Energy Consumption Analysis to Detect Process Failure in Rubber Compound Mixing Process

Agus Triyanto

Department of Mechanical Engineering, Swiss German University, Tangerang 15143, Indonesia

Abstract. There are many ways to detect the abnormality of rubber mixing process regardless of the availability of indicator system of the abnormality. One way is to detect the problem after the result of rubber production tested by laboratory teams. Abnormality will be late to be anticipated because the result of the test will appear after 8 to 10 batch afterward. The abnormality in the mixing process will be detected if the results of the testing compound are out of the specification. The energy consumption will be measured for every batch by using the internal current sensor in the AC motor main drive. By reading the figure of measurement, energy consumption character will be identified and the specification standard of energy consumption can be defined. The process will follow the specification standard of energy consumption and abnormality condition will be corrected immediately.

1. Introduction

Mixing is the most important sequence in the rubber process and very decisive for the next step. The purpose of the mixing process is to produce products that have well distribution and dispersion materials to fulfill the expectation of the final product [1]. The mixing process needs to decide the ingredients, equipment, and also time, speed, pressure, and temperature setting. It means to minimize the labor, energy and equipment cost per unit volume of product. Due to the highest viscosity and elastic properties of the rubber, it needs a lot of power which requires a powerful engine such as an internal Banbury mixer [3].

The tangential type of internal Banbury mixer has a cylindrical short chamber that is united on one side which is contiguous with two slightly spiral rotors where each of those rotates separately. The chamber has a hopper door to insert the material and has a drop door to drop out the compound after the mixing process is complete[2].

The power consumption on the mixer chamber can be one of the urgent matter in the mixing process which indicates the process is running and influences the quality of the compound product [4]. In the normal conditions, the power consumption should be either the same or not with the big difference in value while mixing the same SKU.

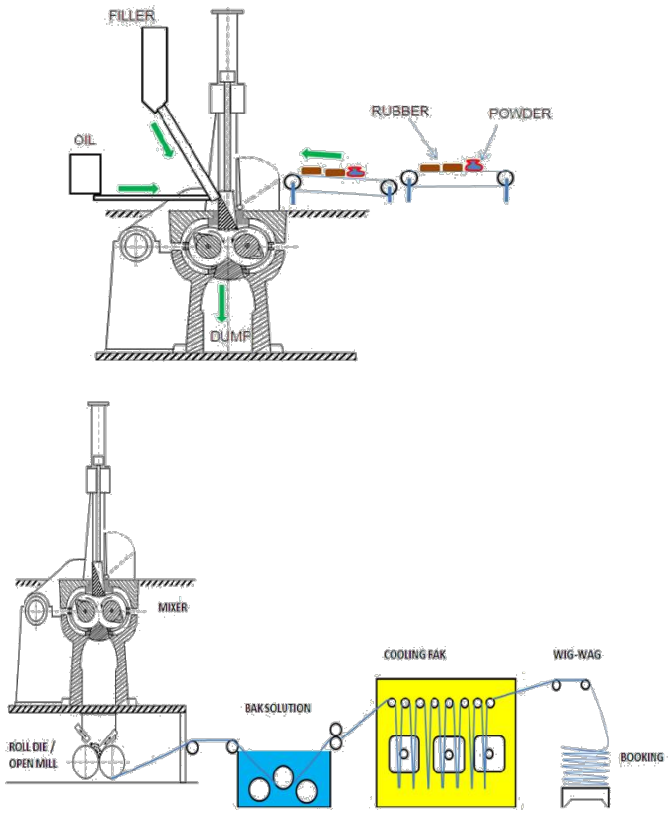

Figure 1 Banbury mixing process

2. Research Problem

Since there is no initial indication system to detect an abnormality in the mixing process, the problem will be detected after the result of production-tested by the laboratory team. Abnormality in the mixing process will be detected if the result of a testing compound such as Mooney viscosity, Mooney scorch time, tensile strength is out of the specification. The abnormality will be detected after 30 to 45 minutes delay, or equivalent 2.000 kgs compound, for waiting the aging time and decreasing temperature of the compound from 120° Celsius to 40° Celsius.

3. Scope

The scope of this study is limited at the internal Banbury mixer with the capacity of 270 Litre, for the final batch compound mixing process.

The limitations of the problem in this research are as follows:

1. The research using statistical and process capability analysis.
2. Collecting energy consumption data in the motor mixer by measuring electric current motor mixer and then processed as energy consumption data in MES (manufacture execution system).

3 Collecting data MH Rheo test from the laboratory department.

4. The analysis focused on the correlation of energy consumption in a motor mixer and the viscosity of the compound.

4. Methodology

The method used in this research is data evaluation research. This research begins by collecting current motor data, which is taken from the internal sensor of the main motor drive mixer, then processed as energy consumption data using MES (Manufacture Execution System) on the mixing machine, then analyzed the pattern to make a warning system and decision making.

