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Manufacturing of Sheet Gasket using a Paper Making Process without Organic Solvents

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Abstract

This paper concerns an eco-friendly manufacturing process for low density compressed sheet gaskets used to maintain gastight properties regarding gases and liquids. The main raw materials in a low density compressed sheet gasket are latex, organic/inorganic textile, and fillers; in this research, a sheet gasket was continuously manufactured without using organic solvents through a method called the paper making process. The results demonstrated properties such as compressibility, recovery, tensile strength, oil resistance, and high temperature leakage, properties suitable for sealing materials. The production environment also improved dramatically as organic solvents were not used during the manufacturing process, and production efficiency was increased as well.

Keywords: Gasket; Low density compressed sheet; Paper making process; Latex; Gasket materials; Rubber

Introduction

A gasket is defined as a static seal used to tighten the bolts that prevents leakage between the pressure vessel and flange. Such gaskets are suited to various conditions such as fluid, pressure, temperature, and the like, and come into contact with, and press on, surfaces of various shapes, demonstrating sealing performance through the material's elastic force. Currently, the most common process for the manufacture of compressed sheet gaskets is to swell rubber in an organic solvent, knead it with short fibers, fillers, and binders, then age the raw materials by compression roll forming and lamination [1-7].

However, during this process, volatile organic solvents are used in large quantities to improve the adhesion of the rubber and additives, thus making the manufacturing environment extremely poor. As is well known, typical volatile organic solvents such as toluene, benzene, and xylene, all of which are air contaminants, are extremely hazardous to humans even at a low concentration of several ppm, and are substances that severely pollute the air. It is therefore imperative to improve the gasket manufacturing process in an eco-friendly manner, and to test the applicability of the paper making process as an alternative. Paper making processes for the manufacture of ceramic textile sheets and fiber textiles are well known [8-17].

In this paper, we introduce the results of technological development aimed at finding efficient manufacturing methods for low density compressed sheet gaskets without the use of volatile organic solvents. The operating temperature for the low specific density compressed sheet that was being developed was in the high temperature range of up to 350°C, and raw materials were considered from the perspective of providing sufficient sealing material characteristics. Ultimately, an optimized technique was realized that can continuously form a gasket sheet through the paper making process using slurry in which the raw materials, including latex, organic fiber, and filler, are effectively mixed.

Methodology

Raw materials

Because low density compressed sheet gaskets are characterized by important properties such as compressibility, leakage, tensile strength and oil resistance, the design of the composition is critical. As such, through various comparative analyses, raw materials suitable for use as main raw materials and fillers were chosen as listed under Figure 1. As shown in Figure 1, aramid fibers, glass fibers, Talc, and graphite powder were used as the main raw materials aside from latex; some fillers and bonding agents were also used but were omitted. Aramid fiber and glass fiber were used mainly to improve the formability and tensile properties of the sheet gasket, and fillers such as talc and graphite powder were used to maintain characteristics such as leakage, compressibility, and oil resistance. Of the materials utilized, latex (Kumho, KNL-860) was an aqueous latex with a solid content of 44.5~45.5 wt%. Aramid fiber (Twaron, T-1091) was selected after analyzing fiber activity and fibril level based on the Canadian Standard Freeness Measure (KS M ISO 5267-2). The length is about 5-40 mm, making it possible to improve bonding strength and dispersibility through high activity. Glass fibers (Owen corning, CS1545) are dispersible in water as they have no coating on the surface of the fiber; they have a length of 13 mm and fiber thickness of 16 μm. The talc (Rexem, TA400) used as the filler has a particle size of 11 μm. The graphite powder (Samjeng, MGF4) used has scales-shaped particles of a size less than 20 μm.

