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Knit Fabric Making From Acrylic Yarn and Monofilament of Recycled Polycarbonate

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Abstract : Raw materials use polycarbonate and acrylic yarn. Polycarbonate an engineering plastic made from a condensation reaction of bisphenol A with phosphagen in alkaline media. (Mujiarto, 2005). Acrylic yarn that is carried out by a knitting process with a type of plain bondage has a stable dimension (Hurley, 1966). Polycarbonate is carried out by the melting spinning process. After that, acrylic yarn is carried out by knitting and inserted into polycarbonate monofilament. Fabrics from these raw materials are tested for moisture content & regained, thermal conductivity, infrared cameras, and broken resistance. Testing the moisture content and moisture regaining the monofilament insertion proves this second thing, ie the level is reduced.

Keywords: polycarbonate; anti-infrared; knit fabric

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1. Introduction

The development of textile technology is now propagating with raw materials sourced from plastic. Plastics are divided into two kinds of thermoplastics and thermosets, and among them are often used in the textile industry on thermoplastic types. Thermoplastics are a group of plastics that can melt when heated and harden when cooled. Characteristic thermoplastics, which lend material names, can be reversed. That is, it can be reheated, reshaped and frozen repeatedly. The types of plastics in the thermoplastic group are Polyethylene Terephthalate (PET), Polypropylene (PP), Polystyrene (PS), Polyethylene (PE), Polyvinyl-chloride (PVC), Polycarbonate (PC), Polyamides (PA), etc. The survey conducted by the Plastic Europe community, that the production of thermoplastics in the world in 2016 amounted to 280 million tons and 50% of that amount was in Asia (Europe, 2018).

Polymethyl methacrylate is commercially the most important member of a series of acrylic polymers which can be considered structurally as derivatives of acrylic acid. Groups of these polymers include polyacrylate, polymethyl acrylic, and important fiber-forming polymers, polyacrylonitrile. This polymer is a transparent material, microscopic and X-ray analysis shows that the material is generally amorphous (Brydson, 1999). PMMA, being the first transparent thermoplastic material, signaled the use of plastics materials as a substitute for optically transparent glass. Rohm and Haas were acquired in 2009 by The Dow Chemical Company (DOW). PMMA is a quasi-commodity thermoplastic resin that has excellent weather ability and clarity. (Trade names: Plexiglas, Lucite, Perspex, and Crystallite, etc.) (Ibeh, 2011). Acrylic yarn made by knitting with plain mesh has a stable dimension (Hurley, 1966).

Polycarbonate (PC) is an engineering plastic made from a condensation reaction of bisphenol A with phosphorus (phosgene) in alkaline media. (Mujiarto, 2005). Bisphenol A (BPA) is one of the highest production chemicals in the world. BPA is found mainly in polycarbonate plastic containers and aluminum can epoxy resin layers (Groff, 2010). Polycarbonate has a unique combination of characteristics such as optical clarity (it is amorphous and transparent), toughness (high impact strength), hardness, dimensional stability, ductility, high thermal resistance, and excellent electrical resistance. These attributes of PC lend it to use in a broad range of applications from typical household items such as eyeglass lenses and digital media (computer and music CDs, DVDs) to automotive and aerospace electronic equipment and accessories, scratch-resistant glazing, riot shields, and to medical devices and construction applications, used engineering thermoplastics, compact discs, riot shields, vandal proof glazing, baby feeding bottles, electrical components, safety helmets, and headlamp lenses. Polycarbonate containing bisphenol A has properties such as absorption of infrared. This was explained by (Thompson, Kraus, & Covington, 2008) in his journal entitled "Infrared absorption spectroscopy of Polycarbonate at high pressure". In the journal also explained that the frequency of infrared absorption was measured using the Grüneisen parameters. This infrared absorption can be applied to military textile clothing.

The current trends in PC's chemistry and applications occurred in the 1950s when Bayer and GE separately commercialized processes based on bisphenol A (BPA). Early productions were based on reacting phosgene with phenol to produce diphenyl carbonate (DPC), which was then reacted with BPA to produce the polymer; the generated phenol by-product was captured for reuse. However, this approach suffered from slow reaction rates and the need for several small-scale batch reactors.

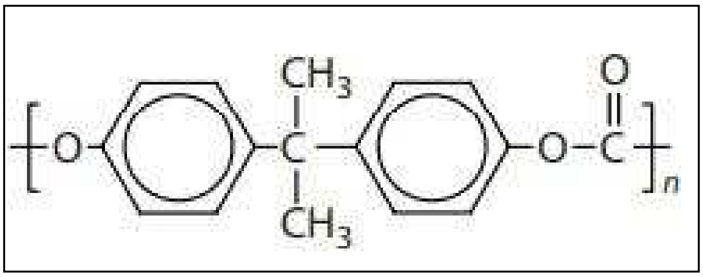

Figure 1. Chemical structure of polycarbonate.

