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REPUBLIK INDONESIA



ICSTSI 2020

PROCEEDING

International Conference on Science and Technology for Sustainable Industry

"Emerging Science and Technology as A Solution for Global Challenge
on Research and Technology Based on Sustainable Resources"

Banjarbaru, August 6th-7th 2020

BALAI RISET DAN STANDARDISASI INDUSTRI BANJARBARU

Badan Penelitian dan Pengembangan Industri

Kementerian Perindustrian

2020

PROCEEDING
INTERNATIONAL CONFERENCE ON SCIENCE AND
TECHNOLOGY FOR SUSTAINABLE INDUSTRY (ICSTSI) 2020

Theme:

*“Emerging Science and Technology as a Solution for Global Challenge on
Research and Technology Based on Sustainable Resources”*

Banjarbaru, 6-7 August 2020



Editor in Chief:

Prof. Rodiansono, Ph.D.

BALAI RISET DAN STANDARDISASI INDUSTRI BANJARBARU
BADAN PENELITIAN DAN PENGEMBANGAN INDUSTRI
KEMENTERIAN PERINDUSTRIAN
2020

**PROCEEDING
INTERNATIONAL CONFERENCE ON SCIENCE AND
TECHNOLOGY FOR SUSTAINABLE INDUSTRY (ICSTSI) 2020**

“Emerging Science and Technology as a Solution for Global Challenge on Research and Technology Based on Sustainable Resources”

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PREFACE

The 1st **International Conference on Science and Technology for Sustainable Industry** (ICSTSI) is organized as a collaboration between The Institution of Research and Standardization of Industry Banjarbaru (Balai Riset dan Standardisasi Industri Banjarbaru) and The Chemistry Department of Lambung Mangkurat University. The theme of this conference is “*Emerging Science and Technology as a Solution for Global Challenge on Research and Technology Based on Sustainable Resources*”. Sustainability remains a crucial issue regarding how the industrial sectors use technology to explore and utilize resources in the era of industrial revolution 4.0. This revolution has started with the applications of advanced manufacturing and digital information technologies. The world is undergoing a fundamental transformation, which is changing the way we live, work and think. The fourth industrial revolution presents a future filled with exciting opportunities and new challenges and the potential to meet specific requirements during the COVID-19 crisis. Industry 4.0 technologies have the capability of providing better digital solutions for our daily lives during this crisis.

The main goal of this conference is to bring together scientists, academics, and practitioners who work in various fields to exchange their ideas by presenting their research findings. This two-day of conference are certainly the moment of scientific forum that can be used as a means of knowledge exchange to connect participants (in any discipline) with each other, so they can discuss their work, learning from one another, and achieving improvements in results.

In the initial plan, this conference should have been held in Banjarbaru, a city in the province of South Kalimantan, Indonesia on August 6th-7th 2020. Unfortunately, due to the extraordinary global health issue with the coronavirus disease (Covid-19) that causes the large-scale social restrictions in the framework of the acceleration of Covid-19 handling, ICSTSI was held virtually while maintaining its original schedule. There were about 250 attendees that participated in the conference meeting, and 154 of them were presenting their papers in the plenary sessions. The meeting was done by virtual instead of being postponed because virtual meetings have become the new normal under COVID-19. The virtual meeting *was held by Zoom meeting video-conference method*. This virtual conference could be used as a tool to speed up existing discussions and timelines among scientists. Each presenter delivered the paper for approximately 7 minutes presentation and followed by 3 minutes discussions and Q&A sessions. The event was appreciated by the participants because it was well-organized and being one of the pioneers in the new normal video-conference trends. The YouTube channel of the opening ceremony ICSTSI 2020 could be found here <https://s.id/u1Kmu>.

The plenary session in the first day consisted of the presentation by keynote speakers and poster presentations. The parallel session in the second day contained of invited speakers and oral presentations, divided into 6 different topics: material and applied chemistry; wood and non-wood forest products technology; food, cosmetics, and medicine; analysis and method validation industrial, process optimalization technology; biorefinery, bioenergy, and renewable energy and biotechnology; and waste treatment and environmental management. The keynote and invited speakers who had been presented on this conference are listed below.

