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Article

Observation Results of the Effect of Pre breaker Machines on Raw Rubber Products at PT Bridgestone Sumatra Rubber Estate

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A B S T R A C T

This report presents the results of a field observation on the strategic role of the prebreaker machine in improving the quality of crumb rubber of the Standard Indonesian Rubber 20 (SIR 20) type at PT Bridgestone Sumatra Rubber Estate. The background of this observation is based on the complexity of processing raw rubber materials (Bokar), which are often contaminated by organic and inorganic materials that can reduce the physical integrity of tire products. The main objective of the observation is to evaluate the mechanical effectiveness of the prebreaker machine in reducing material size, improving contaminant removal efficiency, and preparing the rubber structure for optimal drying stages. The methods applied include participatory observation on the wet processing line, technical sampling, and comparative analysis of quality control laboratory data during the fieldwork practice period. The results indicate that the use of the prebreaker machine significantly reduces dirt content to below the threshold of 0.16% in accordance with SNI 1903:2011 standards and minimizes the formation of white spot defects through improved crumb homogeneity. The conclusion of this study confirms that optimizing blade configuration and rotational speed of the prebreaker machine is a key determinant in producing raw rubber that meets the technical specifications of the global automotive industry, while also supporting energy efficiency in subsequent production stages

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1. Introduction

The natural rubber industry is a fundamental pillar of Indonesia's commodity economy, where product quality is a key determinant of competitiveness in the international market. In the context of global tire manufacturing, the need for raw materials with high rheological consistency and thermal cleanliness is paramount. PT Bridgestone Sumatra Rubber Estate (BSRE), an integral part of Bridgestone Corporation, plays a strategic role in providing high-quality natural rubber from its extensive plantations in North Sumatra (PT Bridgestone Sumatra Rubber Estate Profile, 2024). Established in 1930, the company has adopted various technological innovations to ensure that every kilogram of raw rubber produced supports the company's mission of serving the community with superior quality (Bridge Stone Americas, 2015).

SIR 20 is the dominant product produced and requires intensive mechanical processing to transform raw coagulum into standardized bales for downstream industrial applications (Vachlepi et al., 2014). However, quality issues frequently originate in the early stages of wet processing, where contaminants such as wood shavings, plastic fragments, and soil particles become trapped within coagulated rubber masses. These contaminants may lead to structural discontinuities in vulcanized rubber compounds, potentially affecting tire durability.

The prebreaker machine functions as the first mechanical intervention in the wet processing line, aiming to reduce coagulum size and expose internal contaminants for subsequent washing and separation. Ineffective shredding at this stage may compromise contaminant removal efficiency, drying uniformity, and energy consumption in later stages.

Industrial-based observation provides an empirical platform for evaluating machine–material interaction under full-scale production conditions (Alfaris, 2023). Such field-based investigation allows direct assessment of operational parameters including torque behavior, shear-induced heating, and viscoelastic material response (Atmawati et al., 2017; Laila et al., 2024).

Despite its strategic role, limited empirical documentation exists regarding the thermomechanical influence of prebreaker machines on SIR 20 quality parameters, particularly dirt content, white spot occurrence, and Plasticity Retention Index (PRI). Therefore, this study aims to evaluate the mechanical effectiveness and thermodynamic implications of prebreaker operation in improving raw rubber quality at PT Bridgestone Sumatra Rubber Estate.

2. Literature Review

2.1 Position and function of the prebreaker machine in the crumb rubber processing flow (SIR 20)

Crumb rubber processing in the SIR industry generally consists of two main stages: the wet process and the dry process. The wet process aims to reduce the size of the coagulum or cup lump, remove contaminants through repeated washing, and produce crumb rubber with a relatively uniform size before entering the further milling and drying stages (Utomo et al., 2010; Vachlepi et al., 2014).

In a Bokar-based processing system, a prebreaker machine is placed at the initial stage of the wet process as the first size reduction unit. The main function of this machine is to open the internal structure of the coagulum so that contaminants trapped within the rubber folds can be exposed and separated more effectively in the washing tank (Utomo et al., 2010). A comparative study of energy consumption and operational requirements in the SIR 20 process also shows that the washing and cleaning stages are the main contributors to the operating load, so the effectiveness of the initial size reduction has direct implications for the efficiency of the subsequent process (Utomo et al., 2010).

2.2 Mechanical principle of prebreaker: shear force based size reduction and crumb homogeneity

From a process engineering perspective, crumb rubber manufacturing relies on size reduction principles to increase specific surface area, thereby improving mass and heat transfer efficiency during washing and drying (Sitinjak Januardi Mario, 2025). Mechanically, the prebreaker machine works by utilizing shear force and pressure to break large chunks of rubber into smaller crumbs. This size reduction increases the specific surface area of the material, thereby increasing the contact between the rubber crumb and the washing medium and improving the release of contaminants previously embedded in the coagulum structure (Vachlepi et al., 2014).