The invention of PC resin is attributed to Daniel W. Fox of GE Polymers (now SABIC). Dr. Fox developed SABIC's Lexan PC in 1953 after his experimental work in the effort to develop a new wire insulation material [2]. Bayer AG, Germany was also working on PC, and in 1958 received the first U.S. Patent [3] on the interfacial phosgene method for making PC. Mobay (now Bayer America) followed with the next patent on PC. GE Polymers (SABIC) received its patent in 1960 on the transesterification process for PC, and also developed the interfacial phosgene process. NASA started using Lexan PC resin in its astronaut pressure helmet assemblies (Bubble Helmet) and visors for the history-making lunar landing. PC was introduced commercially in the early 1960s (Ibeh, 2011).

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Military textile has clothing needs in the form of soldier uniforms that have camouflage abilities. At present, the camouflage in the uniform only covers the visible and has an infrared spectrum that is close enough. Visual camouflage is obtained by printing on the fabric by adjusting the color to the background shades to be faced. However, some detectors can detect ultraviolet, near and far infrared, radar, and, seismic sectors (Adanur & Tewari, 1997). Therefore, a fabrication study was carried out using polycarbonate raw material. Based on the description of the background above, the title raised in this thesis is: "Making Knitted Fabric Using Monofilament from Polycarbonate and Acrylic Yarn"

2. Experimental

2.1. Materials

Fiber is a substance that is long, thin, and easily bent. Fiber length several hundred times wide. In terms of its constituent chemicals, textile fibers are composed of very large molecules, namely in the form of cellulose, proteins, thermoplastics or minerals. (Priowirjanto, 2001).

Fiber is the raw material used in making threads and fabrics. There are textile fibers made from raw materials sourced from nature or manufacturing or called synthetic fibers that are made chemically. All fibers have innate characteristics and characteristics of each fiber that are diverse, cannot be separated from the characteristics and have/have various kinds of properties (Noerati, 2013).The raw material used in this study is man-made fiber, which is fiber derived from polycarbonate waste raw material. Artificial fiber is a fiber that is made with the technology of making fibers, the raw materials of artificial fibers can be derived from natural sources such as cellulose or protein can also come from raw materials that must be synthesized first (Noerati, 2013).

2.2. Method

The spinning of artificial fibers in question is not spinning fibers into yarn, but the process of forming polymers into a form of fiber. The method used is generally known as the extrusion technique. In the method of forming polymers by extrusion, the liquid or polymer solution is pressed on a vessel so that it exits through a small hole called the spinneret. The spinneret is a hollow vessel similar to a filter with a very small hole diameter, generally with the size of each hole only a few microns. The process of making polycarbonate fibers uses a melting spinning process. Melting spinning is carried out if the polymer raw material is easily melted and not damaged by heat, after the melt of the polymer passes through the polymer spinneret it is cooled by cold air blowing (Noerati, 2013).

Raw materials for acrylic and polycarbonate are made into knit fabrics using a flat knitting machine. Knitting technology is one of the technologies used to make fabrics, in addition to using weaving and nonwoven technology. The structure of the knit fabric is formed by the threads that are joined together. The location of these snares is regular, which is a row. The row of entanglements towards the length of the fabric is called Wale (B-B), while the row of entanglements towards the width of the fabric is called Course (A-A) (Noerati, 2013). The acrylic yarn raw material is carried out by the knitting process and then inserted by monofilament fiber from polycarbonate. From the process, 3 variations were made, namely 100% acrylic, 1 polycarbonate acrylic, and 1 polycarbonate acrylic with the bond used, namely 1x1 RIB.

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Carbon thread is inserted into the fabric periodically every number of courses. In this way, the carbon thread is inserted between the entanglement of cotton thread, as well as inserting the weft thread in the weaving process. This process requires special techniques because insertion is still done manually. The position of the entrapment on the needle of the front needle bed and the rear bed needle facing each other allows the inserts to fit into the knit fabric so that the carbon thread is right between the threads of cotton thread (Siregar & Eriningsih, 2011).

3. Results

This study has several test results that will be compared between variations of 100% acrylic, 1 acrylic 1 polycarbonate, and 1 acrylic 2 polycarbonates. The fabric is subjected to moisture content & regain testing, thermography, and broken resistance. The results of the test are as follows.