Keynote Speakers:

Dr. Ir. Doddy Rahadi, MT (Ministry of Industry, Indonesia)

Prof. Dr. Shinso Yokota (Utsunomiya University, Japan)

Assoc. Prof. Dr. Azlan Kamari (Universiti Pendidikan Sultan Idris, Malaysia)

Prof Dr. Ir. Umar Santoso, M. Sc. (Faculty of Agricultural Technology Gadjah Mada University, Indonesia)

Mukhlis Bahrainy (The CEO of Pachira Group)

Prof. Dr. Is Fatimah (The Islamic University of Indonesia)

Invited Speakers:

Prof. Rodiansono, Ph.D (Lambung Mangkurat University)

Prof. Gustan Pari (Forest Products Research and Development Center)

Dr. Nazarni Rahmi (The Institution of Research and Standardization of Industry Banjarbaru)

Ir. Lies Indriati (Center for Pulp and Paper)

Dr. Lisman Suryanegara (Center for Research of Biomaterial, Indonesian Institute of Science)

Dr. Aris Mukimin (Center for Industrial Pollution Prevention Technology)

The committee has received 154 papers from both oral and poster presentations, with the participants spread from many countries like Indonesia, Japan and Malaysia. The participants of conference came from various research institutions and universities in Indonesia. These papers were reviewed by scientific committee and 85 full papers were accepted to be published in IOP Proceeding Conference Series, 11 papers were published in ISBN Proceeding, 1 paper were published in the accredited national journal and the rest were rejected and unpublished. We would like to thank the participants who have submitted their papers. We also highly appreciate the sponsors who financially supported this event especially to the Industrial Research and Development Council Ministry of Industry, Indonesia.

Banjarbaru, December 2020

ICSTSI Committee

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Pamulang University. These papers were reviewed by scientific committee and 85 full papers were accepted to be published in IOP Proceeding Conference Series. We would like to thank the participants who have submitted their papers. We are grateful to IOP Publishing as our publication media partner. We also highly appreciate the sponsors who financially supported this event especially to the Industrial Research and Development Council Ministry of Industry, Indonesia.

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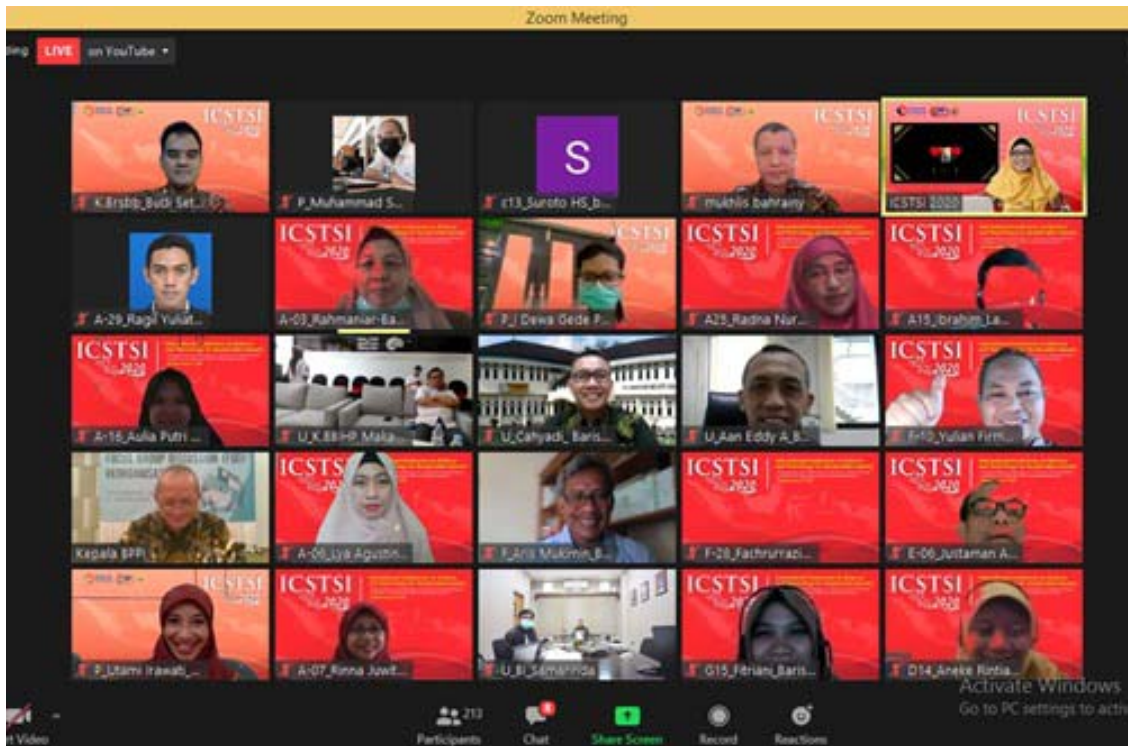


Figure 1. Conference guests and participants.



Figure 2. Conference opening ceremony.



Figure 3. Conference invited speaker.



