A REVIEW ON RUBBER COMPOUND MIXING IN BANBURY MIXER AT TIRE INDUSTRIES

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Abstract: In tire industries the formation of rubber is an important aspect for the manufacturing of tire. This formation is done in the Banbury mixer by adding various different compounds in the rubber. The rubber initially cut in the required proportion by Bale cutter and processed in the mixer. After process Rubber forwarded to the hot extruder and cold extruder for the formation of tread, bead, sidewall, ply etc. In this paper i have completely reviewed the formation of master and final rubber also discussed about the importance of compound added in the mixing of rubber.

Keywords: Mixing process, compound adding, Master rubber formation, final rubber formation, and Bale cutter.

INTRODUCTION
In tire industries for making a tire mixing or compound formation of rubber is most important part. The two major ingredients in a rubber compound are the rubber itself and the filler, combined in such a way as to achieve different objectives. Depending on the intended use of the tire, the objective may be to optimize performance, to maximize traction in both wet and dry condition, or to achieve superior rolling resistance. Compounding is the operation of bringing together all the ingredients required to mix a batch of rubber compound. Each component has a different mix of ingredients according to the properties required for that component. The Mixing process was reviewed at APOLLO TYRES LTD, LIMDA (Gujarat) in which there are four major rubber used: styrene-butadiene rubber (SBR), Polybutadiene rubber (BR), and butyl rubber (along with halogenated butyl rubber). The first three are primarily used as tread and sidewall compounds, while butyl rubber and halogenated butyl rubber are primarily used for the inner liner, or the inside portion that holds the compressed air inside the tire.

This research paper includes brief introduction of compound formation, mixing of compound using Banbury mixer, cycle of Banbury mixer.

Mixing Technology of Rubber:-
This chapter deals broadly with the art and science of mixing rubber. Those unfamiliar with the nuts-and-bolts aspect of the industry may all too readily attribute artistic (or even magical) practice to the exotic ingredients and process techniques involved in manufacturing rubber articles. Others who have experienced the frustration when a composition does not quite meet a required physical property, lacks an anticipated attribute, or processes unsatisfactorily for no apparent reason, only to uncover remedies that are as difficult to explain as the symptoms, they will understand the phrase 'art and science'. These occurrences do not detract from the scientific achievements that have driven the art of mixing to its current level of sophistication.

The goal in mixing is to provide compositions having useful properties and suitable processability with as high a level of consistency as possible. The terms useful and suitable are determined by the application, for example, what is suitable for a sink stopper might not be suitable for an O-ring. In almost all applications there are criteria for the attributes that characterise whether a composition is suitably mixed; the criteria may vary, but they exist nonetheless. It is almost always the case that these criteria must be met with optimum efficiency, i.e., with the maximum output per expenditure of capital and energy.

In order to understand the reasons for the techniques and types of machinery employed in mixing, one must have some familiarity with raw materials, their physical forms, functions in the compound, and behaviour during processing. Several basic categories of ingredients are usually distinguished.

(a) Rubber or polymer-bales, clips, pellets or powder
(b) Fillers-powder, pellets
Reinforcing-carbon
Extending - clay, calcium carbonate, talc
(c) Plasticisers and lubricants-fluids, oils, waxes, process oil, ester plasticisers, processing aids, waxes, proprietary blends, stearic acid.
(d) Miscellaneous additives-powder, pellets, fluids
Antioxidants, antiozonants
Colourants
Release agents
(e) Vulcanising agents and accelerators-
Sulphur
Peroxides
Special ingredients
A knowledge of physical characteristics and forms leads to a certain amount of guidance regarding the most suitable type of mixer. For example, the knowledge that liquid additives need to be mixed into a liquid polymer would direct the technologist to certain types of equipment. But selection of the optimum mixer is not always possible, primarily because of economic factors. The organisation must often make do with what happens to be available; the ingenuity of the compounder lies in his or her ability to achieve specific results with the equipment on hand. On the other hand, given some degree of choice a more appropriate machine is usually available to improve mixing characteristics and, therefore, final properties. Early in the history of rubber compounding, almost simultaneously with Goodyear's discovery of sulphur vulcanisation it was found that kneading or softening the elastomer was useful in increasing its receptivity to incorporation of powders. This is the basis of mixing—masticating the elastomer to make it receptive to other ingredients, yet retaining sufficient stiffness to ensure adequate dispersion. (The more difficult an ingredient is to disperse, the higher the viscosity required during mixing.) This balance of mastication without undue shear softening can be achieved through several means.

1. Mixing with close temperature control.
2. Use of a specific sequence for adding materials.
3. In some cases, remixing after cooling (two-pass mixing).

These three considerations apply to mixing with all the most common types of equipment: two-roll mills, internal batch mixers, continuous mixers, extruders or combinations thereof.

