How Do You Know You’ve Got the Right Cover for Your Roller?

A Conversation Between a Rubber Chemist and an Engineer

By

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Abstract:

Most people who operate coating or laminating lines are not rubber chemists. The specifications for their elastomeric covered rollers come from various sources, many dubious at best. How thick should the wall be? What durometer works best in this application? Why isn’t there a magic compound that will work for all of my products? This paper will examine some of the more common converting applications through a series of discussions between a rubber chemist and a process engineer and how they derive the specifications for an optimal cover.

Introduction:

When it comes time to choose an elastomeric cover for a process roller the end user is only concerned with what compound works best. Sometimes operating conditions and environments are not a concern and do not affect the performance of the cover. In these cases the end user has many choices and can make the decision based solely on economic reasons. In most cases the process and its environment strictly limit the types of covers that can be considered. Because the end user is not usually a rubber chemist, compound limitations are not fully understood. This lack of knowledge leads to incorrect specification of the cover compound. This paper aims to give the end user some basic tools to understand how to specify an elastomeric roller cover.

What Compound Should I Use?

Every rubber family has its own special attributes. Some are great for temperature resistance. Some are great for chemical resistance. Some are almost impossible to cut or scratch. Contrary to every end users wishes One type of rubber is not appropriate for all applications. For instance, polyurethane covers are great for wear resistance. They are incredibly tough and are very resilient. The covers are typically cast and therefore do not leave any seam marks from the manufacturing process. These properties make
polyurethane a very desirable cover material. However, polyurethane has a relatively low maximum operating temperature. Above 160°F polyurethane starts to soften. Above 180°F, polyurethane reverts or returns to being liquid. Fig. 1 lists some of the more common rubber materials and their properties.

1. **Properties for Common Rubber Compounds:**

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When beginning to select a rubber cover material, it is crucial to know all of the working parameters the roll will encounter during operation. Fig. 2 lists important operational questions that should be answered before choosing a roll cover that is right for your process.
2. **Rubber Cover Operational Parameter Questionnaire:**

1. What type of operation does this roll perform?
2. What temperature does the roll face see during operation?
3. Is the roll body chilled?
4. What chemicals are present on or near the roll cover?
5. Is the roll in a nip? If so, what type of pressure does the cover see in PLI (lbs./linear inch)?
6. What durometer is desired?
7. What type of surface finish or RA is desired?
8. What is the T.I.R. (Total Indicated Runout) and Taper required for your cover?

Finding the correct answers to these questions can sometimes prove to be difficult. Do not give up if the answers do not come easy. Proper process optimization cannot be carried out without valid answers.

**Durometer vs. Modulus:**

Durometer is the method in which the rubber industry specifies a particular rubber compound’s hardness. There are actually three different durometer scales, which include Shore A, Shore D, and the P scale. Generally the Shore A scale is used in the rubber roller industry. Durometer is derived by using a calibrated spring-loaded tool which presses a probe into the rubber and reads a value. This reading is affected by the wall thickness of the cover and can be biased by the operator depending on the way in which the instrument is pressed into the rubber. It is a relatively easy test to perform and widely used by both producers and end users alike. The only problem is that durometer only shows a small part of the mechanical properties of the compound.

All durometer readings are performed when the roller cover is static. They are never performed in a process nip. Durometer readings are also usually performed initially before the cover is put into service. The assumption is that the durometer is a constant value. The reality couldn’t be further from the truth! The durometer of a cover will change depending on the chemical makeup of the compound and the forces present in a process. For instance, a Hypalon cover will soften in the presence of heat and pressure. It just so happens that these are the two most common external forces found in most converting processes. This softening is due Hypalon’s molecular make-up. Hypalon is Chloro-Sulfonated Poly Ethylene. Like other plastics, with heat it softens. When the heat and pressure are removed, the durometer usually returns back to its static condition. From compound to compound durometer is not a good predictor of performance under process conditions.
A better predictor of cover performance under process conditions is the material’s modulus. Modulus will tell us how “stiff” or how “pliable” a material will behave as it is exposed to process forces. Modulus is simply the strength of a material at a given force. Each compound has its own modulus curve which is directly related to its molecular structure. Compounds with high modulus numbers are highly reinforced because they have no inherent strength. Reinforcement can be supplied by Carbon Black or by other various inorganic fillers (silicas). Reinforcement promotes resistance to pressure. Compounds with low modulus numbers are crystalline in structure and do not develop their strength until the molecules align. These structures are more flexible and displace much easier.

Rubber families with crystalline molecular makeup include Natural Rubber, Chlorinated Rubber (Neoprene) and Isoprene (synthetic Natural Rubber). As mentioned above these rubber families are very flexible. All other rubber families must have fillers and or reinforcement agents to increase their strength and process ability.

**Which is Harder: 90 Duro Polyurethane or 90 Duro Hydroginated Nitrile?**

This sounds a lot like that old trick question: “Which weighs more; a ton of bricks or a ton of feathers?” The answer of course is they both weigh the same amount, one ton. The reality is that even though both of these abovementioned compounds have a durometer of 90 Shore A, the harder material turns out to be Hydroginated Nitrile (HNBR). This is true because polyurethane has a lower modulus number than HNBR. When the two are placed under the same pressures in a nip, the polyurethane will produce a larger nip impression than the HNBR even though both have the same durometer. This little fact seems to escape even the best roller salesmen and end users.