Figure 4. Conference committee.



Figure 5. Behind the scenes.

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- **Number of submissions received:** 154 papers
- **Number of submissions sent for review:** 120 papers
- **Number of submissions accepted:** 85 papers
- **Acceptance Rate (Number of Submissions Accepted / Number of Submissions Received X 100):** 55.19%
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- **Any additional info on review process:**
The reviewers were asked to answer a number of questions related to the quality of the content (reviewed form). Thus, the review processes were not personal and formalized. The review process for each paper took more than one month. The decision to accept or reject was based on the suggestions of each reviewer. If differences of opinion occurred between two reviewers, the editorial team pointed out one additional reviewer to review. The decision was based on majority votes based on all comments.
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The effect of pumice and clay composition in natural rubber-ethylene propylene diene monomer blends towards its curing characteristics and physic-mechanical properties

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Abstract. Since some adverse effects of using carbon black as petroleum-based filler in rubber compounding, mineral fillers may be a feasible alternative filler. This research studied the effect of the composition of pumice and clay as mineral filler in natural rubber (NR) and ethylene propylene diene monomer (EPDM) blending towards its curing characteristics and physical-mechanical properties. The effect of reinforced filled in EPDM-NR (70/30) phr blends was observed by varying 50, 70, and 90 phr of filler. While the filler was designed as the composition of pumice/clay (P/C): 20/80; 50/50; 80:20 (weight/weight). The rubber, fillers, and chemical were compounded based on ASTM D-3182. The results showed that the loading of P/C fillers in EPDM-NR blends increased scorch time and decreased cure rate index. It was found that the optimum number of filler could enhance density, modulus. Remarkably, the higher pumice composition caused the abrasion resistance and compression set improved significantly, whereas the overloading pumice and clay cause the physic-mechanical properties remained stable or evenly drop. FTIR spectra of the binary blends confirmed that the fine fillers dispersion was obtained due to some interaction bonding between silanol, aluminol of fillers with the EPDM-NR.

1. Introduction

Natural rubber is a polymer material with high elasticity that is widely used for tyres, rubber pad, rail pad, gasket, seal, rubber dock fender Etc. The advantages of using natural rubber as the main polymer are excellent tensile properties, abrasion resistance and highly availability in nature [1]. However, some negative effects of using natural rubber are less chemical resistance, low physic mechanic properties, and oil resistance for rubber product applications are urgent to be addressed [1,2]. Generally, in order to improve those properties, specific rubber products were made using a



combination of synthetic polymers such as ethylene diene, styrene butadiene, chloroprene, or even combined with other thermoplastic polymer such as poly-vinyl chloride, polyethylene low molecular or polypropylene [1-3]. In addition, to increase physical properties such as hardness, density, and other tensile properties some fillers were blended during rubber compounding. In this research, EPDM, petroleum-based synthetic polymer, was studied since it was blended with NR to produce some rubber products application that needs high abrasion and heat resistance, and specific compression set value. However, in order to improve physical properties such as density and hardness, the compatible reinforcing needs to be added as a filler in rubber compounding. The previous research stated unfilled EPDM, NR or EPDM-NR binary blends are weak and lost its physical and tensile properties [1,4-6]. EPDM blends with NR have also been studied and stated that to obtain better tensile and mechanical properties, the plasticizer and fillers need to be compatible with each other with the rubber matrix [7, 8].

Commercial reinforcing fillers such as carbon black are usually added into the rubber phase matrix to reinforce the polymer's properties of polymer and reduce cost. Some non-reinforcing fillers such as Calcium Carbonates is added in rubber compounding to enlarge the products volume. However, some negative effect have risen due to petroleum based on carbon black such as environmental pollution, high price and low sustainability recently [9]. Thus, some deposited mineral from earth has been studied as either reinforce or non-reinforce filler for rubber compounding. Some previous research using clay from montmorillonite, kaolinite, quartz, etc. to improve physical properties NR blending [9]. It is found that the strengthening effects are determined by its large surface area, porous, size and surface polarity of the fillers [4,6,10]. The type and amount of filler determine the rubber products' physical-mechanical properties, and thermal and aging resistance. Since many deposited minerals have very specific physical and chemical properties, a study on the effect of using some minerals needs toward its physic-mechanical properties is urged. The type, amount and its compatibility of filler with polymers determine the specification and standard of the rubber final products' specification and standard.