This research will start from a literature study to find and collect all related document from various books, journals and other related articles to support the research. Then, the researcher makes the conceptual design to determine the hardware to measure and collect all related data needed. Then, the researcher also makes a data simulation and testing. The result of simulation and testing will be analyzed and evaluated. The writing process will start after the testing step is finished

4.1. Materials and Equipment

In designing this system, we use the following components :

1. ABB AC Motor 1.500 kW
2. ABB Single drive modules ACS800-04/-04M/-14
3. Personal Computer - PC Industry
4. Profibus Communication System
5. Communication Protocol Simatic CP5612
6. HMI Touch Screen Siemens 15".

4.2. Block diagram

In general, this research consists of ABB AC Motor 1.500 kW, ABB Single Drive Module ACS800 as a current sensor, PC, Profibus Cable, Simatic CP5612 as Communication Protocol and HMI.

The design of this research is shown as in the following figure :

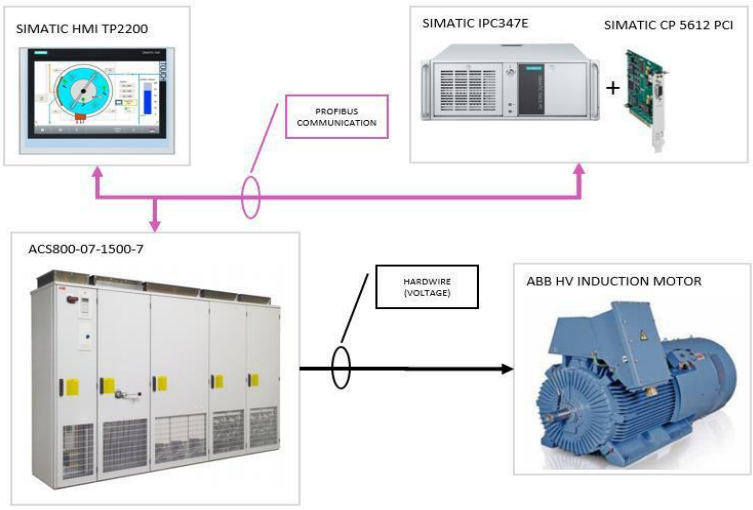

Figure 2 Block Diagram

4.3. MH Rheo Test

Based on ASTM International Standards Organization (ASTM D 2084), MH Rheo Test (maximum torque) is standard test characteristics in rubber mixing vulcanization process, that more deeply on ultimate crosslink density of all ingredients.

