



Rubber Compounding & Mixing: A Breakdown of How to Effectively Engineer & Mix Rubber Formulations

By Cody David, West American Rubber Company

Rubber Compounding

Rubber compounding is the starting point; it defines the performance characteristics of rubber goods used in a wide array of applications and industries. For rubber products to meet the requirements of an application, their essential physical characteristics must be studiously engineered.

This intricate science involves the careful selection and blending of various ingredients to craft formulations that will meet the industrial needs of the application. To ensure optimal performance, longevity and reliability of a rubber formulation must be balanced effectively to create the correct set of properties, process efficiently, and mitigate costs.

1. Effective Rubber Formulations

Achieving the right balance of ingredients in rubber compounding goes beyond mere measurements. Truly, this is an art.

Rubber chemists leverage their expertise to meticulously select and blend components, refining recipes to optimize rubber formulations for superior mechanical properties, and resilience against stress, strain, and environmental factors. The vast variation of requirements that can be engineered in the final product showcases the adaptability and flexibility inherent in rubber compounding.

An experienced rubber chemist will be able to analyze the required properties of an application and craft a formula that will balance the result with the associated cost. The mark of a premier research and development lab is its ability to create a compound that will meet or exceed the customer's needs while remaining cost-efficient. An excessively optimized compound can be just as ineffective as a poor-performing product.

2. Rubber Compound Ingredients Breakdown

Understanding key components of a rubber compound is essential for appreciating their roles:

Ingredient Category	Effect	Explanation
Polymers	Determines critical properties	Whether natural or synthetic, polymers define essential properties such as specific chemical resistances, elasticity, and flexibility. Natural rubber, derived from latex, exhibits high elasticity, while synthetic polymers like styrene-butadiene rubber (SBR) offer improved wear resistance.
Fillers	Enhances mechanical performance	Carbon black and silica, acting as reinforcing agents, provide strength, durability, and wear resistance, enhancing overall mechanical performance. The specific type and amount of filler significantly impact the compound's physical properties, such as hardness and abrasion resistance.
Plasticizers	Contributes to material flexibility	Essential for enhancing flexibility and workability, plasticizers ensure rubber can be molded or shaped without compromising its inherent properties. Common plasticizers include oils and resins, contributing to the compound's processability and elongation.

Curing Agents	Final Shape Retention	Sulfur or peroxides facilitate vulcanization, transforming rubber from a pliable material into a robust, resilient substance. The vulcanization process involves cross-linking polymer chains, creating a network that improves strength, elasticity, and resistance to heat and chemicals.
Accelerators	Aids in Final Shape Retention	These compounds speed up vulcanization, working with curing agents to promote efficient cross-linking of polymer chains. Common accelerators include thiurams and sulfenamides, enhancing the efficiency of the vulcanization process.
Antioxidants	Environmental resistance	Guardians against oxidation and degradation, antioxidants preserve rubber integrity, preventing deterioration due to environmental exposure. Hindered phenols and amines are common antioxidants, extending the service life of rubber products by inhibiting oxidative processes.
Softeners	Aids in processing, and contributes to flexibility	Modifying hardness, softeners enhance processability and impact resistance, contributing to the versatility of rubber. Oils (and some plasticizers) can serve as softeners, improving the compound's flexibility and low-temperature performance.
Stabilizers	Additional environmental resistances	Defenders against degradation caused by heat, light, and environmental factors, stabilizers ensure long-term stability. Hindered amine light stabilizers (HALS) and UV absorbers protect against degradation induced by exposure to sunlight and environmental elements.
Colorants	Hue determination	Beyond aesthetics, colorants allow for identification or customization, serving practical and branding purposes. Inorganic pigments and organic dyes provide color options, ensuring the rubber product meets specific visual and branding requirements.

Each ingredient plays a crucial role in the composition, contributing uniquely to the final product's properties and performance.

3. Additional Considerations

Integrating a research and development lab with an in-house mixing facility and form production, such as calendering, molding, extruding, and splicing, is pivotal. The feedback loop allows for both processing and engineering units to improve their products optimally. This holistic approach ensures consistency and quality throughout the manufacturing process, transforming the rubber compound into the final product with precision and efficiency.

