

Custom Urethane Coefficient of Friction for Reliable Document Handling

Thermoset polyurethane formulation for currency and document handling in self-service machines.



— INTRODUCTION

This white paper from Mearthane Products Corporation (MPC) focuses on the advantages and applications of customized thermoset polyurethanes for use in currency and document handling self-service machines such as ATMs, ticketing kiosks and vending machines. MPC, an ISO 9001: 2008 company located in Cranston, RI, is a specialty formulator and global supplier to self-service machine manufacturers, supplying custom fabricated solid elastomers and microcellular foams for certain critical moving parts within the machines. MPC was formed in 1965 and has been solving difficult document and currency handling problems for its global customers for over 50 years.

1965

FOUNDED IN CRANSTON, RI

20+

URETHANE FORMULATION PATENTS

50 yrs

CURRENCY HANDLING EXPERIENCE

The growing self-service machine market & the customer expectation

Advances in point-of-service automation technology continues to drive the proliferation of consumer use, self-service machines worldwide. The global market for these machines, which include banking ATMs to a wide range of transportation ticketing kiosks and vending machines, is expected to grow in revenues from \$54 billion in 2016 to over \$80 billion by 2021, with a compound annual growth rate (CAGR) of almost 9% for the near-term five-year period.

MARKET SIZE

\$80B

Projected self-service machine revenues by 2021, up from \$54 billion in 2016 — a CAGR of almost 9%.

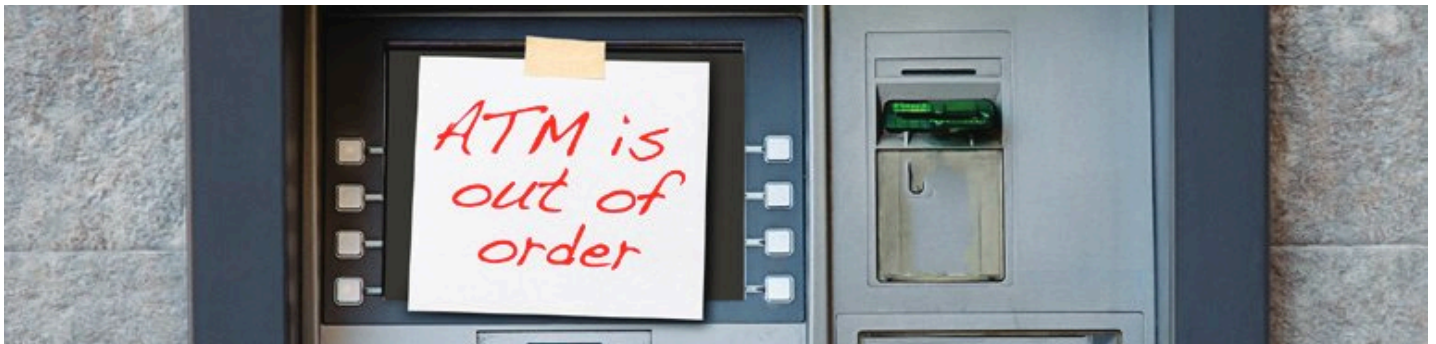
Source: Research and Markets report: Self-Service Markets: ATMs, Kiosks, Vending Machines 2016-2021.

These machines allow consumers to directly interact with an automated terminal and exchange credit/debit cards for cash (ATMs) or the same for tickets and receipts. In the case of vending machines, consumers select and pay for a range of items from consumables to personal electronic products.

Although they are subject to heavy daily use with very little or no allowed downtime, and often are located out-of-doors and exposed to changing weather and barometric pressure variables, automated self-service machines are expected to complete transactions and exchanges in quick time and without breakdowns.

Consumers exhibit little patience with self-service machines while allowing for the human element when conducting transactions or exchanges in person. Machines are not expected to malfunction.

When they do, costs associated with downtime, maintenance and customer disappointment can come at a high price to the machines' owners.



Chemically engineered parts

The reason self-service machines perform at a very high rate of successful operation on a 24-hour basis is because they are expertly engineered machines. This is despite the fact they employ many moving parts like belts, rollers and wheels to move currency of many varieties as well as checks, receipts and credit and debit cards. High speed, high-volume self-service machines require precise parts movement and reliable media capture at high speeds and volumes.

Adding to the complexity of these applications is the introduction of many new materials used to make currency around the world. As anti-counterfeiting technology is employed by governments, they are designing currency with new types of paper, plastics and even metals woven into the currency. As a result, each type of currency will handle differently in an ATM's transport mechanism.