Slurry manufacturing for gasket forming

The slurry used to manufacture low density compressed sheets through the paper making process was prepared by dispersing all additives in water. First, water was filled in a slurry tank capable of high-speed stirring at 1,000 rpm or higher and maintained at around 90 cps using a viscosity agent to effectively disperse the additives. Next, organic and inorganic fiber in compositions based on previous experiments were added and stirred for more than 30 minutes. After checking fiber dispersion, the filler and powder shape raw materials were added. The mixture was stirred for about 2 hours until all additives were dispersed and well mixed. Aqueous latex was added while

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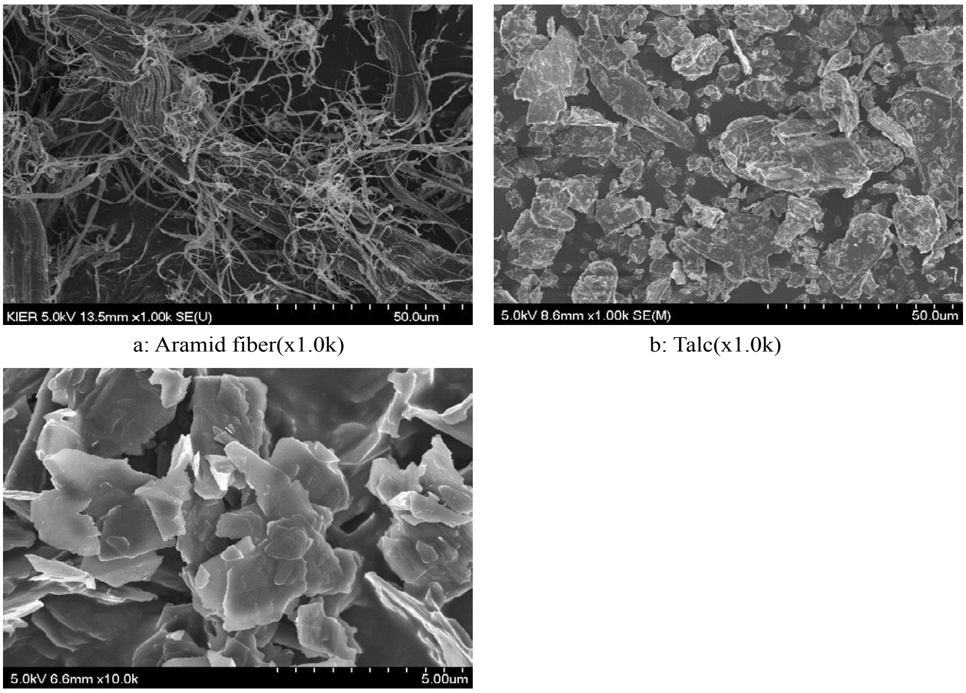

a: Aramid fiber(x1.0k) b: Talc(x1.0k) c: Graphite powder(x10.0k)

Figure 1: SEM images of raw materials (a: Aramid fiber, b: Talc, c: Graphite powder).

maintaining stirring speed at a very low level. The mixture was stirred for about 30 minutes to confirm that latex and other additives were well mixed. Next, coagulant was added. The coagulant used was a cationic coagulant commonly used in the paper making process. Using a Zeta potential analyzer, coagulant levels were maintained at the maximum coagulation efficiency range. To maintain an optimum composition, the amount of each raw material was changed and total inorganic solvent content was kept at 70% or higher. Slurry concentration was maintained at less than 3.5 wt%, and the pH showed a value of 7.4.

Continuous manufacturing of low density compressed sheet gasket using the paper making process

Figure 2 shows the process of manufacturing low density compressed sheet gaskets. As seen in the figure, it is very similar to the paper making process and is mainly composed of the slurry feeding part, sheet forming part, natural dehydration part, vacuum dehydration part, drying part, compression part, and product recovery part. A ventilated 425CMF, 69 mesh wire endless felt (Albany, Ultra5000-XK574) is installed at the sheet forming part. The equipment used in this research was also used before to continuously manufacture ceramic fiber sheets, carbon fiber sheets, zeolites and active carbon sheets. Continuous manufacturing of sheet gaskets was tested under the same configuration. The product's width was 600 mm and production speed was relatively low at 1.5~2.0 m/min. Slurry was supplied using a metering pump according to sheet production thickness, and slurry moisture content was maintained at levels lower than 60% through the suction and dehydration process using natural dehydration and vacuum pump. After vacuum dehydration, the process moves on to a two-step steam dryer with surface temperature of 135°C. Once through the steam dryer, moisture content is kept below 10%. Through compression and roll recovery, a low density compressed sheet gasket was continuously manufactured [10,11].