In industrial practice, the output of prebreaker machines is not only targeted at size reduction, but also at crumb homogeneity. Size uniformity plays a crucial role in maintaining material flow stability, increasing washing effectiveness, and ensuring consistency of the drying process in subsequent stages (Suwardin, 2015). The literature on crumb rubber production process management consistently places initial size reduction and washing as critical quality control points, particularly in Bokar-based production with highly heterogeneous characteristics (Utomo et al., 2010; Vachlepi et al., 2014).

2.3 Bokar contamination and its implications for the quality of rubber products

Rubber processing materials (Bokar) from various sources generally contain organic contaminants such as wood shavings and tree bark, as well as inorganic contaminants such as sand, soil, plastic, and metal. The presence of these contaminants can increase dirt content, accelerate wear on cutting components, and cause irregularities in the crumb structure, which impacts the quality of rubber bales (Suwardin, 2015).

Quality control research on SIR 20 production reported that white spot defects and foreign contamination were the dominant types of quality nonconformities, so that strengthening control in the early stages of processing—especially size reduction, washing, and contaminant detection—became a recurring technical need in various crumb rubber factories (Suwardin, 2015).

2.4 SIR 20 quality parameters and quality standards framework

The quality of SIR 20 crumb rubber is determined by several key parameters, including dirt content, ash content, volatile matter content, initial plasticity (Po), and Plasticity Retention Index (PRI). A characterization study of SIR 20 for tire industry applications shows that compliance with dirt and ash content thresholds is a key indicator of raw material cleanliness and its suitability for automotive needs (Aryanti et al., 2018).

In addition to national standards, the global specification widely used in the natural rubber trade is ISO 2000 on Technically Specified Rubber (TSR). This standard emphasizes quality grouping based on dirt, ash, and volatile matter parameter limits, as well as plasticity and PRI attributes to ensure post-processing stability (ISO, 2014). This framework reinforces the view that achieving SIR 20 quality operationally depends heavily on effective mechanical cleaning and process controls that do not damage the integrity of the natural rubber polymer.

2.5 The white spot phenomenon on SIR 20 and its relationship to crumb uniformity and drying

White spot defects in SIR 20 products are generally associated with uneven water content or an uneven drying process, resulting in undercooked rubber in the bale (Suwardin, 2015). Statistical Quality Control-based studies indicate that white spot is one of the main defects that needs to be suppressed through process improvements and quality control discipline at all stages of production (Suwardin, 2015).

From a thermal perspective, crumb rubber drying requires high energy and a relatively long time due to limited heat transfer and moisture diffusion from the interior of the material. Technical studies on crumb rubber drying emphasize that non-uniformity in crumb size can exacerbate non-uniform drying and increase the risk of white spots (Tham et al., 2014). Therefore, a preprocessing process that produces a more homogeneous crumb is considered an important prerequisite for ensuring successful drying and the quality of the final product.

2.6 Energy efficiency and sustainability of crumb rubber processing

The crumb rubber processing industry is known to be energy-intensive, particularly during the drying stage. Energy audits of rubber factories have shown a strong correlation between energy consumption and production volume, making identifying energy savings opportunities through equipment improvements and process management a strategic issue (Suwardin et al., 2016).

In the context of production systems, the closed production process approach in the crumb rubber industry highlights the importance of early-stage control to minimize energy waste and environmental impact. Improving the effectiveness of prebreaker machines, which produce clean, uniform crumb, can be positioned as an upstream intervention with the potential to reduce the rewashing load and the risk of uneven drying, thereby supporting energy efficiency in downstream production stages (Kartika & Wahyuni, 2024).

3. Methodology

This research uses a field case study method with a descriptive observational approach at the crumb rubber processing facility of PT Bridgestone Sumatra Rubber Estate. The focus of observations is directed at the wet production line, specifically the prebreaker machine operational unit. The observation time coincides with the Field Work Practice schedule, allowing access to daily operational data and direct monitoring of material interactions with the machine in real time.

