Unvulcanized Rubber Tape Made from Natural Rubber and Synthetic Polyisoprene Modified with Rosin as a Tackifier

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Abstract. This presented work was to study mechanical and tack properties of unvulcanized rubber tapes made from STR 20 and IR 2200 with various amount of carbon black and rosin as reinforcing agent and tackifier, respectively. Mixing process of solid rubbers and all chemicals was carried out by two roll mill machine. All rubber compounds were subjected to increasing the stickiness by aging under hot air at 150ºC for 3 hours. From the experiment, green strength of the sticky rubber tape mixed with carbon black and rosin showed higher than that of the commercial rubber tape. The formulation exhibited the highest tensile stress at 400% strain is STR 20 mixed with 15 and 5 phr of carbon black and rosin, respectively. Mooney viscosity of the rubber tape made from STR 20 and IR 2200 was also reduced with the higher content of rosin. Although Mooney viscosity of the adhesive rubber tape normally decreased after heating under hot air, its tack property investigated by rolling ball test on the surface predominantly became increased. Moreover, Mooney viscosity of the rubber tape made from IR 2200 would be remarkably enhanced by blending with only 20% of STR 20.

1. Introduction
Unvulcanized rubber insulation tape is well known as several names such as cork insulation tape, rubberized cork tape, sticky rubber tape, adhesive rubber tape, etc. However, their main purposes are regularly designed for use on heating, refrigeration, air conditioning and piping applications. Hot pipes, valves, tees, fittings and other gasket materials are normally employed by the tape. This tape can also be efficiently used on cool and hot pipes to prevent the condensation, provides insulation as well as reduce vibration [1, 2]. One of special properties of the adhesive rubber tape is a wide range of a service temperature [3, 4]. There are a lot of types and brands of the rubber insulation tape not only depending on applications but also using conditions. For example, cork insulation tape is a combination of cork, rubber, tackifier and other polymers to improve the adhesion performance [5]. It is well recognized that Thailand is the number one producer of raw natural rubber in the world for a few decades. There is a lot of rubber products that have been daily manufactured in the country. Although unvulcanized rubber tape has normally been launched in the industrial market many brands, fewer papers and researches have been reported, excepting for many patents. Thus, the authors tried to domestically make a value-added for a raw rubber. Standard Thai rubber (STR) can be separated into many grades according to prices, usage and production processes. STR 20, a solid natural rubber, was selected to develop the unvulcanized rubber tape comparing to synthetic polyisoprene IR 2200 in this work.
2. Experimental

2.1. Preparation of unvulcanized rubber tapes
STR 20 and IR 2200, representatives of natural and synthetic polyisoprene rubbers, were masticated and mixed with both of carbon black and rosin on a two-roll mill (Labtech Engineering LMR 1100) at 60ºC by using a rolling nip of 0.3 mm. Mixing time of all rubber compounds were about 30-60 min depending on the amount of fillers. All rubber tapes were subjected to increasing the stickiness by heating under force air flow oven (Memmert model UF450) at 150ºC for 3 hours.

2.2. Investigation of green strength
Tensile specimen was prepared by hot press machine (Labtech Engineering LP20-B) at 100ºC for 15 min with a flat mold before cutting to a dumbbell shape according to ASTM D412 (type C). Green strength of the rubber tape was carried out by a Testometric model M500-25 AT with 100 N of load cell under crosshead speed of 300 mm/min. Three samples were measured and the average value was calculated. Tensile stress at 400% strain (M400) was determined as a representative data to report because of a limitation of maximum strain of all tensile specimens.

2.3. Determination of Mooney viscosity
Measurement of Mooney viscosity (ML1+4) was carried out by an EKTRON Mooney viscometer model EKT-2001M. Approximately 20-25 g of rubber sample was divided into two portions to cover up and down of a large rotor. Pre-heating and testing temperatures was set at 100.0 ± 1.0 ºC while the shear strain rate was applied at 2 sec⁻¹. The rubber specimen was preheated for 1 min and then continuously tested for 4 min before decay of torque when the rotor was stopped.

2.4. Analysis of tack property
The tack property of all unvulcanized rubber tapes after heat aging was determined by using a rolling ball tester. Steel ball with a diameter of 4.0 mm was released from the starting point of an inclined plane with an angle of 30º. The ball was allowed to accelerate down and rolled onto a rubber tape specimen. The stickiness of rubber tape is obtained by means of measuring the distance that the ball moves across the tape before stopping. Three times of measurements with other lanes were carried out to get an average value.