Low density compressed sheet gasket property analysis

Properties were assessed for the sheet gasket, which was continuously manufactured using the process explained above and manufactured as an end-product after post-processing methods that include compression, lamination bridging, and calendering. Post-processing methods involved placing the roll sheet produced using the paper making process onto the supply equipment and passing it through a calendering roll with a surface temperature of 100°C to acquire a thickness of 0.5 mm. Multiple sheets were laminated and bridged in a hydraulic press under a compression load of 170 kgf/cm^2, temperature of 150°C, and maintenance time of 30 seconds, which was then followed by continuous recovery. Standard compressibility and recovery tests (ASTM F36), tensile strength tests (ASTM F152), and oil resistance tests (ASTM F146) were conducted to analyze core gasket product properties. Heat analysis tests (TGA Q-500) were conducted at 650°C to confirm heat resistance. Maximum instantaneous-use airtightness tests were done based on the "soft gasket 150Class 2" standard after being fastened on a flange at a temperature of 350°C for 1 hour with 400 surface pressure torque (=1,082 kgf/cm^2) and the injection of 10 bars of N_2 gas. In addition, aerial organic solvent concentration was analyzed for each part of the manufacturing process [12].

Results and Discussion

Raw material composition and formation characteristics of the sheet gaskets

Table 1 shows the slurry titration composition obtained from the consolidated results of the standard sheet formation test in which specific raw material contents were altered, and the sheet gasket formation test using the paper making process. Of course, these results are not an optimum composition for manufacturing gaskets of the highest quality, but as mentioned in the introductory part of this paper,

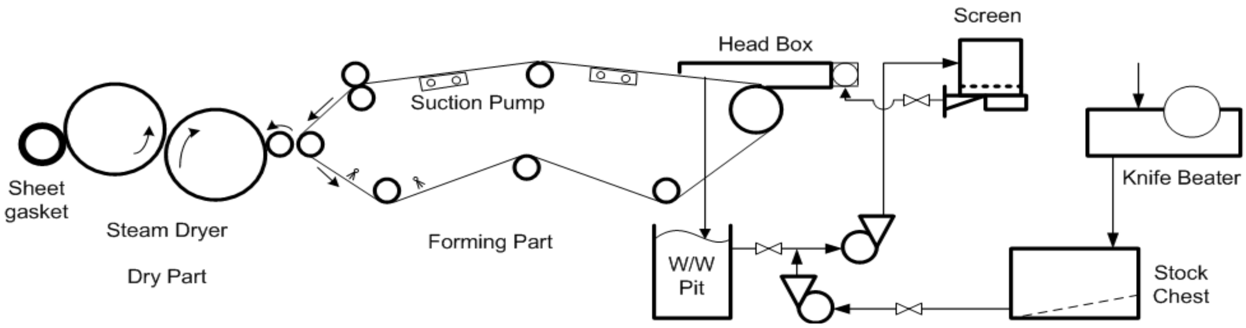

Figure 2: Continuous production process diagram for low density compressed sheet gasket production based on the paper making process.