In this research, similarly with the zeosil as reported by [3,11], pumice and clay were studied due to the physical and chemical properties of those minerals that may be reinforced filler in rubber compounding. Montmorillonite, bentonite and other clay commonly used as filler in rubber compounding [5,9,12,13]. It is reported that clay has good positive effects on the physical properties of natural rubber composites. Meanwhile, pumice is a new alternative reinforced filler that has not been explored widely. Pumice fine powder is a natural mineral that has high availability from explosive eruptions [14-16]. Pookmanee, Wannawek [16] stated that generally pumice in Indonesia has chemical composition as follows 70% SiO₂; 14% Al₂O₃; 4.39% Fe₂O₃; 4.39 %; 3.77% Na₂O; 4.03% K₂O; 2.6% CaO, 0.71% TiO₂, Etc. This mineral contain also reported by Bahri and Rahmaniar [12]. Naturally, the pumice has a crystalline structure due to alumina, silanol, and hydroxyl groups [15-17]. It has a highly porous glass that has huge surface area [15]. The polar groups on the surface can be mixed easily with the polar polymer [17]. Because of its properties, pumice has mostly been used as an adsorbent, poly aniline mixtures, and other industrial application [17]. In addition, pumice also has excellent chemical resistance and thermal stability [16,17]. The clay added in this research was obtained from Banyuasin. The density was 1.6 g/cm³ that dominated by kaolinite and a small amount of smectite, quartz, cristo-ballite and quartz in a very small portion [18,19]. Thus, the pumice and clay mixtures may have positive effects on physic-mechanical properties that are not had by carbon black, calcium carbonates, kaolin and other commercial fillers.

Bearing in mind that lack of information and research on pumice usage reinforces filler in NR/EPDM blending, this research would be valuable as reinforcing filler in polymer blends. Therefore, based on some excellent properties of pumice, clay and natural rubber properties, this research studied to prepare a pumice-clay based composite of EPDM-NR. This study emphasized on the formulation of rubber compounding particularly the effect of the number of pumice and clay as fillers towards it density, modulus, abrasion resistance, and compression set. Therefore, some information and knowledge on developing reinforced fillers based on mineral may be published.

2. Materials and methods

2.1. Materials

The materials used in this study were Ribbed Smoked Sheet (RSS) which is produced in Indonesia. Polymers: Natural Rubber types of RSS-1 (Ribbed Smoke Sheet) was obtained from PT Air Muring Indonesia and Ethylene Propylene Diene Monomer (Bayer M Ltd/ THEP130865W) spec as follows ethylene 67%; ENB 43%; density 1.3 g/cm³; hardness 65±5 Shore A; compression set 40%. Fillers: Pumice was obtained from the local market, Sumatera and Clay was obtained Banyuasin, Sumatera. Plasticizers / Lubricants / Peptiser: paraffinic oil, brown factice, Stearic Acid, paraffin wax (Oleo-chemicals Industry, PT Sumi Asih). Activators: ZnO (NC 105 Global Chemical Co, Ltd). Other chemicals as follow CBS N-cyclohexyl-2-benzothiazyl sulphenamide; DPG iphenyl guanidine, and sulfur curative agent (Brataco Chemical).

2.2. Pumice and clay preparation

Pumice rock was bought from the local market, Sumatera, Indonesia. The pumice rock was dried at sun light, crushed and ground until obtaining a fine pumice powder. Then, it was sieved at size 200 mesh, dried at the temperature of 70-80°C using air oven and then desiccated to maintain the moisture content before compounded. The density of pumice used in this research was 0.71 g/cm³.

Clay was obtained from a local pottery market in Banyuasin, Sumatera Regency, Indonesia. Similar to the pumice preparation, the clay was dried, ground to be clay powder, and then sieved at 200 mesh size powder. Both of clay and pumice were maintained the moisture content before compounded with polymers and other chemicals.

2.3. Rubber compounding

The vulcanizate was compounded based on the formulation as follows: 40 phr of EPDM; 60 phr of natural rubber type: Ribbed Smoke Sheet (RSS-1); 2 phr of paraffinic oil, 2phr of brown factice, 4 phr of Zinc Oxide; 1.5 of Stearic Acid; 0.5 of Paraffin Wax; 1.5 of CBS; 0.5 phr of DPG; 2.5 phr of Sulphur. The total number of filler was varied 50; 70; and 70 phr for rubber compounding. Meanwhile, the filler was a mixture of pumice and clay that also varied by mixing pumice/clay (weight/weight) as follows 20/80; 50/50; and 80/20 w/w. Polymer and other chemicals were compounded using laboratory mill XK-160 (type: open two roll mill, Shanghai Rubber, China) based on the standard procedure of ASTM D3182. The preparation of vulcanized sheets standard was done using the ASTM D3184-89 procedure. In order to examine the tensile properties, the compounded rubber sheet was vulcanized for t90 at 150°C using heating press hydraulic (YG-220, Shanghai Rubber Machine Worker, China). These procedures were replicated three for each formula in order to obtain highly accurate data.