MIXING MACHINERY FOR RUBBER

Two-roll Mills

Every mixer must provide two basic functions, both equally important—acceptable dispersion (intensive or dispersive mixing) and high uniformity (extensive or distributive mixing). The equipment used most often by the rubber technologist is the two-roll lab mill—a device for preparing small quantities of mixed compound. This mixing device is usually set for a ratio of roll surface frictional speed of about 1.25:1.

Roll Nomenclature

Diameter (D) Usually same for both rolls
Face length (L) Roll length (mill sizes expressed as D Å—L)
Roll gap Distance between rolls
Sank size Material sitting above gap
Banded roll Roll which material follows
Front roll Roll on operator's side

Slow roll Roll rotating at slowest speed
Fast roll Roll rotating at fastest speed
Friction ratio Roll speed ratio
Separating force Resultant force exerted by material in roll gap

The rolls are bored to permit cooling or heating the gap between the rolls adjustable within a range related to roll diameter. The mixing procedure is relatively standard. The operator places portions of elastomer on the mill, kneading the sample by multiple passes through the gap, until sufficient reduction in stiffness permits it to wrap and adhere to one roll. The gap is adjusted so that a reservoir of elastomer is always rotating above the nip. This reservoir is called the rolling bank. Rolling is rarely observed when the polymer has only limited elastomeric character at the milling temperature. In such cases the reservoir may flop about or break into discrete sections. This behaviour may often be corrected by a different choice of mill temperature on one roll or both, sometimes merely by using a different nip setting.

Powders are now added into the gap with frequent pan sweeping to recover increments which drop through. Process oil or plasticiser is also added usually after pan of the filler content has been incorporated. Only then does the mill operator begin to cut the rubber from one side of the mill, passing it to the other side, to cross-blend the batch. At the conclusion of mixing (usually determined by the judgement either of the operator or a supervisor) the batch is cut from the mill for cooling and storage. A major advantage of mill mixing is the high shear developed at the mill nip, this breaks up agglomerates and drives incorporation of ingredients. Furthermore, the massive surface exposure imparts good cooling, thereby maintaining the stiffness of the compound. And due to the roll friction ratio the rolling bank imparts further high shear.
The disadvantages of mill mixing usually far outnumber the advantages and may be listed as follows:
1. Length of the mixing cycles
2. Dependence on operator skills
3. Dust and dirt levels that are typical
4. Difficulty in standardising subjective procedures
5. Difficulty in controlling batch to batch uniformity.

Mills are used more in forming and breakdown applications than in actual mixing except for addition of curatives to pre-mixed masterbatch. The most common ratio of roll speeds in the past was 1.25:1, with the slower of the two rolls usually on what is most frequently the operator's side (often called the 'front' roll). Recent investigations have shown that the temperature rise of rubber on a two-roll mill is directly related to the sum of the speeds of two rolls. Therefore, whether the sum reduced by slowing the faster of two rolls (a change of friction ratio), or by reducing the speed of both rolls (maintaining the same friction ratio) the result is a reduction in rubber temperature build-up. Mills built in recent years have had lower total speed ratios closer to 1.1:1 and the fast roll at the front. In addition to improved processing of a broader range of elastomeric compounds, many such mills have also featured drilled rolls, permitting better temperature control and leading to easier compound release.

Internal Batch Mixers

The Banbury internal mixer was originally manufactured to replace the two-roll mill. The original nomenclature indicated the approximate number of 60° mills that a specific Banbury size could equal in output. The basic design of the machine includes two rotors that operate at a slight speed differential. The rotors are non-interlocking. Mixing or shearing action occurs between the rotors and the sides of the mixer and between the rotors themselves. The mixer is top loaded through an opening large enough to accommodate bales of elastomers (as well as the other ingredients). Pressure is exerted on the batch using a ram which closes the feed opening. Discharge of the batch occurs at the bottom of the mixing chamber. The rotor design is such that material in the chamber is constantly being displaced, corresponding to the cross-blending action of the mill operator cutting the batch on a two-roll mill. The compound is subjected to the shearing action of the rotors against the sides and the action of the rolling bank between the rotors.

The mixing chamber sides and the rotors are copied to maintain a high rate of shear during the mixing process. Improved cooling has been one of the most significant changes in modification of Banbury mixers over the years. The currently used cooling passages, called drilled sides impart an ease of heat transfer never before obtainable. In fact, the heat transfer efficiency of drilled-side mixers is so great that too much cooling can occur, leading to inefficiency when mixing certain types of compounds. This is corrected, and mixing generally much improved, by the use of a closed-circuit coolant tempering system. This system is used to dial in the proper temperature, optimising the degree of heat transfer and complementing the viscosity of a specific compound.

