The effect of screw rotating speed on mass flow rate, temperature, viscosity, mooney scorch time and die swell of cold feed rubber blending prepared by qsm 200 extruder machine

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Abstract. The effect of screw rotating speed on cold feed rubber blending production were evaluated. The specimens were prepared by using QSM 200 extruding machine with variable screw rotating speed 4, 6, 8, 10, 12, 16 and 20 RPM. The temperature set in the screw and head of the barrel was around 80 °C by using Temperature Controll Unit (TCU), and was set around 70°C in zone 1 and 2. Mooney Viscometer was used to evaluate the viscosity and Mooney Scorch Time of cold rubber blending before and after extruding process. In addition, the dynamic rubber process analyzer was used to evaluate the Die Swell of rubber blending after extruding process. The result indicated that the increase of screw rotating speed has a significant effect to increase the flow rate, temperature and the viscosity of the rubber blending. Otherwise, the Mooney Scorch Time (MST) increases due to the decrease of the screw rotating speed. It does not have a significant effect to the die swell of rubber blending.

1. Introduction
Consumption of polymeric materials has greatly increased over the past few decades due to their use in diverse industrial sectors [1]. The manufacturing process in this polymeric material undergoes several processes. One of the process is extrusion using extruder machine. It is one important process in polymeric material making. The extrusion process is used to create a semi finished product whose output is rubber blending [2-6].

Screw rotation speed and temperature setting is needed in order to maintain the quality and quantity of the product. Controlling setting barrel temperatures and screw rotation speed directly influences process stability and product quality [7]. The various barrel temperature is the main challenge in the extrusion process [8] for the temperature distribution in this process influence viscous and swelling of the extrusion output [9]. The extrusion result, however, define the characteristics of the rubber blending. The viscous characteristics is used to define the way it is processed on the next process. Time characteristic for schorch is used to define the time before the rubber blending is schorched. viscosity characteristics and time for schorch define how good is the material resulted from the extrusion process [10].
In addition, it is also important to know the score of the die swell parameter for in an extrusion process, rubber blending will experience changes in its viscosity, Mooney scorch time (MST) and die swell [11]. Die swell is an important parameter to characterize the elasticity of the polymer in the extrusion process when it is melting [12]. Die swell measurement is the best qualitative measurement of the flow behavior [13]. Cold feed extruder machine has better control of stock temperature than that of the hot feed one [4]. Therefore, it is important to conduct this study. This study is done to figure out the influence of screw speed variation and fixed temperature control toward the mass flow rate, viscosity, Mooney scorch time and die swell using the cold feed extruder machine.

2. Experiment
The material, machine, measurement test equipment, experiment methods and analytical methods used in this study will be explained as follow:

2.1. Material.
This study used the cold material known as rubber blending processed by using a openmill machine whose output is sheet of rubber blending. This material composition Per Hundred of Rubber was a mixed of these following (table 1).

| MATERIAL     | CATEGORY       | COMPOSITION [PHR] |
|--------------|----------------|-------------------|
| SIR-10       | Natural Rubber | 100               |
| N-330        | Carbon Black   | 30                |
| HISIL 225    | Silica         | 12                |
| X-50 S       | Coupling Agent | 2                 |
| ZINC OXIDE   | Activator      | 3                 |
| RHENOGRAN SBR-80 | Bounding Agent | 1.38 |

2.2. Machine
The extrusion process used QSM 200 machine whose diameter of the screw is 200 mm, screw length is 3200 mm, pin rows number is 12 (with 8 pins each), the speed rotation screw is 1.6-32 RPM, the Max output is 2000 kg/h, and Max temperature is 125 °C. This is a cold feed extruder rubber blending machine.

2.3. Measurement Test Equipment.
Research support tools used are thermocouples, and stopwatch and weigher. Ektron EKT-2003M was the Mooney viscometer used to know the value of viscosity and Mooney Scorch Time. To analyze Die Swell, Mount Tech D-RPA 3000 was used.