This intricate combination, guided by the expertise of rubber chemists, defines the dynamic and intricate process of rubber compounding. The understanding of polymers, fillers, plasticizers, curing agents, accelerators, antioxidants, softeners, stabilizers, and colorants contributes to the creation of formulations that stand the test of time and performance. The journey from formulation to production is a testament to the intricacies of rubber production, crafting quality that meets and exceeds industry standards.

Rubber Mixing

This transformative process initiates the creation of versatile materials that ultimately become functional rubber products. The process goes beyond the mere mechanical amalgamation of these ingredients; it's a precise science, amplified with artistry, that determines the intrinsic properties of a rubber compound. Physical characteristics, performance attributes and, ultimately, the quality of finished rubber products are directly influenced by the mixing process. Understanding the nuances of rubber mixing is essential for delivering products that consistently meet and exceed both industry standards and customer expectations.

1. The Goal: Ingredient Dispersion

Understanding dispersion and shear in rubber mixing is crucial for achieving consistent and high-quality results. Dispersion refers to the uniform distribution of all ingredients, which ensures that each component is thoroughly blended. The ultimate goal of rubber mixing is to achieve a high level of dispersion as poor ingredient distribution can lead to failed physical properties and a lack of desired characteristics. Lumps, pinholes or a bumpy, uneven textured surface on finished parts can be a key indicator of poor dispersion. This can result in sub-standard wear and propagate fissures and tears.

Shear describes the force applied to the rubber compound to drive dispersion, with higher shear rates leading to better dispersion. By controlling shear forces, rubber manufacturers can optimize the mixing process to develop the desired properties in their products.

There are four key measurement parameters that play a significant role in achieving effective dispersion:

- **RPM** or revolutions per minute indicates the speed of mixing equipment rotation
- **Amps** measure the electrical current drawn by the mixer and correlates to the workload of the mixer
- **Temperature** is monitored to precisely blend ingredients and prevent scorching or premature curing
- **Time** is fundamental to control the duration of mixing required to reach homogeneity

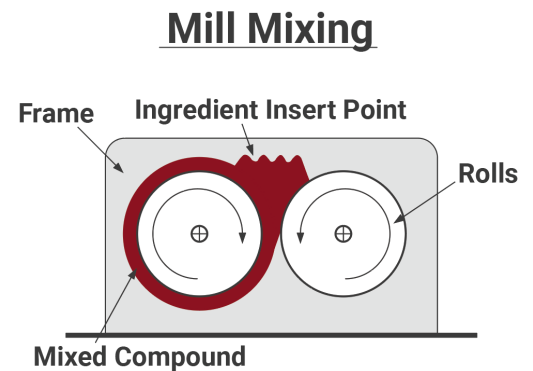
2. Two Methods of Rubber Compound Mixing

There are two primary methods for mixing rubber compounds: mixing with an open-mill or utilizing an internal mixer. While open-mill mixing offers simplicity and provides for small batch sizes, internal mixer mixing provides enhanced control and efficiency gains through speed and larger batch sizes.

Open-Mill Mixing

Open-mill mixing occurs on a two-roll mill, a foundational method facilitating efficient blending and dispersion. The shear rate is primarily controlled by adjusting the speed of and the nip or space between the mill rolls. However, achieving uniform dispersion may be challenging due to the limited control over mixing parameters compared to internal mixer mixing.

Open-mill mixing's strengths lie in its simplicity, low equipment cost and ability to mix small batches. However, it comes with limitations regarding precision and control over mixing parameters. It typically allows for the measurement of only two of the four key mixing parameters: RPMs and time. Moreover, it is a slower process with each batch requiring 30-45 minutes to blend properly. Achieving nuanced formulations, particularly those with specialized requirements, may present challenges.