2.4. Testing procedures

Curing characteristics such as ML, MH, cure time and scorch time were determined using a Monsanto moving to die rheometer (HT8756P) according to ASTM D5289. Then the samples were tested at a vulcanization temperature of 155°C.

For physical-mechanical and tensile properties, the compounded rubber was sheeted and cooled for about 24 hours at room temperature. After that, the sample was heated and pressed using hydraulic press machine YG-220, China, for about 20 minutes at 155°C. The samples were tested based on the standard procedures as follows: modulus (ASTM D412); abrasion resistance (ASTM D5963); Compression set at 25% deflection, 70°C for 22 hours (ASTM D395); and density (ASTM D297). The experiments were conducted three replication to obtain accurate results.

In order to observe the functional group interaction between clay, pumice, natural rubber, and EPDM, the spectra of FTIR was pictured. The FTIR of Perkin Elmer System 2000 was used in a range 4000 cm⁻¹ to 500 cm⁻¹. The evaluation of the spectra was following the ASTM D3677 procedure.

3. Results and discussion

3.1. Rheological analysis

Table 1. Curing characteristics of EPDM-NR composites filled by pumice and clay.

Pumice/Clay (w/w)	Total Filler (phr)	ML (kg.cm)	MH (kg.cm)	ΔF (kg.cm)	t_{90} (min)	t_{s2} (min)	CRI (/min)
20/80	50	0.04	18.21	18.17	20.17	14.38	17.29
	70	0.02	19.40	19.38	20.43	14.78	17.70
	90	0.05	19.52	19.47	20.38	14.92	18.29
50/50	50	0.52	16.44	15.92	14.77	2.67	8.26
	70	0.28	16.64	16.36	16.18	3.60	7.95
	90	0.19	17.45	17.26	16.58	3.95	7.92
80/20	50	0.02	20.90	20.88	7.20	1.60	17.86
	70	0.21	23.29	23.08	12.15	3.08	11.03
	90	0.27	24.15	23.88	12.58	3.90	11.52

The rheology analysis on the effect of filler number and the composition of pumice and clay filler in EPDM and NR blending are shown in table 1. It lists the torque differences that reflect the crosslinking degree of the matrix polymer and also the curing rate index which describes the filler's processing ability of the filler within the polymers. The higher loading of total filler of pumice and clay caused the increase of MH (maximum torque), indicating viscosity due to the high number filler. Similarly, the increased loading of total filler also contributed to the increasing of torque difference ($\Delta F = MH - ML$) that is assumed as cross-link density.

It could be explained that silanol and alumina from both clay and pumice could make interaction among the ethylene and isoprene groups within the rubber matrixes as reported by Ramesan, George [17]. Pumice and clay with a specific area and large porous also could adsorb some chemicals such as sulphur curing agents, plasticizers and chemicals during the rubber compounding [6]. In addition, the high number of pumice and clay also may inhibit the curative agent and other chemicals dispersion within the rubber matrixes as reported Sengupta, Esseghir [10]. The existence of excess sulphur and precursor cross linking also inhibit the curing process. Therefore, it affect the cure time of the rubber blending. In addition both pumice and clay surfaces have a high number of hydroxyl groups and water (as hydrate) that may span the vulcanization of EPDM-NR blending [1,4,6].

As the pumice and clay increased, the CRI relatively decrease. The EPDM and NR have a huge molecular weight that needs some extra energy to melt mixing during the mastication and compounding with the big-sized filler such as pumice and clay [5,13,20]. Hence, the more shear force and heat were needed during melting the mixture due to the high viscosity and the presence of plasticizer and softener in the compounding.

Those higher viscosity of EPDM-NR filled with pumice and clay may shorten the scorch time as listed in table 1. Compared to previous research by [5,13,20], this finding met an agreement that the clay loading on EPDM-NR blending influenced the curing and rheological characteristics. The higher total filler that had a big size of 200 mesh of pumice and clay could also limit the rubber matrixes' molecular movement within the rubber matrixes. Thus, it would affect the physical properties like 300% modulus and density as depicted in figure 1. The pumice and clay molecule restriction could affect the stiffness and rigidity of the rubber products as the density value shown in figure 1.