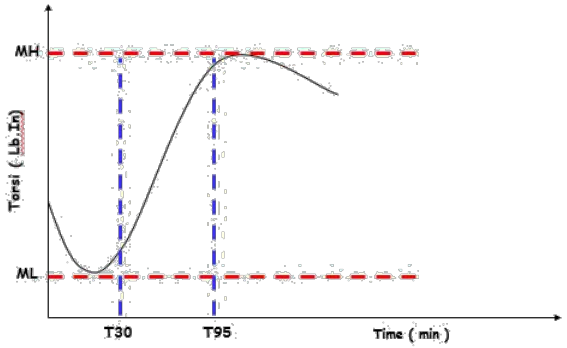

Figure 3 MH Rheo Test

5. Data Analysis

5.1 Measurement current

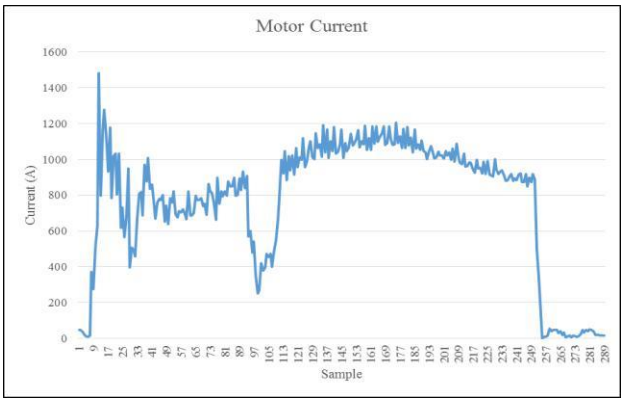

Figure 4 Motor Current Compound H1193 in machine BM2

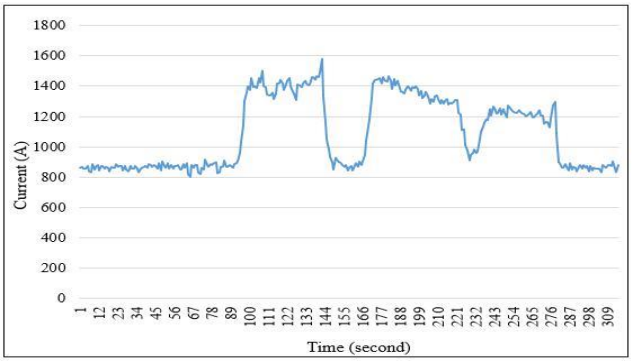

Figure 5 Motor Current Compound H1234 in machine BM2

5.2 Energy Consumption & Compound Quality Correlation Analysis

By using the Microsoft Excel program to analyze the data, we find out that the energy consumption in the mixing process has a strong relationship to MH Rheo test results. From the figure, it can be seen that if the energy consumption rises to the top level, then the value of the MH Rheo test will be on the top level. On the other hand, if the energy consumption in the production process falls to the bottom level, then the value of the MH Rheo test of the product will be on the bottom level.

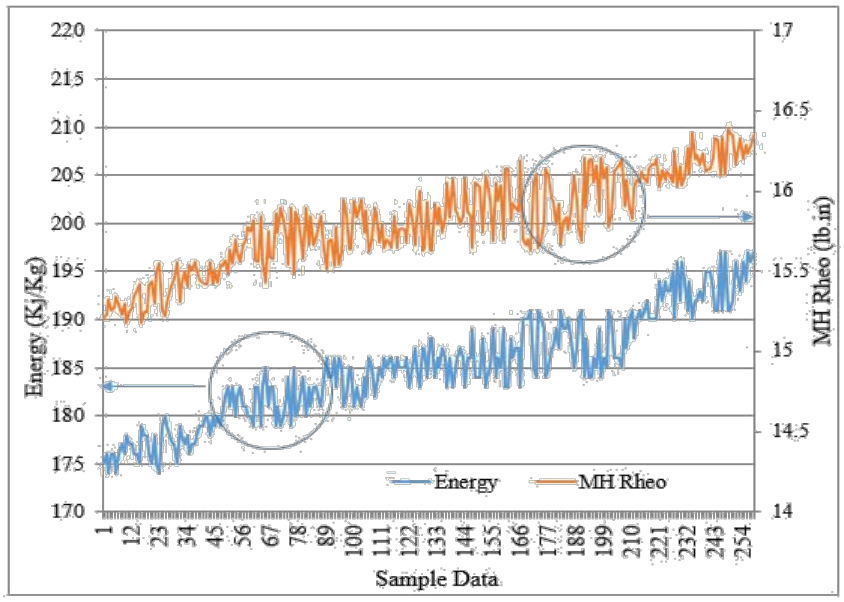

Figure 6 Data Graphic of energy consumption and MH Laboratorium test

By using Minitab, the correlation coefficient value of abnormality condition between energy consumption and MH Rheometer test is 0.700 with the level of significance P-Value is 0.000. It means that the parameters have a strong relationship. The positive value of the coefficient correlation means that the relationship is proportional.

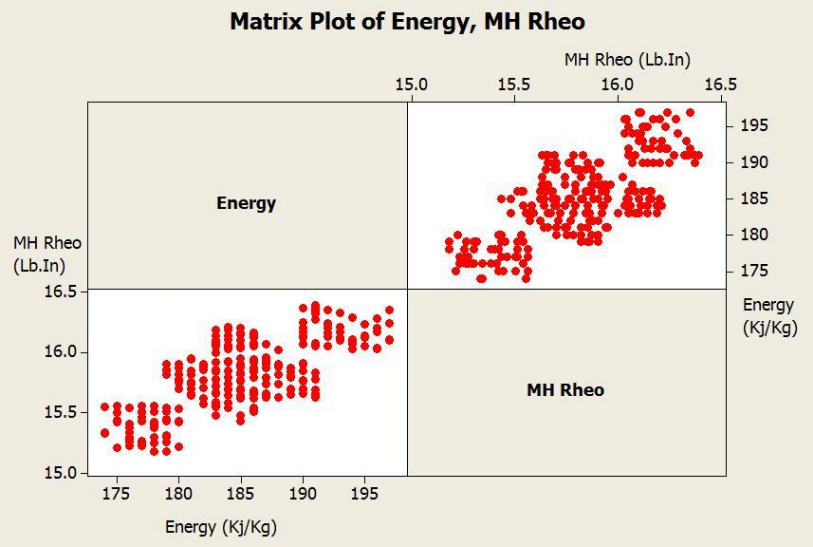

Figure 7 Matrix Plot of Energy Consumption and MH Rheometer Test

5.3 Define Specification Standard

Index capability process method is used to define the specification standard of energy to determine the center line, the upper limit and lower limit of energy consumption. The following is the detail of energy consumption inner liner compound data :

