Rubber-to-Metal Bonding
Part Art, Part Science

By
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Automotive and industrial manufacturers are increasingly are turning to rubber to metal technology to reduce the raw number of components, eliminate vibration and improve the performance of individual components and subassemblies used in harsh environment applications.

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Background
Rubber to metal bonding is a generic phrase that covers several interdependent processes used to manufacture a wide variety of automotive and industrial products used to isolate noise and vibration. Years ago the subject was regarded as a ‘black art’ but today technology allows sophisticated manufacturers like Delta Rubber to produce high quality, defect-free, uniform rubber to metal components.

Rubber to metal bonding has three essential elements…the rubber, the bonding agents and the substrate. The polymer base and the associated compounds that are chosen depends on the product being produced. Assuming the rubber can flow into the mold with less than 2% cross-linking, a bond can be formed using any rubber compound. While there are few restrictions on the use of any individual compounding ingredients, it is generally a good idea to avoid substances that could bleed rapidly to the surface of the uncured stock. A rubber compounder, like Delta Rubber, is most often used to match the physical requirements of the cured rubber to the molding process.

The Bonding Layer
For many years the bonding agents have consisted of proprietary polymer/solvent solutions, with a primer coat based on phenolic-style resins and a polymer topcoat. Bond formation is produced via the development of a very high modulus layer in the rubber immediately adjacent to the surface of the substrate.

Selection of Bonding Agents
The selection of bonding agents depends on the type of rubber to be bonded, the modulus of the rubber and the component design. The selection process is critical to the robustness of the bonding process. With the advent of greater concern for environmental safety, water-based versions of bonding agents have been introduced, which after much development are now effective replacements for the solvent-based bonding agents. Bonds tend to be up to 10% lower but components show good resistance to the usual environmental conditions found in automotive applications.

The application methods for water-based bonding agents are similar to those for the solvent systems, but inserts do need to be preheated to 60-80 °C before spraying with the primer, and reheated before applying the topcoat. Drying times are quick and are no barrier to high volume production.
Choice of Substrate
The choice of substrate depends on the strength and durability requirements for the component being produced. The most common substrate has often been steel, but the use of aluminum alloys and polyamides to save weight is increasing dramatically. Almost any material can be bonded to rubber, provided that it can withstand the heat and pressures of the rubber molding process. For practical purposes this eliminates polyolefin plastics. Polyacetal inserts can be bonded but require careful etching and rubber molding temperatures below 150°C. PTFE provides a useful low friction material for use in anti-roll bar bushes. It can be bonded successfully to the rubber by chemically etching the surface of the plastic prior to application of the bonding agents. However, its use in such applications has been largely superceded by woven PTFE/Terylene fiber material, which offers a mechanical bond, and, more recently, by slip agents that bond freely to the surface. Delta Rubber offers bonding of a variety of metals such as CRS, 304SS, 430 SS and several grades of 1010CRS to a long list of polymers including Vamac, NBR, HNBR, FKM, EPDM, Neoprene, ACM and Natural rubber.

The Bonding Process
The process begins by loading a specific volume of inserts into a perforated, motorized SS drum. The volume is determined by the size of the inserts. The drum is equipped with a motor and timer which tumbles the inserts for a specified time in each subsequent operation of the treatment process. The
first operation is to pre-clean in a 400 gallon, heated tank of alkali. This removes all traces of oil, grease and solid lubricants to promote good bonds.

At the end of the pre-clean cycle, the drum automatically rises out of the tank and is then manually moved through two water rinse cycles. The drum of inserts then goes thru an acid dip followed by two water rinses to etch the metal, preparing the surface for good attachment when immersed in a heated zinc phosphate solution. The zinc phosphate coats the metal surface providing a good foundation of the application of the adhesive.

After the phosphate dip there are two water rinses and an air dry prior to immersion in either a solvent or water based adhesive. The combination of the type of metal and of rubber determines the selection of adhesive. The coating of the zinc and adhesive not only bonds the rubber to the metal but also imparts rust resistance. Following the adhesive dip the inserts are air dried prior to use.

The temp and concentration of each of the chemical tanks are measured and plotted daily. The percent solids of the adhesives are also checked daily and recorded.

During molding, a bond pull test using pliers is made three times each shift by the press operator to be sure the bond is such that the rubber fails before the bond is broken. Additionally, samples of the rubber bonded inserts are put through a salt spray chamber according to ASTM B117 daily to check for corrosion resistance.

**Rubber molding**

The rubber molding operation is the most critical point in the process. If there is a problem with even a single element in the production cycle for the inserts or bonding agent, it is likely that the product will fail. For automotive production injection molding is the most common method employed. This method provides a significant amount of control over the process by tailoring the condition of the rubber as it enters the cavity to produce consistent product quality.

**Mold Design**

Molds do need to be designed to ensure exact balance between cavities and the elimination of trapped gases. The presence of gases causes a high incidence of bond failures through the ‘diesel effect’, whereby elements of the bonding agent film burn under the combined effects of heat and high-pressure gas. Lack of balance between cavities will result in some components that are imperfectly formed and give rise to bonds that may fail.
Problems such as these are readily avoided by study of the rubber flow through the mold using computer flow simulation packages. These model the effect of mold design on pressure gradients and the cross-linking behavior of the rubber. Computer analysis allows the optimization of runner sizes and molding conditions before the mold is manufactured, so that components are produced to specification.

**Plated Inserts**

The use of plated inserts is popular with some designers. Good bonds can be obtained with plated inserts, but some problems can arise in service if the bond edge is subjected to frequent exposure to electrolytes. Salt solution from roads will produce ‘battery’ cells between the plated metal and the carbon black in the rubber. Up to 0.8 V has been measured under salt spray test conditions. The production of nascent hydrogen at the electrode surface causes a localized de-bonding process, known as cathodic disbondment, that will cause eventual failure.

**Applications**

While there are many industrial applications for rubber to metal bonding the largest market for the technology is motor vehicles. Motor vehicles use a large number of rubber components, many of which are bonded including:

- The engine and gearbox units are mounted on a rubber bonded unit that may incorporate hydraulic damping systems to damp out engine noise and vibration more perfectly over a wide spectrum of frequencies.
- The strut units mount the wheels to the vehicle chassis via a shear style rubber bonded bush.
- Sub-frames need to be coupled by stiff mounts that allow some flexibility.
- The steering wheel is joined to the steering rack by bonded components and the various link arms in the suspension and steering …all incorporate bonded bushes. They act together to provide the comfort and road handling characteristics that are demanded in the modern motor vehicle.
- Bonded units are also used to correct harmonic vibrations that are sometimes found in the chassis of the lighter, less rigid bodies. Using a rubber bonded mass, called a harmonic damper, that is connected to a vibration node allows the damping of these vibrations.
**Summary**
As automotive and industrial companies put a greater emphasis on continuous improvement in their manufacturing processes for precision rubber components, they are increasingly turning to rubber to metal technology to reduce the raw number of components, reduce vibration and improve the performance of individual components and subassemblies used in harsh environment applications.

As a result, manufacturers are drawing on the rubber to metal expertise of key suppliers, like Delta Rubber, by bringing them into projects early in the design process. Doing so helps design engineers focus on reducing inefficiencies designed into rubber to metal components early in the design process when revisions are least expensive and easiest to make.

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**Note:**
*Source materials for this articles included rubber to metal bonding articles written by John Lindsey for Materials World Magazine; information from the Institute of Materials; AZOM.com and a host of Delta Rubber scientists and engineers.*