The stages of the methodology applied include:

1. Technical Survey and Machine Identification: Conduct an inventory of the technical specifications of the pre breaker machine in operation, including motor power, shaft rotational speed, number of blades, and screen plate configuration. This data is obtained from the machine nameplate and factory operating manual.
2. Input-Output Process Monitoring: Observing the physical characteristics of the processed rubber material (Bokar) before entering the machine (input) and the resulting rubber crumb (output). Parameters observed visually include lump size, the presence of coarse contaminants, and material color. Crumb size is measured randomly using a caliper to ensure consistency of the crushed results.
3. Laboratory Secondary Data Collection: Access daily reports of laboratory quality test results for SIR 20 parameters. Data collected includes dirt content, ash content, volatile matter content, initial plasticity (Po), and Plasticity Retention Index (PRI). This data is used to see the correlation between machine operational conditions and final product quality.
4. Cleaning Effectiveness Analysis: Observing the type and quantity of contaminants successfully separated in the washing tank located immediately after the prebreaker machine. This process involves recording the dominant type of contaminant (wood, plastic, or stone) exposed after the shredding process.
5. Discussion with Experts: Conduct unstructured interviews with machine operators, production foremen, and quality control staff to gain practical perspectives on technical constraints, knife maintenance cycles, and handling raw material variability.

The collected data were then processed using simple statistics to determine the average value and standard deviation, and presented in the form of tables and descriptive narratives to provide an objective picture of the influence of the prebreaker machine on the quality parameters of raw rubber.

4. Results and Discussion

4.1 Results

Field observations indicate that PT Bridgestone utilizes a heavy-duty pre breaker machine integrated with an automated cleaning system. This machine acts as the front line in addressing the physical variability of raw materials. Direct observations revealed that the raw material entering the machine's hopper consists of large rubber lumps with an average diameter of 40 cm to 60 cm. After undergoing the shredding process, the material exits as crumbs with a much smaller and more uniform size.

During operation, the prebreaker machine generates significant compressive and shear forces. This causes a temperature increase in the rubber material leaving the machine. Measurements of the surface temperature of the crumb immediately after leaving the filter plate indicate temperatures ranging from 45°C to 55°C. This temperature increase is localized and controlled, but sufficient to soften the rubber structure, facilitating the subsequent separation of impurities in the water tank.

The technical specification data and operational parameters of the observed prebreaker machine are presented in the following table:

Table 1. Mechanical and Operational Specifications of Prebreaker Machine

Parameter	Specification
Machine Configuration	Horizontal Prebreaker
Drive System	60 HP Electric Motor (1500 rpm, 380 VAC, 50 Hz)
Gear Reduction Ratio	32:1 (Reynold TWU 12 Gearbox)
Effective Rotor Speed	~ 59 RPM
Cutting Mechanism	Dual Scroll (R/H & L/H) Ø 299 mm
Replaceable Sleeve Diameter	Ø 305 mm (Stainless Steel)
Die Plate Hole Diameter	Ø 25–27 mm
Structural Material	High Quality Steel Housing
Lining Material	Stainless Steel
Transmission System	Spur Gear & Pulley Ø 11"
Estimated Output Crumb Size	10–15 mm
Measured Surface Temperature	45–55°C

The mechanical configuration shown in Table 1 indicates a low-speed, high-torque design architecture. The 32:1 gear reduction system converts the 1500 rpm motor rotation into an effective rotor speed of approximately 59 rpm, which is consistent with shear-dominant size reduction mechanisms required for viscoelastic materials such as natural rubber. The scroll diameter and die plate configuration directly influence crumb geometry and contaminant exposure efficiency.

Motor = 60 HP

1 HP = 0.746 kW

$\rightarrow$ 60 HP $\approx$ 44.76 kW

The 60 HP motor provides approximately 44.76 kW of mechanical power input, ensuring sufficient torque availability for processing high-density rubber lumps without significant rotational speed fluctuation.

Analysis of laboratory quality data for SIR 20 products generated during the observation period indicates high compliance with SNI standards. The average data from 10 production batches is presented in the following table:

Table 2. Quality Characteristics of SIR 20 Raw Rubber Products

Quality Parameters (SIR 20)	**Average Observation Value**	**Maximum Limit of SNI 1903:2011**	**Status**
Dirt Level	0.068%	0.16%	Passed
Ash Content	0.51%	1.00%	Passed
Volatile Matter Content	0.31%	0.80%	Passed
Initial Plasticity (Po)	36.2	Min 30	Passed
Plasticity Retention Index (PRI)	72.4%	Min 40	Passed

Visually, the crushed wood from the prebreaker machine demonstrates the highly effective separation of wood contaminants. Before entering the machine, the wood is often embedded within the rubber wadding. After exiting the prebreaker, the wood breaks into small fragments that float on the surface of the water during the washing stage, while the heavier rubber (due to its water content) sinks or moves to the next grinding stage. A summary of the types of contaminants found after the prebreaker process is presented in the table below:

Table 3. Distribution of Contaminants Successfully Exposed by the Prebreaker Machine

Types of Contaminants	Percentage of Findings (%)	Separation Method
Wood Chips / Tree Bark	55.2%	Flotation in Washing Tank
Plastic Flakes	28.4%	Visual & Manual Picking
Sand and Soil	12.5%	Sedimentation in the Washing Tank
Others (Thread, Metal)	3.9%	Metal Detector / Manual

4.2 Discussion

Observations confirm that the prebreaker machine is a critical component determining the effectiveness of the entire wet processing production line at PT Bridgestone. Its primary function in size reduction is not simply a change in physical dimensions, but rather an intensive mechanical cleaning process. By reducing large chunks to 10-15 mm crumbs, the specific surface area of the rubber dramatically increases. Based on the principle of mass transfer, this increased surface area allows the wash water to reach deeper into the rubber structure and release previously trapped dirt.