The value of t_{90} (scorch time) explained the processing-ability of the filler and polymer of the rubber mixing the mastication and compounding process particularly. This process was connected

with the amount of heat that could be energized before the rubber cross link-state transformation. The increasing viscosity of filler may shorten the scorch time as reported by some research by Ismail and Mathialagan [6]. The excess number of filler loading within EPDM-NR blending may cause the decreasing of cure time. The competition for cross-linking agents between NR and EPDM and the overload pumice and clay may cause a decrease of cure time. The competition for cross-linking agents between NR-EPDM and the overload pumice and clay casue the decreasing the rate of curing due to the less mobility of the curative agent in highly dense of EPDM, NR, pumice, and clay.

Process-ability and blending of fillers within the EPDM-NR is affected by the presence of pumice and clay [6,10]. Pumice and clay has hydroxyl groups that may enhance the rubber filler networking due to the hydrogen bonding and van der Waals effect. The same explanation was also reported by Azizli, Abbasizadeh [21]. It was shown that the stronger bonding interaction between EPDM, NR and pumice and clay fillers that was determined by ΔF (MH-ML) in table 1. In addition, the pumice and clay dispersion in a sufficient composition of EPDM-NR matrixes also contribute to the cross link density as assumed by the ΔF .

3.2. Physical properties

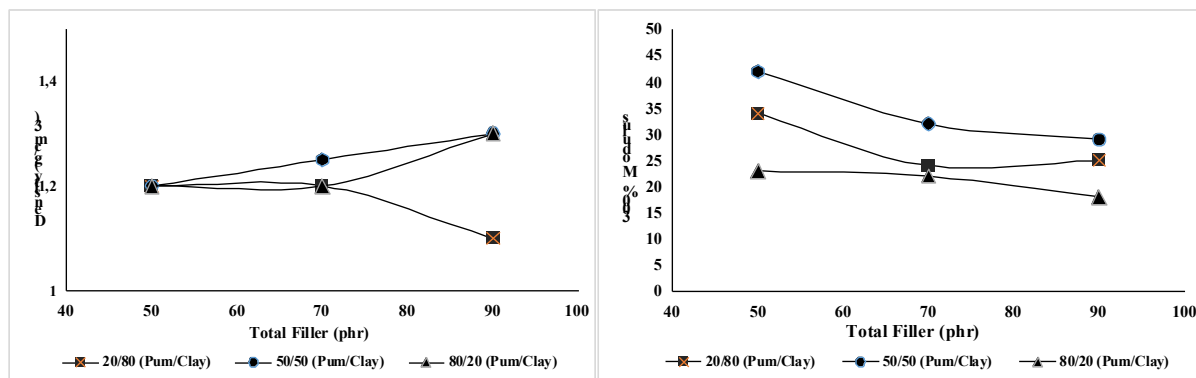


Figure 1. Physical properties (density and 300% modulus) of EPDM-NR blending filled by pumice and clay.

The presence of pumice and clay contributed positively to the increasing of density as shown in figure 1, whereas it decreased the modulus of the polymer blending. The density increased as the loading of pumice and clay, but at an optimum number of filler the density tended to remain stable. Conversely, the modulus of the polymers experienced the decreasing by the increasing filler. The overloading of pumice and clay cause the aggregation of the filler and some chemicals may agglomerate due to the presence of excessive filler [5,11,13]. It might interrupt the filler matrix bonding of oligomer of alumina, silica, isoprene from the filler and polymer matrixes. Thus it reduced the modulus properties as shown in figure 1. As confirmed by the cure rate index in table 1, the modulus might be represented as cross-linking density and its stiffness [6]. Compatibility between rubber and the fillers of mixture between pumice and clay influences the rubber compounding's processing ability. The fine filler dispersion may enable the stronger rubber filler interaction that lead to improve the modulus and other tensile properties [4,6]. However, due to the big size of pumice and clay fillers, at a specific portion of excessive fillers, the pumice and clay may agglomerate and its aggregate could decrease the strength of filler rubber interaction and even rubber-rubber networking bonding [5,13,20]. Thus, physically, the rubber products are more fragile and stiff.

3.3. Mechanical properties

The effect of pumice and clay loading towards its abrasion resistance and compression set is shown in figure 2. Pumice and clay loading had a less significant effect on abrasion resistance and compression set value as reported by some research [22,23]. Due to the scrapping, the volume loss, mechanical

rubbing and erosive action is a key mechanical properties for rubber products such as tire, rail pad, rubber pad, etc. Figure 3 illustrates that filler loading of pumice and clay increase the abrasion resistance of the rubber blending. Unlike the modulus trend, better abrasion resistance could be obtained by improving of the filler rubber interfacial adhesion and rubber-rubber networking bonding. The value of abrasion resistance in figure 2 indicated the loss material during the testing, so the lower value indicated the higher mechanical properties. The pumice and clay addition of 50 up to 90 phr might fill the optimum space on the EPDM-NR composites matrix finely, so that its strong bonding interaction could resist the friction and decrease the lost volume. The homogenous particle size of clay and pumice at 200 mesh also contributed to the strength cross-link density and its hardness so that the abrasive treatment could be resisted [4, 6]. As shown in figure 2, due to the differences bulk density of pumice and clay, the abrasion resistance of composites containing high number of pumice had the lowest value of abrasion resistance. This finding is in agreement with some research by Tabsan, Wirasate [22].