The fact that differing compounds behave differently even though they have the same durometer is huge. The following case study reinforces this fact. Customer A initially used a 90 durometer polyurethane in a high pressure embossing application. This cover produced a near perfect replication of the desired embossed pattern. Unfortunately, the casting process used to produce the cover left an undesirable background pattern in the clear embossed film. HNBR was chosen as a replacement cover due to its high strength and wear properties. Customer A felt that because 90 duro polyurethane worked well that the replacement cover material should also be 90 duro. When the HNBR roll was put into service, it did not produce the same replication of the embossed pattern. As more pressure was added to produce the pattern, the roll began to bend and then even worse defects were produced. What Happened?

A durometer model does not explain what happened. They were both 90 Durometer! A quick look at the two materials’ modulus tells the whole story. The polyurethane cover, which has a relatively low modulus, “flowed” more easily in the nip impression producing a longer dwell time for the material to be under pressure and be allowed to pick up the embossed pattern from the embossing roller. This longer dwell time produced a more perfectly formed pattern. The HNBR with a high modulus produced a narrower nip impression, shorter dwell time in the nip, and a less-formed embossed
pattern. Material modulus needs to be well understood when specifying durometer and compound for any given process.

**Can Modulus be Altered for a Given Polymer Family?**

As mentioned at the beginning of the paper sometimes a process limits the type of cover that can be used on a roller. For instance, people who use UV cured chemistries in their process limit themselves to the use of EPDM due to its superior chemical resistancy. One of the problems with EPDM is that it tends to take on permanent sets (dents) in its surface. Once again this is due to its molecular structure. EPDM does not have any inherent strength; it must be reinforced. The good news is that there are many different ways to compound roller covers including many different types of reinforcing agents. If customer A needs certain properties and customer B needs other properties then a given polymer family can be compounded different ways to try and meet those needs. The two different compounds could even have the same durometer and act drastically different. EPDM’s modulus can be changed by varying the reinforcement agent. Using Carbon Black, which is an organic compound, strengthens EPDM more than using silica an inorganic compound.

Another way to change modulus and to differ properties of a given compound is to use different cure systems. For the rubber industry there are two major types of cure systems. The first is the sulfur cure system and is the type of system that Goodyear used to perform the very first vulcanization (cross-linking) process. The other major type of cure system is a Peroxide system.

The sulfur based cure system is used for many reasons. First of all sulfur is cheap. Sulfer also acts as a process aid and allows for easier mixing. It produces generally lower modulus compounds and promotes longer elongation. However, because of its weaker ability to cross-link the compound, sulfur cures generally produces a weaker cover more prone to compression set. These types of compounds are also less abrasive resistant and have overall less heat resistance.

Peroxide cures promote higher cross-linking within the cover compound. With the higher cross-links comes a higher modulus material. These covers do better at heat and abrasion resistance. Peroxide cured rollers also are more resistant to compression set. The down side is that peroxide cures systems are generally more expensive and harder to process. They also are stiffer and do not elongate as easily as sulfur based compounds.

Finally, modulus can be changed in a polymer family by chemically altering the base polymer. This is true for the Nitrile or Buna rubber family. Buna comes in three forms: Nitrile (NBR), Hydroginated Nitrile (HNBR) and Carboxylated Nitrile (XNBR). These three forms of the same base polymer family behave differently when compounded into covers. HNBR is Nitrile that as been combined with Hydrogen molecules. XNBR is Nitrile that has been combined with Carboxilic Acid. By changing the base polymer the modulus will be different for each compound even though they may have the same durometer.
To Step Cut or Not to Step Cut: That is the Question

Once an appropriate elastomeric cover has been chosen, it is also important to think about the geometry of the roller. Besides roller concentricity and diameter variation, face width must be considered. Many times webs are narrower than the roller nips they are traveling through. This occurs for many reasons. Sometimes the reason is simply because the latest product running on the line changed widths. Whatever the reason, careful thought should be given to adjusting the face width to match the web. Non-productive nip impressions produce nothing but the requirement for more work and more wear and tear on the equipment.

Consider a heated embossing nip. This is illustrated in Fig. 3. The web runs through the center of the nip. The web is four inches narrower than the roller face so that there is 2 inches of nip on either side of the web doing nothing but being nipped together. As with many embossing lines a great deal of heat and pressure were being applied to the roller and its cover. Over time, the covers generated cracks, which eventually lead to cover failure. Upon careful examination it became evident that the cracks always originated in the area of the cover where the web edge existed (indicated by arrows). Along those edges, the cover sees very large stresses because of the shape of the nip around that web edge.

3. **Un-stepped Embossing Nip:**

By adding step cuts just outside of the web edge, the required pressure to generate the desired image was reduced dramatically.(Fig. 4) This resulted from the fact that pressure was not needed to produce nip impressions outside of the nip. Lower operating pressure translates to lower wear and tear on the equipment. The best result from the addition of the step cut was that the cracking failure along the web edge ceased. The geometry change in the cover prevented the rubber along the web edge from being continually over stressed. The reduction in stress kept the material from cracking.
4.

**Stepped Embossing Nip:**

![Diagram of Stepped Embossing Nip]

**Conclusion**

The converting process will always dictate the type of cover that is required to produce a finished product. The problem is that most people specifying the cover are not aware of their process’ need. Each rubber family has different property strengths and weaknesses. Some are better at heat resistance, some better at solvent resistance, some are stretchy, and some are stiff. While durometer is one of the most widely used specifications for a rubber roller cover, it does not describe the properties of a cover in motion. Modulus is a dynamic property and better describes a compounds’ behavior while exposed to changing forces in a process. Materials can have the same durometer and perform drastically different due to the differences between their molecular structures. When specifying a cover it is absolutely necessary that the roller’s function be defined and understood in order to choose the correct cover for the job. Without this knowledge, the correct cover cannot be chosen and the process will never be optimized.
BACK TO LIST