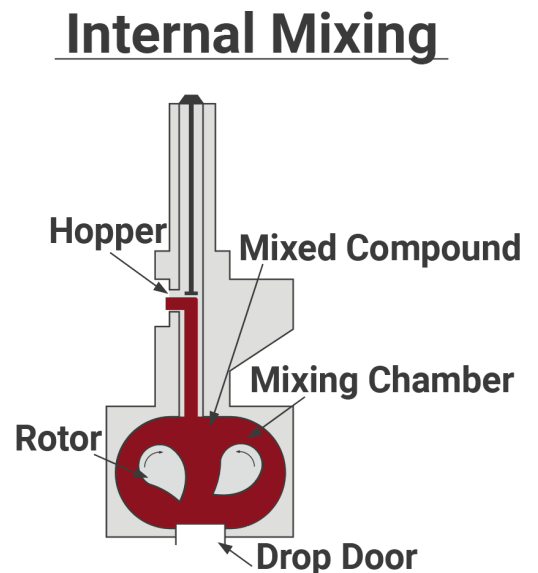


Internal Mixer Mixing

Internal mixers are specialized machinery, offering heightened control over mixing parameters which provides more consistent results. This method ensures a precise blending process that enhances the overall quality of the rubber compound.

Each of the four key mixing parameters are precisely optimized as well as a host of additional controls and monitoring functions. Operators can perfect the shear rate of the mixer rotors against the walls of the mixing chamber to ensure thorough dispersion of ingredients, leading to a uniform and consistent rubber compound.

Internal mixer mixing is a complex process that offers improved control and efficiency along with a higher investment in machinery. The benefits include a precise blending process, significant speed improvement of a mere 5-7 minute cycle time per batch, and command over mixing parameters. This level of control is integral for high performance compounds designed for applications requiring critical performance and specific requirements.



3. Steps in the Rubber Mixing Process

1. Introduction of the Polymer

The rubber mixing process commences with the introduction of the polymer, the fundamental building block of rubber compounding. The choice of polymer establishes the foundation for the material's performance and dictates its inherent characteristics. See warco.com/polymers to learn about each polymer's properties.

2. Sequenced Addition of Ingredients

While the polymer typically has the largest impact on the characteristics, additional ingredients are included to determine features such as curing and processing performance, cost consideration, hue designation, anti-degradation, and much more. This includes fillers, plasticizers, curing agents, accelerators, etc. See our previous article, warco.com/the-art-of-rubber-compounding for a general breakdown of each ingredient type's effect.

3. Achieving Homogeneity in the Compound

The ultimate goal is achieving thorough homogeneity. A seamless blend of all ingredients creates a uniform and consistent rubber compound. A homogeneous rubber compound ensures uniform characteristics throughout production processing, curing and the final application of finished rubber goods. This is achieved by carefully moderating the four key mixing parameters according to the compound requirements while carefully considering chemical interactions of ingredients. Each rubber compound performs and reacts differently to the process and therefore requires an experienced operator execute on each compound's detailed and exact mixing procedure to create the ideal mix.

4. Key Takeaways

The key to manufacturing quality rubber products begins with precise control over compound mixing parameters coupled with a deep understanding of the materials and their interaction with each other through the process. Our technical managers leverage their expertise in chemistry, mixing parameters, compound ingredient reactions, form production process and cure methods, and more to establish the ideal procedure of temperature, time, ingredient sequences, and shear rate.

An effective rubber manufacturer must be well equipped with testing equipment to measure the unique parameters of a compound prior to and after the form/cure production process. This feedback loop allows for a higher standard of quality and consistent, repeatable, and reliable results.

WARCO develops proprietary formulations, mixes compounds, and produces your sheet, molded and extruded rubber products in a single facility. Our expertise spans beyond our 114-year history providing quality rubber products to American industry and the global supply chain. Our wealth of experience, unique flexibility and integration, and tight control over each step of production are among the key contributors to how WARCO became America's Choice for Quality Rubber.

If you have any questions for us, please reach out by phone, 714-532-3355, by email, sales@warco.com or learn more at warco.com.



JOIN THE WOMEN OF THE GFA LINKEDIN GROUP

Scan the QR Code to Join the Women of the GFA LinkedIn Group.

The Women of the GFA (W-GFA) is a thriving community of women united in a commitment to positivity, support, and education.

