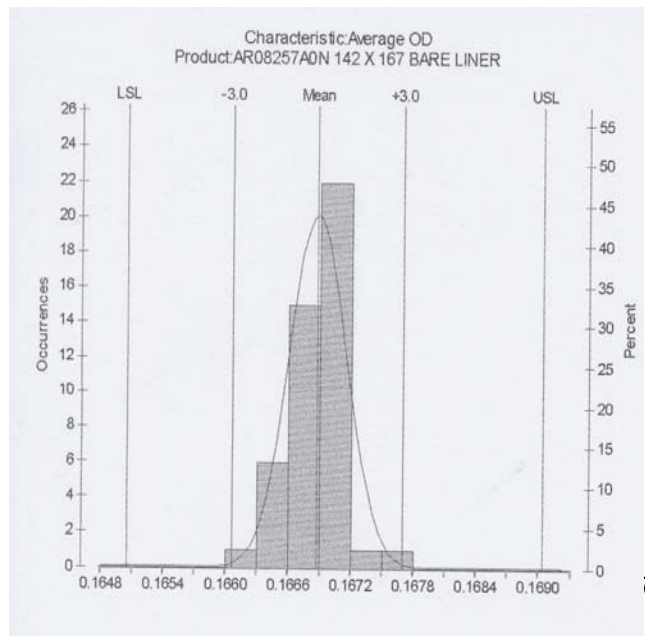
Dimensional Control

As cable manufacturers can attest, good dimensional control on the liner is critical to making good quality cable assemblies. A liner that is extruded with undersize ID can, in some cases, cause the inner member to bind when the cable is in its routed position. Conversely, if the ID is oversize, backlash can develop to a point of creating degrading performance. The OD of the liner is also important. Variation can cause the metal wrap to be too tight in places and too loose in others. In areas where the wrap is applied too tightly, the liner can stretch and then snap-back when the finished conduit is cut to length. It is possible to get 36” of conduit and 35” of liner. Markel is now using a third generation computerized control process along with specific manufacturing standards (optimum machine tooling and set-up) for each liner grade to ensure consistent dimensional control of the liner. Samples and records are retained for each production run of ARTM liners.

Average OD measurements are charted for each production run. A typical chart is shown below.



The histogram for the above average OD readings is shown below.



Long Continuous Lengths of PTFE Liner

Longer lengths of liner enable cable manufacturers to increase productivity by reducing both down time and material waste. Fine powder PTFE is processed with a ram extruder loaded with fixed length pre-forms (see below). It can not be continuously extruded as is common with melt processed plastics.



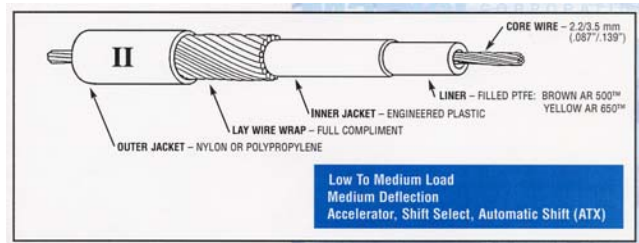
Loading a Perform in a Ram Extruder.

Variables that affect the maximum continuous length of extruded liner include the extrusion cylinder length and bore diameter, the dimensional stability of the extrudate (i.e. the frequency of undersize, oversize, surface imperfections, etc.) and the cross-sectional area of the liner itself. Markel uses “state-of-the-art” long barrel machines to provide the longest possible continuous lengths of liner.



PTFE Liner Jacketing

Continuous economic pressures require manufacturers to consider every possible way to reduce both cost and weight of cable assemblies. Substitution of a plastic jacket over the liner in place of flat wrapped steel offers both cost and weight savings without sacrificing cable performance in most applications. A typical conduit with a plastic jacketed liner is shown below.



Conduit Construction with Plastic Jacketed Liner

A plastic over-jacket, like a flat metal wrap, provides support for the thin wall liner and will help to keep it from crushing and / or kinking. It also helps to keep the liner round which is very important for both optimum efficiency and as an aid in the conduit manufacturing process. The type of jacket required for a particular application is dependent upon many variables including cable routing (flexibility), operating temperature range, jacket hardness, price sensitivity and chemical resistance (if needed). Some of the jacketing materials commonly used include nylons, PBT (polybutylene terephthalate), polypropylene and PVC (polyvinyl chloride). During the jacketing extrusion process, some longitudinal stretch is introduced to the PTFE liner. Since nothing sticks to PTFE, including plastic jackets, the liner is subject to a slight shrink-back when the finished conduit is cut to length. If even the slightest shrink-back can not be tolerated in a given application, Markel offers a technology of liner construction that mechanically locks the liner in place under the jacket.