3.1. Moisture Content and Moisture Regain

This test is conducted to determine the moisture content in the three variations of fabric that have been made. This test uses SNI 8100: 2015 Textiles - Test method for moisture content (moisture content or moisture regain). The following are the tools and materials used and the method of testing carried out according to the SNI.

3.1.1. Tools and Materials

Tools and materials used in accordance with SNI 8100:2015 Textiles - The method for testing moisture content (moisture content or moisture regain) is as follows :

- Oven
- Weigh Bottle
- Analytical Balance
- Knit Fabrics

3.1.2. Test Method

Test methods carried out in accordance with SNI 8100: 2015 Textiles - The method for testing moisture content (moisture content or moisture regain) is as follows:

- Preheat the weighing bottle with the sharpening lid separately in the oven at a temperature of 105 ° C to 110 ° C for one hour.
- After heating for one hour, move the weighing bottle closed to the desiccator and allow it to cool to room temperature.
- Open the sharpening lid briefly to equalize the air pressure inside the weighing bottle. Then weigh it closed.
- Reheat the weighing bottle and cover it in the oven at a temperature of 105 ° C to 110 ° C for 15 minutes, then transfer it to the desiccator, let it cool and weigh. If the difference in weight of the weighing bottle twice in a row is not more than 0.1%, it is called fixed weight.
- Enter test samples that are already in standard conditions into weighing bottles,

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- close and weigh. This weight minus the weight of the weighing bottle (9.d) is the air dry weight of the test sample, called A.
- Place the weighing bottle containing the test sample open in the oven at a
- temperature of 105 ° C to 110 ° C for one hour
- Weigh the bottle cap and transfer it to the desiccator. After reaching room temperature, open the bottle weigh a little to equalize the air pressure. Then close again and weigh.
- Reheat the weighing bottle containing the test sample into the oven at a
- temperature of 105 ° C to 110 ° C for 15 minutes, then transfer it to the desiccator, let it cool and weigh. If the weighing difference is not more than 0.1%, it is called fixed weight. This weight minus the weight of the weighing bottle (9.d) is the oven-dry weight of the test sample, called B

3.1.3. Test Result

Testing the three fabric variations using testing standards namely SNI 8100: 2015 Textiles - The method for testing moisture content (moisture content or moisture regain) is in the following Table 1.

Table 1. Data of Moisture Content and Moisture Regain Result

Fabric Variation	Moisture Content	Moisture Regain
Acrylic 100%	0.010652%	0.010768%
1:1(Acrylic:Polycarbonate)	0.007113%	0.007164%
1:2(Acrylic:Polycarbonate)	0.004409%	0.004428%

3.2. Determination of Mass Per Unit Area

This test has two test methods, namely testing using fabric weight per unit length and weight of fabric per unit area based on ISO ISO 3801: 2010. Based on SNI ISO 3801: 2010 the method of testing the weight of the fabric per unit length and weight of the fabric per unit area is a revision of SNI 09-0274-1999 the method of testing the dimensions and weight of the fabric. SNI ISO 3801: 2010 originally contained a method for testing the length, width, and weight of the fabric.

3.2.1. Tools and Materials

Tools and materials used for the test is as follows :

- Cutter
- Metallic Ruler
- Metal Plate
- Table
- Analytical Balance
- Knit Fabric

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3.2.2. Test Method

Test methods carried out in accordance with SNI ISO 3801: 2010 Textiles – Determination of mass per unit length and mass per unit area is as follows:

- Cut the 10x10 cm fabric in parallelogram so that the fabric of the knit fabric is not separated.
- Measure the mass of cutted fabric.
- Record the test results on the fabric.

3.2.3. Test Result

Fabrication testing is carried out to determine the weight of the fabric in area units, gram/m2. For the results of testing of the three variations of the fabric are in Table 2 as follows.

Table 2. Data of mass per unit area

Fabric Variation	Mass
Acrylic 100%	274.7667 gram/m^2
1:1(Acrylic:Polycarbonate)	322.2333 gram/m^2
1:2(Acrylic:Polycarbonate)	327.5333 gram/m^2

3.3. Thermography Test

This test is carried out using two intermediate media namely heating media and human media. The following are the tools and materials as well as the work steps taken in the test.

3.3.1. Tools and Materials

Tools and materials used in thermography test is as follows :

- Smartphone with installed flir one application
- Flir one infrared camera
- Knit fabric sample

3.3.2. Test Method

The work steps taken in the test are as follows:

- Prepare a smartphone that has the flir one application installed.
- Connect the flir one camera to the smartphone that has the flir one application installed, then turn on the flir one camera.
- Place the test sample cloth on the media provided (heater or human).
- Then take a picture of the cloth using the installed flir one camera.