As with the two-roll mill, the sequence of ingredient additions is critical. In the case of the high viscosity elastomers, the polymer is usually added and masticated before the fillers are added; then the plasticisers and softeners are finally introduced. If the particular compound contains no curatives it is then discharged at an appropriate predetermined temperature. If the compound is a single-pass thermosetting composition, the curatives and accelerators are also added and the batch discharged at a lower temperature to prevent scorch (premature curing). The criterion for completion of the batch is often mixing to a specific temperature. Other criteria include elapsed time, and total power input into the batch. A combination of these observations is commonly used to judge the end-point and related to further processing of the batch during fabrication or to observe properties after vulcanisation. The selection of rotor speeds, mixer size and the extent of materials handling automation are all related to the demands of the specific sector of the rubber industry. At one extreme there is the massive quantity of compound mixed by tyre manufacturers, where most compounds are two-stage mixed (masterbatch and final) using high speed, automated materials handling equipment and large mixers. On the other hand, many custom compounders and mechanical goods manufacturers (who have a large number of recipes) prefer lower speeds and smaller machines and they have too great a variety of materials for totally automated handling. In many cases their compounds are mixed in a single cycle to reduce handling and inventories. The major advantages of the internal batch mixer are as follows:-
1. Highly reproducible cycles
2. Minimum dependence upon operator skills
3. Large capacity and high output
4. Relatively short mixing cycles
5. Potentially clean factory operations.

But there are some disadvantages, compared to mill mixing:-
1. More rapid temperature rise in mixing
2. More time needed for cleaning equipment
3. Much higher initial investment.

Continuous Mixers

Compared to thermoplastics, continuous mixing of rubber compounds is a relatively new concept. The machinery available ranges from simple single screw extruders to twin rotor, multistage machines. All of these mixing extruders place a common demand upon materials; the ingredients need to be available in a free-flowing form capable of being continuously weighed and metered to the mixer. The continuous mixer receives the compound ingredients and disperses them to the extent needed to develop target physical properties. The required extent of mixing can be directly related to the ease or difficulty experienced with the same compound in batch mixing. Ingredients such as powders and liquids usually involve no undue problems in accurate continuous metering. The polymer, on the other hand, is often supplied in bales, requiring grinding or pelletising to provide a form suitable for continuous feeding. Recent demand has caused some polymer producers to offer a range of elastomers in pellets or powder form, thereby improving the option of continuous mixing. The advent of powdered rubber could revolutionise mixing. The advantage is that most or all of the distribution could be accomplished by using low power high intensity blenders. The resultant blend could then be fed to a simple relatively low horsepower mixer to masticate the compound and render it useful for fabrication. Vulcanisate properties often appear to depend upon a specific level of work input during mixing. In general, it is probably not significant whether this work is provided by a sequence of several machines or by a single mixer although the properties of all polymeric compositions are path-dependent to some degree.

BASIC OPERATION CYCLE OF BANBURY MIXER

1. Start operation
2. Discharge door closed
   a) Ram up
   b) Hopper door open
3. Compound inputted
4. Mixing started (Rubber + Chemical powders)
5. Close hopper door
6. Carbon is charged
7. Mixing for given period
8. Ram up
9. Oil injection
10. Ram down
11. Ram up/down
12. Ram float
13. Open discharge door
14. Start the next cycle

The temperature in each step changes simultaneously initially the temperature is 350°C and the mixer speed is set at 55 rpm and the ram pressure is at 135 bar then the mixing starts and the temperature goes to 1050°C and the ram pressure decreases to 110 bar after the mixing completes the temperature in the mixer is 1300°C and discharge time after the ram float is 10 to 12 sec.

CONTROLLABLE FACTORS AT BANBURY MIXER

1. Batch size
2. Sequence of addition
3. Ram cylinder pressure
4. Rotor speed
5. Mixing time
6. Temperature of the finished mix, chamber, rotors, discharge door top
7. Energy for mixing

In Banbury two different type of product can be made as a final product and master product. The final product is further sent to the extrusion and the master product is again gone through the cycle once. Initially the bale cutter is used to cut the rubber from batch as per the requirement. The bale cutter is hydraulically operated with a pressure of 90 kg/cm². After making the master compound it is further sent to the extrusion for the further processes to be done on it.

RESULT AND DISCUSSIONS

1. Approximately 120 different materials are added for the formation of rubber compound.
2. The maximum ram pressure in the Banbury mixer is 6.6 kg/cm².
3. The Banbury mixer is of capacity 220 and 370 litres of Farrel Corporation.
4. The operation of Banbury is of energy type (35.5 kWh), temperature type (165°C) and time based (120 sec).

CONCLUSION

From my research i have concluded that the formation of rubber for a tire is an process of mixing different compound as per the required result of tire and distributing the compound for the further process by which the single cycle master compound are send to the bead and ply formation and final compound is sent
to the extrusion department for the manufacturing of tread the is division is done for reduce of cost as proceeding master compound to the bead formation further. This distribution of master and final compound make a reduce of 4.5% price of overall tire.