The dirt content of 0.068% found in this observation is well below the SNI maximum limit of 0.16%. This indicates that the combination of sharp shredding by the prebreaker machine and the subsequent washing stage work in excellent synergy. Without the pre-breaking stage, organic contaminants such as wood would remain in the clumps, and if carried over into the drying process, would become weak points in the crumb rubber structure. Unremoved wood can lead to a decrease in the dynamic properties of tire vulcanizate, increasing the risk of flex cracking.

Furthermore, the heat generated during the shredding process (45°C – 55°C) has positive implications for reducing the white spot phenomenon. White spots in crumb rubber are usually caused by portions of rubber containing high water content or serum concentration that are not uniformly dried in the dryer. The heat and pressure from the prebreaker blades assist in breaking down air and water cells trapped within the coagulum, thereby promoting more uniform moisture redistribution throughout the crumb. This improves the subsequent evaporation process and contributes to more homogeneous drying.

From a thermodynamic standpoint, the observed temperature rise indicates localized frictional heat generation resulting from shear deformation. The mechanical energy supplied by the motor is partially transformed into thermal energy through viscoelastic internal dissipation and blade–material friction. Unlike high-speed impact crushing systems, the low rotational speed configuration (approximately 59 RPM) ensures that temperature elevation remains moderate and controlled, preventing excessive thermal spikes. Such controlled thermomechanical conditioning enhances moisture diffusion kinetics during the drying stage, as supported by studies on crumb rubber drying behavior (Tham et al., 2014). Therefore, the temperature range recorded in this observation can be interpreted as a beneficial pre-conditioning mechanism rather than an indicator of material degradation.

However, a critical aspect that needs to be considered in this discussion is the stability of the Plasticity Retention Index (PRI) value. Although mechanical processing is necessary, excessive shear forces can trigger thermo-oxidative degradation of the natural rubber polymer chain. The average PRI value of 72.4% recorded indicates that the mechanical treatment at PT Bridgestone remains within a safe thermomechanical corridor. The low-speed, high-torque operational design minimizes mechanical fatigue and oxidative stress while maintaining effective size reduction. This thermomechanical balance explains why the elevated temperature during shredding does not negatively affect polymer stability, as reflected in PRI values well above the SNI minimum requirement. Comparison with findings from studies at other plants shows that PT Bridgestone's crushing efficiency is very high. Some plants experience problems with uneven crumb size, often caused by input loads exceeding design capacity or infrequent blade sharpening. At PT Bridgestone, the use of a 315kW power transmission system ensures that the machine has sufficient torque reserves to handle even the toughest rubber lumps without experiencing a significant drop in rotational speed, thus maintaining consistent output size.

The implications of these findings for operational management include the importance of scheduled preventive maintenance on the blades. Blade wear will change the cutting mechanism to a tearing mechanism, which not only increases the material temperature excessively but also produces rubber dust that can be lost during the washing process (reducing yield). The limitation of this observation lies in the lack of control period data on the rate of blade wear for various types of Bokar. However, overall, the data indicate that quality control at PT Bridgestone has successfully integrated prebreaker machine performance as an integral part of SIR 20 quality assurance**.**

5. Conclusion

Based on the results of observations during fieldwork practices at PT Bridgestone Sumatra Rubber Estate, it can be concluded that the prebreaker machine has a very significant and determining influence on the quality of SIR 20 raw rubber. This machine successfully carries out its function in reducing the size of rubber lumps efficiently into uniform crumbs, which directly exposes internal contaminants such as wood and plastic so that they can be effectively separated during the washing stage. This is evidenced by the low level of product impurities (0.068%) which is far below the maximum standard of SNI 1903:2011. In addition, the heat and mechanical pressure generated by the prebreaker machine helps material homogeneity, which contributes to the prevention of white spot defects and the stability of plasticity values (Po and PRI). Optimizing the performance of this machine, supported by strong motor power and appropriate rotational speed, has proven to be a key factor in maintaining the consistency of raw rubber quality for the needs of the Bridgestone tire industry globally.

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