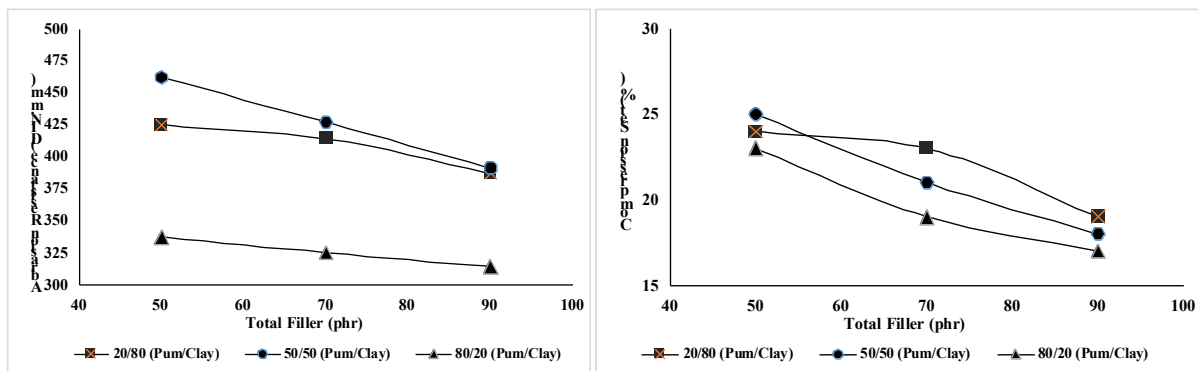


Figure 2. Mechanical properties (abrasion resistance and compression set) of EPDM-NR blending filled by pumice and clay.

Another important mechanical property is the compression set. The compression set's value was measured by evaluate the changes in thickness and elasticity of vulcanization after pressed at a certain deflation and temperature [2,13]. This property contributed to flow, stress relaxation, recover from compression or setting during rubber product usage. The residual deformation or the percentage of deflection after compressed 25% of its original thickness. These properties were very important in rubber padding for heavy construction or transportation. Figure 2 shows the deflection percentage of NR/EPDM filled pumice and clay rubber products that recover to its early shape and how much the rubber failed to return to its previous shape. Generally, the lower percentage indicated a good compression set. It was clearly seen that the compression set value of the rubber less than 30%. It indicated the compression set of this ternary blends complied good the specification standard of rail rubber pad. However, for static usage such as gasket or rubber sealing, the loss of ability to seal may cause leakage, therefore the low compression set is needed for this application. Apart from shrinkage and swelling properties by contacting with the fluids, more prolonged usage and increasing temperature increase the compression set. It was found that the increase of pumice clay total filler caused a positive effect on the improvement of compression set. Similarly to abrasion resistance, the higher number of pumice also gave a lower value of the compression set. The bulk density and chemical properties pumice and clay may enhance the decreasing of mechanical properties of the rubber products due to deterioration in rubber filler interaction bonding and finely filler rubber dispersion [17].

Aforementioned the density and modulus changes by the increasing number of pumice and clay, the compression set also shown a similar trend as shown in figure 2. The formation of more cross-linking bonds, the stronger interaction could resist the changes during compress and set at a certain condition. The previous studies also reported that the number filler and its type of reinforcing

influence the mechanical properties [10,13,20,21]. Those results are in consistent with the 300% modulus in figure 1, which the rubber stiffness was reduced, so the rubber became more elastic and the compression sets improved.