Environmental conditions as well as the nature and cleanliness of dispensed currency and paper can affect static build up, friction and debris build-up on the paper handling machine parts, and these factors can lead to disruptive paper jams and multiple feeds/misfeeds, which forces the machine to be taken out of service for emergency service. Inconsistent or inadequate electrical conductivity or the level of coefficient of friction (COF) of the belts, tires and rollers in the transport mechanisms are often the culprits in self-service machines' operating failures.

Addressing the cause of these failures involves the application of chemical engineering at the molecular level. Self-service machines' moving parts can be formulated from metal, rubber, plastic or from polyurethanes. The choice of the material and its specific properties, especially electrical conductivity, compressibility, wear resistance and COF, are critical design considerations.

URETHANE VS. METAL

Polyurethane offers significant advantages over metal. It weighs less, is easier to handle, generates far less noise and outperforms metal. Polyurethane components can outlast metal parts by up to three times. Polyurethane can also be cast using relatively inexpensive tooling as opposed to the machining and welding needed for manufacturing metal.

POLYURETHANE VS. RUBBER

Polyurethane provides superior abrasion, cut and tear resistance over rubber. Polyurethane can be easily formulated to outlast rubber and stand up to sunlight and outdoor environmental conditions. Polyurethane also boasts higher load-bearing capacity, better compression set and superior tolerance to grease, oils oxygen and ozone.

Additionally, most cast polyurethanes can be formulated in colors that range from clear to opaque, in any color shade from black to white. This allows for easy color-coding of parts. Polyurethane rollers and belts used in self-service machines are often color-coded to simplify maintenance, ensure proper placement, and to make it easier to detect wear or debris build-up.

Polyurethane vs. plastics

Strictly speaking, cast thermoset polyurethane is not a “plastic” and it has many benefits that plastic lacks. With plastic parts, the higher the durometer (a measurement of the hardness of a material against permanent indentation), the more likely plastic is to crack and break. Unlike plastics, the long flexible polymer molecules that comprise polyurethane make it a true elastomer capable of tremendous impact resistance even at very high hardness. More importantly, polyurethane retains its elasticity and strength over the complete range of hardness. Even at high hardness (as measured by its durometer), polyurethane can be stretched to substantial elongations and will still return to its original dimensions, whereas beyond a certain point stretched plastics will remain permanently stretched or even break.

MPC’s expertise with polyurethane elastomers: working at the molecular level

MPC’s half-century of experience working with urethanes has led to over 20 patents relating to unique urethane formulations. During the past five years MPC has significantly strengthened its urethane formulation and product development capabilities.

MPC excels in developing urethane-based materials to enhance hardness, wear resistance, electrical conductivity and electrostatic dissipation (ESD) for critical high-wear components like belts, pads, wheels and rollers. MPC is unique in its ability to custom formulate semi-conductive urethanes in both solids and microcellular foams, with a wide range of hardness, densities and other properties.

MPC’s ability to provide customizable levels of electrical conductivity, hardness, compressibility and coefficient of friction (COF) greatly increases self-service machines’ reliability and performance, and also eliminates the need for overly tight tolerances in design.

The key reason for using conductive polyurethane (available in both solid and microcellular foam) is to dissipate a static charge without the use of conductive carbon black. The high-speed motion of self-service machine operations can quickly lead to a build-up of static electricity: this charge must be managed in order to prevent critical malfunction, equipment damage and even the chance of combustion. Conductive polyurethanes can be formulated to be very uniform in electrical conductivity so they are ideal for providing ESD protection.



Conductive polyurethane elastomers are formulated to be semi-conductive within a prescribed range of conductivity to dissipate harmful static electricity buildup. MPC accomplishes this by modifying the urethane structure at the molecular level, avoiding the use of carbon black or conductive particles, which can shed and cause equipment short circuits as well as marking the currency or documents issued by a self-service machine with a black smear.

Other manufacturers control conductivity by adding high concentrations of carbon black or metal powders (20-80% by weight). Due to the large particle size of the carbon black and the high weight of the metallic powders, they do not disperse uniformly inside the urethane matrix, which results in uneven conductivity and migration of the carbon black and metal powder to the surface. Migration of carbon to the surface of the components after abrasion wear will stain the transported medium, producing dark marking on paper and low wear resistance. Conductivity achieved in this manner is likely to decline over time, changing the performance characteristics of the components and leading to equipment failure.