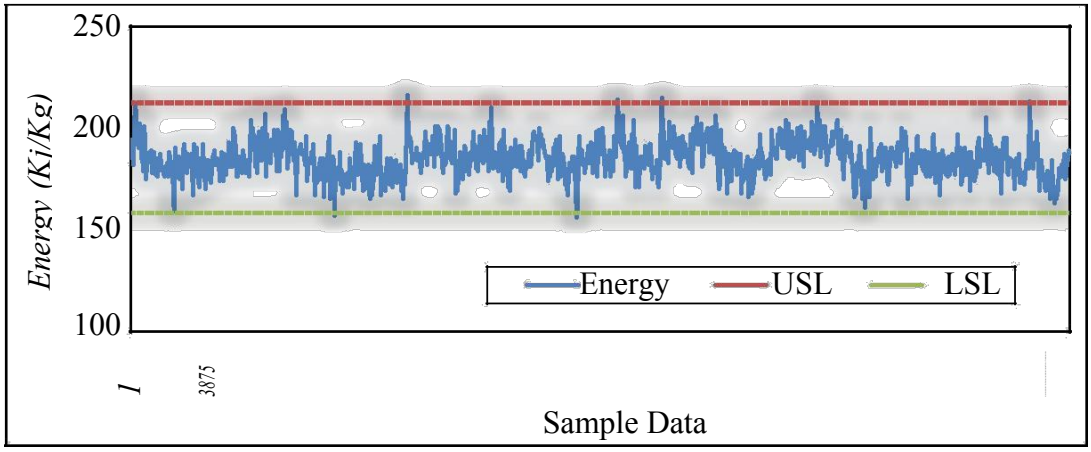

Figure 8 Upper limit and lower limit energy

The maximum standard of energy consumption in inner liner compound (USL) is 212.14 KJ/Kg, the minimum standard (LSL) is 157.84 KJ/Kg and the target center line is 184.99 KJ/Kg, with the detail as follows:

Item	
Average	184.99
Stdev	9.05
USL	212.14
LSL	157.84
Target	184.99
% Tolerance	15%

R-bar	7.54
s (Rbar/d2)	6.69
Cp	1.35
CpK	1.35

Where :

- *Average (Mean) is the sum of all the data entries divided by the number of entries*
- *Stdev measure variability and consistency of the sample or population*
- *USL is the upper specification limit (USL = Average + (3 x Stdev) [5]*
- *LSL is the lower specification limit (LSL = Average - (3 x Stdev) [5]*
- *Target is middle value about USL and LSL*

5.4 Implementation specification energy

The standard of energy consumption has been embedded in the machine control system as a complement to the other parameter controls. The setting of upper limit, lower limit and target center line standards becomes the responsibilities of a technical engineer, who will control them by using IPC dashboard or using HMI touch screen in the engine control room.

Thus, the energy consumption of each production process is maintained to be in the range that has been set. If there is an abnormality, the alarm will sound and the production process will stop automatically. Then, the operator will check all the supporting parameters to make sure everything still in the right rules.

6. Conclusion

In the mixing process, the abnormality will be detected after the test result of product quality conducted by the laboratory team. The result of the test will appear after 8 to 10 batch afterward. It is about 30 to 45 minutes delay waiting for the aging time and decreasing the temperature of the compound from 120°C to 40°C.

By monitoring the energy consumption, which is closely related to the viscosity of the material, we can prevent and decrease the losses caused by the out of spec production. The energy consumption will be measured for every batch with certain cycle time, using an internal current sensor in AC motor main drive. From the measurement, energy consumption characters will be identified and specification standard of energy consumption can be defined. The process will follow the specification standard of energy consumption and abnormality condition will be corrected immediately.

By using Minitab, the correlation coefficient value of abnormality condition between energy consumption and MH Rheometer test is 0.700 with the level of significance P-Value is 0.000. It means that the parameters have a strong relationship. The positive value of the coefficient correlation means that the relationship is proportional.

7. References

[1]. John S. Dick, Rubber Technology Compounding and Testing for Performance, August 1992.
[2]. Sharma Anil R, “A Review on Rubber Compound Mixing In Banbury Mixer at Tire Industries”, International Journal of Engineering Research and Reviews. Vol. 2, Issue 4, pp: (106-109), Month: October - December 2014
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[4]. M. Bratina, Z. Šušterič, Kranj (Slovenia), B. Šter, U. Lotrič, A. Dobnikar, Ljubljana (Slovenia), “Predictive Control of Rubber Mixing Process Based on Neural Network Models”, Energy, 2017
[5]. Douglas C. Montgomery, Introduction to Statistical Quality Control, John Wiley & Sons, Inc., 2009.