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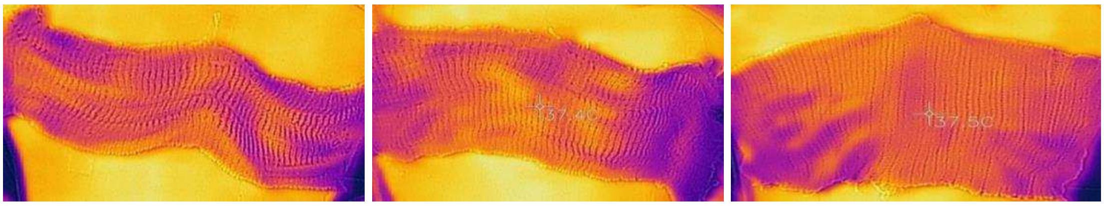
3.3.3. Test Result

Visual testing using infrared cameras is done to determine the ability of polycarbonate which has anti-infrared properties. The following are temperature data which is muted by samples with humans in the table 2.

Table 3. Data of Reducing Temperature

Fabric Variation	Temperature Reduced
Acrylic 100%	2.167^{0}C
1:1(Acrylic:Polycarbonate)	2.333^{0}C
1:2(Acrylic:Polycarbonate)	2.767^{0}C

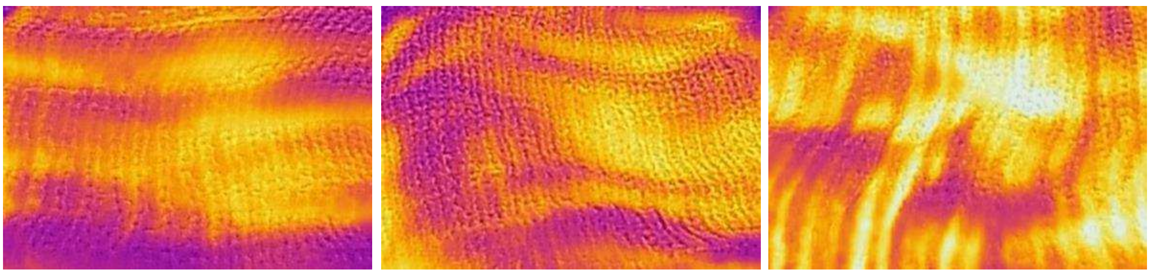
The following is an image taken using an infrared camera using the human back in Figure 1.



(a) (b) (c)

Figure 2. Thermography test on human back from 3 variation of knit fabric : (a) acrylic knit fabric with 2 sheet polycarbonate insertion; (b) acrylic knit fabric with 1 sheet polycarbonate insertion; (c) acrylic knit fabric without polycarbonate insertion.

The following is an image taken using an infrared camera using heater with 68^{0}C temperature in Figure 3.



(a) (b) (c)

Figure 3. Thermography test on heater with 680C temperature from 3 variation of knit fabric : (a) acrylic knit fabric with 2 sheet polycarbonate insertion; (b) acrylic knit fabric with 1 sheet polycarbonate insertion; (c) acrylic knit fabric without polycarbonate insertion.

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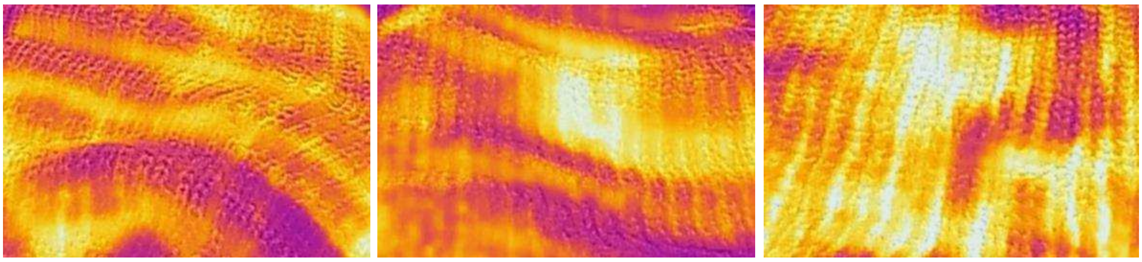
The following is an image taken using an infrared camera using heater with 680C temperature in Figure 4.



(a) (b) (c)

Figure 4. Thermography test on heater with 1000C temperature from 3 variation of knit fabric : (a) acrylic knit fabric with 2 sheet polycarbonate insertion; (b) acrylic knit fabric with 1 sheet polycarbonate insertion; (c) acrylic knit fabric without polycarbonate insertion.