Raw materials	NBR Latex	Aramid fiber	Glass fiber	Talc	Graphite powder	Others
Content, wt%	23.7	4.9	1.2	47.9	3.9	18.4

Table 1: Slurry titration composition for low density compressed sheet gasket (JGP170919).

can be a composition for producing one with properties suitable for sealing materials. As can be seen from the table, the amount of organic matter in the total composition is about 28.6%, indicating that the major component is composed of inorganic matter. This was to improve the heat resistance characteristics at a specific temperature or higher, and it was confirmed that the characteristics of the gasket varied depending on changes to the raw material composition ratios. In particular, it is necessary to consider that a proper fiber reinforcement composition ratio when preparing the slurry not only greatly enhances the tensile properties of the product, but also helps control coagulation size before gasket formation [14,15].

After completing the slurry composition for gasket manufacturing, the gasket was formed by supplying the slurry to the paper making equipment as shown in Figure 3. The amount of slurry supplied during formation was measured using a metering pump, allowing for continuous sheet gasket production at the desired thickness. Proper operating conditions were identified to transfer the sheet gasket, formed through natural dehydration and vacuum dehydration processes and separated from the wire mesh, to the dry part. Rolls were finalized after going through a two-step steam dryer with a surface temperature of 138°C. The thickness of the formed sheet gasket was highly level at around 0.8 ± 0.01 mm. Raw materials like carbon black hardly bonded to hands during sheet gasket handling, confirming the product's solid composition. This can be important criteria for end-users during product selection. The total weight of the raw material used in the experiment was 103.41 kg and the amount of slurry produced was about 4 tons. The slurry was used to continuously produce a sheet gasket with a width of 60 cm and a length of 180 m.

Characteristics of low density compressed sheet gasket

Figure 4 is a surface photograph of the low density compressed sheet gasket manufactured in this experiment. As shown, ceramic fibers, aramid fibers, and fillers are uniformly distributed. The paper making process yields a mixture of a very low mixed concentration of 2.5%. It is very useful in completing a uniform mixture based on stirring levels, resulting in outstandingly uniform formed products [16].

Figure 5 shows the change in tensile strength due to changes in the amount of aramid fiber. Aramid fiber's pulp-like shape and large surface area allows for many filler penetrations between nanofibers, increasing tensile strength. However, any addition of aramid fibers of 4.9 wt% or more results in a significant decrease in dispersibility, which

Figure 3: Manufacture of sheet gasket using a paper making process without organic solvents (JGP20170919).

increases the size of agglomerates, with the filler acting as an obstacle to the manufacture of gaskets with uniform characteristics. Figure 6 shows changes to tensile strength based on the addition of glass fiber chop. Tensile strength increased with additional amounts of glass fiber, peaking at 12 wt%; any additional amounts had a negative effect. It was found that added fiber was effective in improving tensile strength, although after a certain threshold additional amounts negatively affect

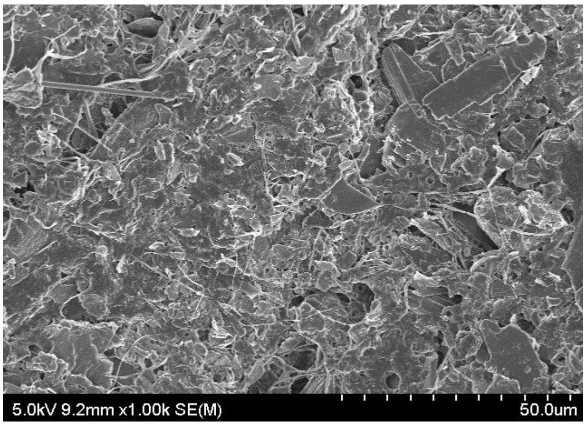

Figure 4: SEM image of gasket sheet surface (JGP20170919).