MPC adds its conductive chemicals to the precursors during the liquid phase. It uniformly mixes proprietary conductive additives during the liquid phase of precursor materials, including pre-polymers, curatives and extenders. The chemicals then react to form cross-linked thermoset polyurethanes that have uniform conductivity throughout.

COEFFICIENT OF FRICTION

COF is also an important consideration in self-service machines for controlling the grip of a belt, wheel or roller against a range of paper currency, paper receipts, tickets and cards. COF is a measure of the resistance to motion between two contacting surfaces. Consistent COF enables a machine part to grab one item at a time, move it a precise distance, and let go exactly at the right moment.

MPC can accurately target the best COF through exact materials formulation and specialized coatings. These methods ensure a consistent COF over a long period of time, ensuring trouble-free performance. MPC's materials also prevent clogging and glazing at the contact surface, which can be a cause of machine failure with other materials.

Working with MPC

MPC tailors its customized polyurethane formulations for each customer and then designs a specific component to meet the performance needs of the application. Because MPC formulates and produces customized parts, the company first takes the time to understand the unique challenges of its customers' applications. With vast experience in urethane chemistry and processing, MPC's chemists and engineers collaborate closely with its customers' engineering departments to develop formulations close to optimum specifications.

They begin by selecting the best base material for each custom formulation. Base urethane materials include ethers and esters with varying diisocyanates (chemical building blocks for making polyurethanes) which possess the following general characteristics:

ETHERS	ESTERS
<p>Excellent hydrolytic stability</p> <p>Lower COF</p> <p>Excellent resilience</p>	<p>Excellent abrasion resistance</p> <p>Excellent physical strength</p> <p>Higher COF</p> <p>Higher temperature stability</p>

TDI	MDI	PPDI
<p>High tensile strength</p> <p>High COF</p> <p>Excellent compression set characteristics</p>	<p>High resilience</p> <p>Good hydrolytic stability</p> <p>Good fatigue characteristics</p>	<p>Excellent physical properties</p> <p>Excellent flex fatigue characteristics</p> <p>Good resilience</p>

With its extensive working knowledge of urethane process parameters, MPC will then use a wide range of high-quality additives, adjusting performance specifications for the following:

- Abrasion resistance
- COF
- ESD
- Flame retardance
- Rebound
- Thermal conductivity
- Adhesion
- Color
- Excellent performance & physical properties
- High flex modulus
- Reversion resistance
- Transparency
- Aging
- Electrical conductivity
- Excellent release characteristics
- Hydrolytic stability
- Temperature resistance
- UV protection

— CASE HISTORY

Solving an ATM feed failure problem

THE PROBLEM

Misfeeds in an ATM document collection unit were causing field failures, customer frustration and a high service call rate. The OEM-selected feed unit tires and timing belts were not functioning properly.

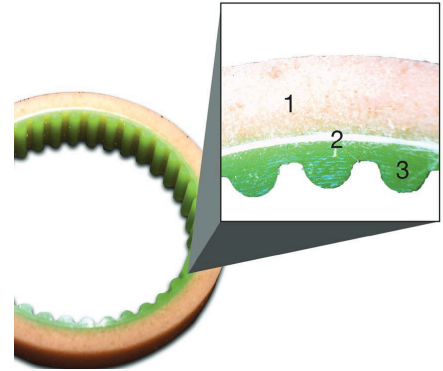
THE MPC SOLUTION

MPC proposed combining the functions of the tires and the timing belt into one multi-layer belt with varying durometer and COF on each side of the belt as well adding an internal strength layer to improve operational life.

The top layer (1) is MPC's "self-cleaning" microcellular foam with a COF tailored to the type of material being transported. The middle layer (2) is a series of cords to improve strength and limit stretch. The bottom layer (3) is a hard, durable solid urethane with a customer-designed tooth pattern.

THE RESULT

The OEM customer was able to replace multiple parts with MPC's custom-formulated three-layer belt. Although the initial cost of this new replacement belt was higher than the components it replaced, field failures virtually ceased. The customer estimated that the MPC custom belt will save them over \$9 million per year in service calls, downtime and replaced parts. MPC has shipped over 300,000 of these belts to date, vastly improving the customer experience and the client's peace of mind.

**\$9M**

ESTIMATED ANNUAL SAVINGS

300,000+

BELTS SHIPPED TO DATE

Tell us what you're working on.

For more information on MPC's capabilities and experience, visit www.mpcurethane.com

[Get Started ›](#)