3.4. FTIR spectra

FTIR spectra were pictured in figure 3. Compared with EPDM-NR filled carbon black, the spectra of EPDM-NR filled pumice and clay have a higher intensity and more peaks in specific wavenumber. The spectra showed that the higher number of total filler loading might increase the peaks' intensity at specific wavenumber. As depicted in figure 3, adsorption bands derived from mixture clay and pumice were observed as follows: 450-460 cm^{-1} (Si-O-Al), 750-770 cm^{-1} (Si-O-H), 1010-1300 cm^{-1} (Si-O-Si) and 3400-3450 cm^{-1} (OH). Those adsorption bands also explained as the same functional groups [15-17]. The intense high peaks approximately at 3450, 3000, 1200, 1000 cm^{-1} were the vibration of -OH, C-H, C=C, and Si-OH respectively. It was highlighted that pumice and clay were dispersed in EPDM/NR caused new changes of spectra in 1000-4000 cm^{-1} and some new adsorption bands. This was due to the presence of aluminol, silanol, and the interaction between other functional groups in pumice and clay within the polaric groups of NR and EPDM. It was noticeable that peak intensity at 3450 cm^{-1} became broader and higher due to the presence of OH from pumice/clay and some hydrogen bonding between silanol and aluminol groups from pumice/clay with isoprene and ethylene propylene. Ramesan, George [17] also state the same clarification on filler dispersion with the rubber matrixes. Thus, the dispersion of pumice/clay within binary blends was obtained.

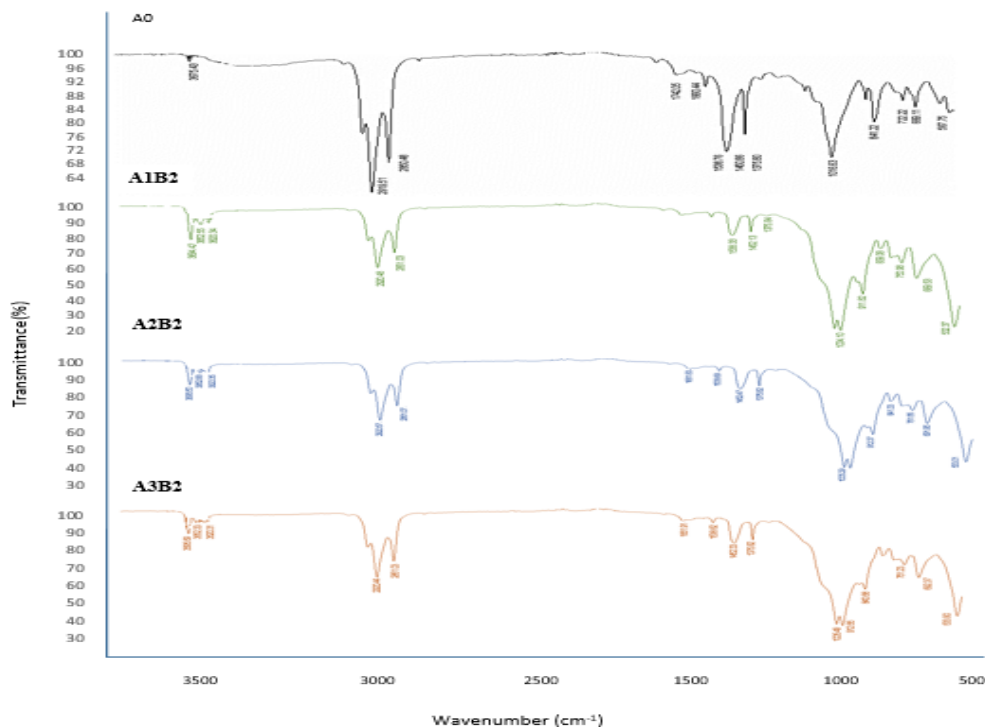


Figure 3. FTIR Spectra of EPDM-NR filled with 70 phr Carbon Black (A0); 50 phr of pumice:clay (50/50 w/w) (A1B2); 70 phr of pumice:clay (50/50 w/w) (A2B2); 90 phr of pumice:clay (50/50 w/w) (A3B2).

4. Conclusions

The binary blending of NR and EPDM filled by pumice and clay was successfully compounded. To sum up, pumice and clay were possible alternative as reinforcing filler in EPDM-NR polymers that

contribute positively in density, modulus, abrasion resistance and compression set. Based on the rheological analysis, an optimum number of total filler mixture of pumice and clay could improve the processing ability included its cure rate index and the degree of cross linking formation in the rubber matrixes. The higher loading of total filler pumice and clay might contribute positively and affected the abrasion resistance, compression set and density. However at overloading filler the values might remain stable or evenly drop. Another finding is that the larger pumice composition over clay at NR/EPDM binary blends would improve abrasion resistance and compression set remarkably. The FTIR spectra of EPDM-NR filled by pumice and clay confirmed that pumice and clay might have a strong interaction bonding between silanol, aluminol within EPDM-NR matrixes. However, in order to improve the degree of dispersion of the pumice clays fillers, morphological analysis needs to be evaluated.

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