2.4. Experimental Methods.
Cold Rubber blending is the compound processed by openmill machine which passes through the hopper to get to the next process – extrusion. Extrusion process was done in screw rotation variation of 4,6,8,10, 12 and 20 RPM. While the barrel temperature was divided to four zones, namely: screw, zone 1, zone 2 and head, with the temperature variance of 80 °C, 70 °C, 70 °C and 80 °C which is controlled by TCU.

2.5. Analytical Methods.
Mass flow rate was analyzed after the extruding process. Viscosity and Mooney Scorch Time (MST) was evaluated, done before and after the extruding process by using Mooney Viscometer Ektron EKT-
2003M and refering to standart ASTM D1646. Whereas die swell was evaluated after the extruding process by using D-RPA 3000 Mount Tech and refering to ASTM D6601

3. Result and Discussion

3.1. Analysis Of Screw Rotation Speed Toward Mass Flowrate.
The evaluation result of the effect of Screw Rotation Speed to the mass flow rate using QMS 200 machine was done by changing the screw speed is shown in figure 1

![Mass Flow rate Extruder machine QSM 200](image1)

**Figure 1.** Graph result screw rotating speed on mass flow rate

Figure 1 shows the minimal score of 418 kg/h and the maximum score of 1902 kg/h. in terms of screw speed and mass flow rate, it showed that the increase of the screw rotating speed, will increase the mass flow rate.

3.2. Analysis Of Screw Rotating Speed Toward Temperature.
The evaluation of the effect of screw rotating speed toward the material temperature resulted by the QMS 200 machine done by changing the screw speed is shown by figure 2

![Temperature Extruder machine QSM 200](image2)

**Figure 2.** Graph result screw rotating speed on Temperature

Figure 2 showed the result of the evaluation which is done by increasing the screw speed. It showed 83.3 °C as the lowest temperature and 109.57 °C as the highest temperature. In this case, the increase of the screw rotating speed increases the temperature.

3.3. Analysis Of Screw Rotating Speed Toward Viscosity.
The viscosity test on the pre-extruding process material, which is done in 5 minutes - refering to ASTM D1646 - showed 55.62 mooney. After the extrussion process, the viscosity test was done. The test is aimed at figuring out the viscosity value. The test showed 54.02 mooney as the minimum value
and 54.53 mooney as the maximum value. Viscosity test result on the extruded material can be seen in figure 3.

![Viscosity Rubber Blending After Extrusion](image1)

**Figure 3.** Graph result screw rotating speed on viscosity after extrusion

Based on the result shown in figure 3, screw rotating speed influenced the viscosity. The increase of the screw rotating speed, will increase the viscosity.

3.4. **Analysis Of Screw Rotating Speed Toward MST**

Before the extrusion, the MST showed 9.12 minutes. While after the extrusion, the MST showed 9.28 minutes as the minimum scorch time and 10.32 minutes as the maximum. it is shown by figure 4

![MST Rubber Blending After Extrusion](image2)

**Figure 4.** Graph result screw rotating speed on MST after extrusion

Based on the data shown in the figure above, screw rotating speed influenced the MST. The higher the RMP the lower the MST would be.

3.5. **Analysis Of Screw Rotating Speed Toward Die Swell.**

The die swell test result can be seen in figure 5. Die swell test showed the minimum score of 0.3379 and maximum score of 0.3449
In this case, screw rotating speed did not influence the die swell score since die swell has the unstable score. The changed screw rotating speed score did not give significant effect toward die swell score.

4. Conclusion
The result of the experiment showed that the increase of the screw rotating speed increased the mass flow rate, temperature, and viscosity. In another way, the increase of the screw rotating speed decreased the mooney scorch time. However, the screw rotating speed did not influenced the die swell score at all. To conclude, based on that findings, the characteristics of the extruded rubber blending can be identified. Therefore, the exact screw rotating speed can be determined to meet the required extrusion result.

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