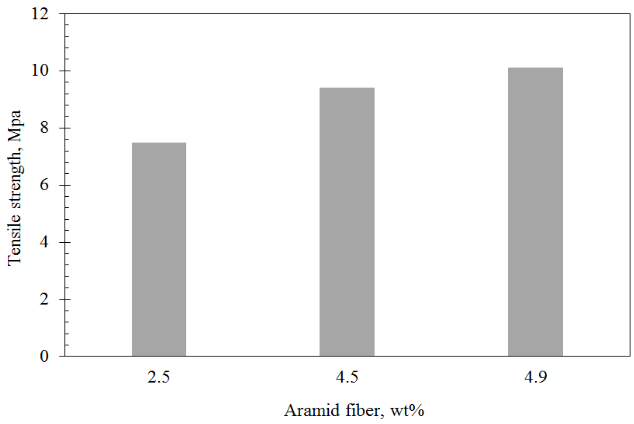

Figure 5: Tensile strength based on added aramid fiber.

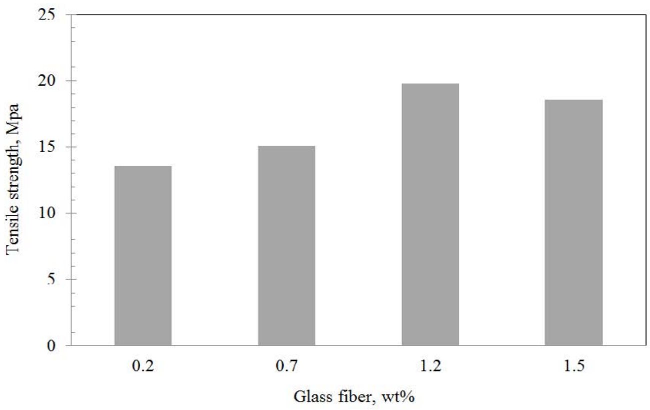

Figure 6: Tensile strength based on added glass fiber.

product uniformity. It was found that agglomerate size greatly increases when fibrous material is present in the slurry coagulate, and this was also related to fiber length. Figure 7 shows the compressibility and recovery results based on varying talc content. Compressibility decreased and recovery increased with added amounts of scales shaped talc particles as they enhance compactness when combined with fibers and other fillers. Test results based on varying amounts of aramid fiber glass fiber

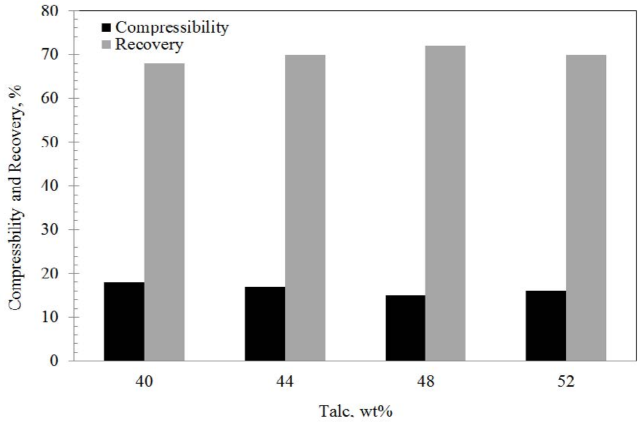

Figure 7: Compressibility and recovery based on added talc.

and talc content were tested without compromising the gasket's leakage properties, thus showing the optimum composition ratio for each raw material.

Table 2 is a comparison of property analysis results between the post-processed low density compressed sheets gaskets manufactured with the composition proposed in Table 1 and an existing product (JIC60110) that was manufactured using the current manufacturing process. As seen from the table, the average density of the sheet gasket made by the paper making process with optimum slurry agglomeration and bonding conditions is about 0.3 g/cm^3 lower, all the while showing improvements to nearly all properties including recovery, tensile strength, and oil resistance. In relation to these properties, the leakage rate in all areas was 0 cc/min after fastening the flange under N_2 pressure of 10 bar and different temperatures of 300°C, 320°C, 350°C for 1 hour each, exhibiting excellent gastight properties.

Comparison of gasket manufacturing processes

Table 3 compares the two gasket manufacturing processes. As shown in the table, gasket production using the paper making process is a very simple process involving mixing the raw materials before gasket forming. Meanwhile, the process using organic solvents includes swelling and mixing, with pre-processing periods that can run for over 24 hours. Therefore, the production of sheet gaskets by the paper making process can be advantageous in terms of work hours and recovery rates.