3. Results and Discussion
The first part is an attempt to characterize both of mechanical and tack properties of the commercial rubber tape so as to choose two types of solid raw rubber continually making an unvulcanized rubber tape as a model. Table 1 presents Mooney viscosity and M400 of sticky rubber tapes made from STR 20 and IR 2200 with various amount of carbon black. It was revealed that Mooney viscosity of the commercial rubber tape exhibited very low at 5.84, while its stress at 400% strain (M400) and the tack properties could not be investigated. This is because a specimen preparing from the commercial rubber tape was too weak. Mooney viscosity of the unvulcanized STR 20 tape was found to be increased with the increasing of carbon black loading both before and after accelerated heat aging but not for the IR 2200. However, all types of the sticky rubber tape showed decreasing in Mooney viscosity after heat aging. That means unvulcanized rubber tapes might be thermal-oxidative degraded under heating in the oven at 150ºC for 3 h. It is well recognized that carbon black is one of the best reinforcing agent to improve the hardness and strength of the compounded rubber [6]. Thus, STR 20 and IR 2200 mixed with various contents of the carbon black up to 45 phr were studied. The results showed that carbon black is an effective additive by serving the M400 of all unvulcanized rubber tapes. Figure 1 shows rolling distance of a steel ball on the surface of sticky rubber tapes made from STR 20 and IR 2200 with various amount of carbon black. All unmodified rubber tapes made from both STR 20 and IR 2200 displays the highest rolling distance at 35.0 and 22.5 mm, respectively. This implies that stickiness on surface of the rubber tape is the lowest comparing to their mixed with carbon black.
Table 1. Mooney viscosity and stress at 400% strain (M400) of sticky rubber tapes made from STR 20 and IR 2200 with various amount of carbon black.

| Type of Rubber | Carbon Black (phr) | Mooney Viscosity (ML 1+4) Before heat aging | Mooney Viscosity (ML 1+4) After heat aging | M400 (MPa) |
|----------------|-------------------|------------------------------------------|------------------------------------------|------------|
| STR 20         | 0                 | 54.42 ± 4.84                             | 23.34 ± 2.35                             | 0.11 ± 0.01|
|                | 15                | 55.19 ± 4.82                             | 20.80 ± 2.12                             | 0.17 ± 0.01|
|                | 30                | 73.09 ± 4.09                             | 31.00 ± 0.71                             | 0.43 ± 0.04|
|                | 45                | 67.55 ± 3.18                             | 39.11 ± 1.71                             | 0.84 ± 0.07|
| IR 2200        | 0                 | 60.77 ± 0.66                             | 33.82 ± 4.55                             | 0.10 ± 0.02|
|                | 15                | 53.16 ± 3.87                             | 22.76 ± 3.20                             | 0.08 ± 0.00|
|                | 30                | 63.26 ± 4.33                             | 21.28 ± 1.39                             | 0.17 ± 0.02|
|                | 45                | 58.03 ± 1.32                             | 28.79 ± 0.30                             | 0.27 ± 0.04|
| Commercial Rubber Tape | - | 5.84 ± 1.19 | N/A | N/A |

Figure 1. Rolling distances of a steel ball on sticky rubber tapes made from STR 20 and IR 2200 with various amount of carbon black.

The presence of only 15 phr of carbon black might improve the stickiness of the sticky rubber tape. However, the higher amount of carbon black loading demonstrated higher in rolling distance or lower in stickiness of the rubber surface. It might be explained by the dilution effect of the rubber phase. Moreover, the results of Mooney viscosity and rolling distance of all rubber tape prepared by adding the carbon black were significantly consistent. Rosin, brittle resin obtained from pines, was chosen as a tackifier in this work to improve the tackiness of sticky rubber tapes [7]. Mooney viscosity and M400 of compounded rubber tapes made from STR 20 and IR 2200 mixed with 15 phr of carbon black and various amount of rosin up to 10 phr was demonstrated in Table 2. Mooney viscosity of the rubber tapes modified with 2.5 phr of rosin exhibited the highest at 32.37 and 24.05 for STR 20 and IR 2200, respectively. Hence, rolling distance (see figure 2) and M400 of the rubber tapes were seemingly to be lower when the rosin content was increased. This is actually due to the effectiveness of the rosin.
### Table 2. Mooney viscosity and stress at 400% strain (M400) of sticky rubber tapes made from STR 20 and IR 2200 mixed with 15 phr of carbon black and various amount of rosin.

| Type of Rubber          | Rosin (phr) | Mooney Viscosity (ML 1+4) | M400 (MPa) |
|-------------------------|-------------|---------------------------|------------|
| STR 20 / Carbon Black 15 phr | 0           | 20.80 ± 1.70              | 0.17 ± 0.01 |
|                         | 2.5         | 32.37 ± 3.08              | 0.15 ± 0.01 |
|                         | 5.0         | 26.68 ± 1.91              | 0.14 ± 0.01 |
|                         | 10.0        | 24.62 ± 0.81              | 0.14 ± 0.00 |
| IR 2200 / Carbon Black 15 phr | 0           | 22.76 ± 3.35              | 0.08 ± 0.00 |
|                         | 2.5         | 24.05 ± 2.90              | 0.05 ± 0.00 |
|                         | 5.0         | 15.26 ± 2.18              | 0.03 ± 0.01 |
|                         | 10.0        | 5.31 ± 0.59               | N/A        |

### Figure 2. Rolling distances of a steel ball on sticky rubber tapes made from STR 20 and IR 2200 mixed with 15 phr of carbon black and various amount of rosin.