Figure 8 compares volatile organic compound concentrations (THC, ppmc) between the two processes during sheet gasket production. As shown in the figure, the current production process results in very high VOC concentration in the air due to the use of organic solvents in order to swell rubber. Thus, additional equipment is necessary to reduce VOC emissions during rubber swelling and raw material mixing. However, a sheet gasket manufacturing process that utilizes a paper making process does not utilize organic solvents, allowing for a clean and VOC-free environment to be maintained throughout the entire process. It is an eco-friendly process that dramatically improves the environment and is capable of protecting workers' health [17].

Conclusion

A paper making process that does not use any organic solvents during the production of low density compressed sheet gaskets composed mainly of raw materials such as latex, organic fibers, fillers and the like was used in this paper. The optimum slurry composition for

Item		Existing process (with Organic solvents)	Paper making process (without Organic solvents)
Density, g/cm^3		1.6~1.8	1.3~1.5
Compressibility, %		7~17%	8~13%
Recovery, %		35	79
Tensile strength, MPa		8~9	13~15
Oil resistance test (ASTM #3 Oil)	Tensile loss, %	20	12
	Thickness increase, %	6	10
	Weight increase, %	14	8
Creep relaxation, %		20	16
leakage, cc/min		0.04	0

Table 2: Property comparison between product using organic solvents (JIC6010) and product using paper making process (JGP20170919).

Manufacturing Method	Composition of the Process
Existing process (with Organic solvents)	Rubber mill → Swelling (solvents) → Mixture → Ripening → Forming compress → Layer compressing → Calendering
Paper making process (without organic solvents)	Mixture of raw materials → Forming → Drying → Rolling, Layer compressing → Calendering

Table 3: Comparison of gasket manufacturing processes.

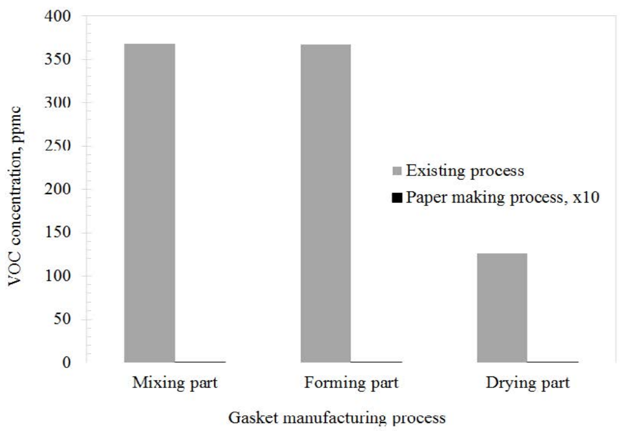

Figure 8: VOC concentrations from sheet gasket manufacturing using organic solvents and sheet gasket manufacturing using the paper making process.

the gasket was obtained through experimenting with the characteristics and amounts of each raw material. The addition of fiber reinforcement significantly improved tensile strength, but affected agglomerate size after a certain amount, reducing uniformity at the gasket forming phase. In addition, inorganic filler bonded well with the fiber materials, enhancing heat resistance, compression, and reparability. A gasket sheet of width 60 cm, thickness 0.8 mm, and length 180 m was continuously produced using 4 tons of the optimum composition slurry. This process showed excellent production results in all processes including forming, drying, and recovery of the gasket. Analysis of the characteristics of the produced gasket showed that all of the process yielded superior results compared to the manufacturing process that uses organic solvents.

The development of a low density compressed sheet gasket manufacturing process without using organic solvents, the important objective of this research, was achieved. There are absolutely no VOC emissions for all of the processes, and production efficiency is greatly improved, resulting in great advantages from an economic perspective. Reductions in atmospheric pollution and enhanced worker health through production environment improvements resulting from the industrial application of this research are eagerly anticipated for the future.

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