From the previous results, mechanical property of sticky rubber tape made from natural rubber or STR 20 shows outstanding while tack property of the tape made from synthetic rubber or IR 2200 presents predominantly. In order to possess the optimized properties of the sticky rubber tape, effect of STR 20/IR 2200 blends was finally studied. Table 3 shows Mooney viscosity and M400 of sticky rubber tapes made from STR 20/IR 2200 blends modified with fix amount of carbon black and rosin at 15 and 5 phr, respectively. It was found that IR 2200 blended with natural rubber in the range of 20 to 80% clearly resulted in enhancing of the Mooney viscosity or maximum increasing by about 146%. This is probably because STR 20 generally composes of natural branching structure, which was generated or initiated by non-rubber component [8]. Among all blending formulations, the ratio of STR 20/IR 2200 at 20/80 was found to be the highest in stickiness demonstrated by the lowest in rolling distance as shown in figure 3.

### Table 3. Mooney viscosity and stress at 400% strain (M400) of sticky rubber tapes made from STR 20/IR 2200 blends mixed with 15 phr of carbon black and 5 phr of rosin.

| Ratio of STR 20/IR 2200 | Mooney Viscosity (ML 1+4) | M400 (MPa) |
|-------------------------|---------------------------|------------|
| 0/100                   | 15.26 ± 1.51              | 0.03 ± 0.01 |
| 20/80                   | 33.90 ± 2.79              | 0.13 ± 0.00 |
| 40/60                   | 36.05 ± 1.97              | 0.11 ± 0.02 |
| 50/50                   | 33.77 ± 2.33              | 0.09 ± 0.00 |
| 60/40                   | 37.56 ± 2.04              | 0.10 ± 0.01 |
| 80/20                   | 32.31 ± 2.56              | 0.06 ± 0.01 |
| 100/0                   | 26.68 ± 3.28              | 0.14 ± 0.01 |
Figure 3. Rolling distances of a steel ball on sticky rubber tapes made from STR 20/IR 2200 blends mixed with 15 phr of carbon black and 5 phr of rosin.

For the overall experimental results, the unvulcanized rubber tapes were preliminary tried to apply on a steel pipe comparing with the commercial rubber tape. Figures 4 and 5 are the appearances of sticky rubber tapes made from IR 2200 and STR 20 mixed with 15 phr of carbon black and 5 phr of rosin comparing to commercial rubber tape after cooling at 5°C for 5 days and after sunlight exposure for 5 days, respectively. After testing under cooling condition the rolled unvulcanized rubber tapes on a steel pipe (see figure 4), it was found that both of IR 2200 and STR 20 seem to be completely tighten on a steel pipe but not for the commercial tape.

Figure 4. Appearance of sticky rubber tapes made from IR 2200 and STR 20 mixed with 15 phr of carbon black and 5 phr of rosin comparing to commercial rubber tape after cooling at 5°C for 5 days.

Figure 5. Appearance of sticky rubber tapes made from IR 2200 and STR 20 mixed with 15 phr of carbon black and 5 phr of rosin comparing to commercial rubber tape after sunlight exposure for 5 days.

On the other hand, after exposure by the sunlight both unvulcanized rubber tapes made from IR 2200 and STR 20 appear a bit of disintegration as demonstrated in figure 5. This might be explained by the fact that all recipes of the sticky rubber tapes compounded in this work were not consisted of stabilizers or antioxidants. Although many properties with various amounts of chemicals and types of the rubber have been already reported in this paper, other significant characterizations such as peel strength and chemical resistance of the unvulcanized rubber tape should be studied further.
4. Summary
The unvulcanized rubber tapes have been successfully produced both from STR 20 and IR 2200. Preliminary characterizations such as Mooney viscosity, M400 and tack properties of all sticky rubbers tape have been clarified as well as blending ratio between STR 20 and IR 2200 to improve the mechanical properties. Mooney viscosity of the unvulcanized rubber tapes can significantly reduce by heat aging the compounded rubbers at 100ºC for 15 min. The best recipe for the unblended rubber exhibited that the highest M400 is STR 20 mixed with 15 and 5 phr of carbon black and rosin, respectively. After characterization of the blending ratio of STR 20/IR 2200, it might be concluded that 20% addition of the natural rubber can enhance the Mooney viscosity of the rubber tape.

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