3.4. Bursting Strength Test

Bursting strength test for the fabric variation are applied to SNI 08-0617-1989 with the following tools and materials and work steps.

3.4.1. Tools and Materials

Tools and materials used in accordance with SNI 08-0617-1989 is as follows :

- Bursting strength tester
- Knit fabric test sample
- Cutter

3.4.2. Test Method

The work steps of fabrication testing in accordance with SNI 08-0617-1989 are as follows:

- Adjust the diaphragm on the tool until evenly distributed by removing the pressure. Every test starts, the needle scale must be in the zero point position.
- Clamp the test sample.
- Increase the pressure on the rubber diaphragm at a steady pressure rate until the fabric breaks / breaks.
- Remove the pressure after the cloth has broken down. Record numbers on a scale up to the nearest hundred grams.

3.4.3. Test Result

Fabric breakdown testing is carried out to determine the maximum pressure produced to break down the knit fabric. For the results of testing of the three variations of the fabric are in Table 3 as follows.

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Table 4. Data of Bursting Strength Test

Fabric Variation	Temperature Reduced
Acrylic 100%	77.03 N
1:1(Acrylic:Polycarbonate)	87.69 N
1:2(Acrylic:Polycarbonate)	96.21 N

4. Discussion

In this section of the journal we will discuss the results of the tests that have been carried out, and also we will compare it with the literature that we have.

4.1. Moisture Content and Moisture Regain

There are differences in the results of humidity in the variations of 100% acrylic, 1 acrylic 1 polycarbonate, and 1 polycarbonate 2 acrylics. The effect is that the more monofilament is inserted into the acrylic knit fabric, the lower the moisture content and moisture regain. So, from the three variations, it can be concluded that the insertion of monofilament polycarbonate can reduce the percentage of moisture content and moisture regain in Figure 5 as follows.

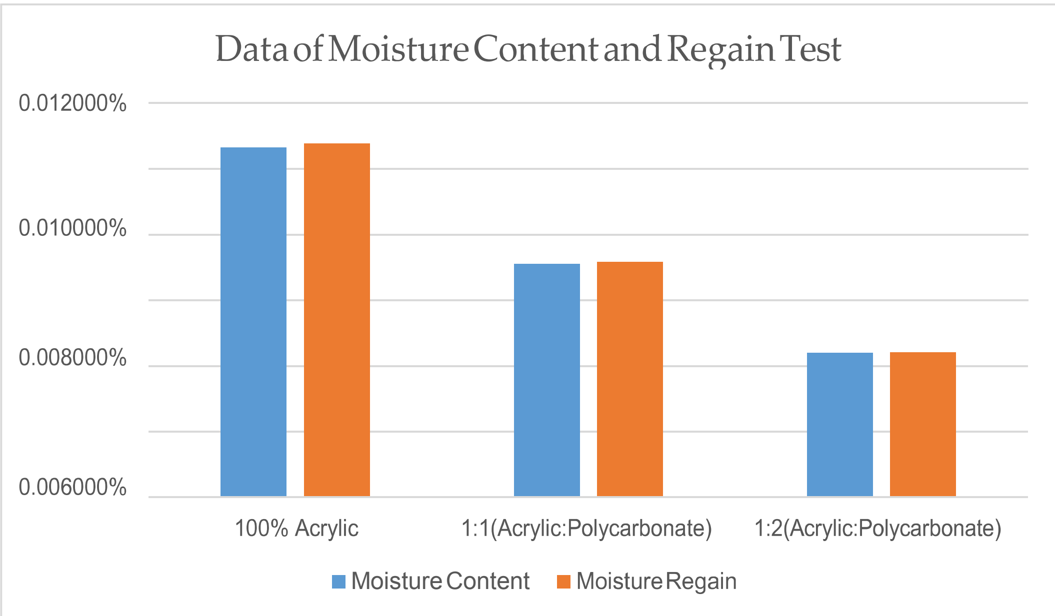

Figure 5. Chart of the moisture content & regain test

4.2. Determination of Mass per unit area

Tests of fabric grading on all three variations of the fabric were carried out to determine the weight of the fabric of broad unity. According to Chang The more material, the greater the mass (Chang, 2003). It can be seen from the picture that the more insertion of polycarbonate fibers in knitted fabrics, the acrylic knit fabric will also increase in weight. As quoted by Leo, the density of acrylic is 1.18 g / cm3 while for polycarbonate is 1.2 g / cm3 (Leo, 2010), therefore the addition of polycarbonate can add weight to the fabric. Test results obtained following the literature above in Figure 6 as follows.

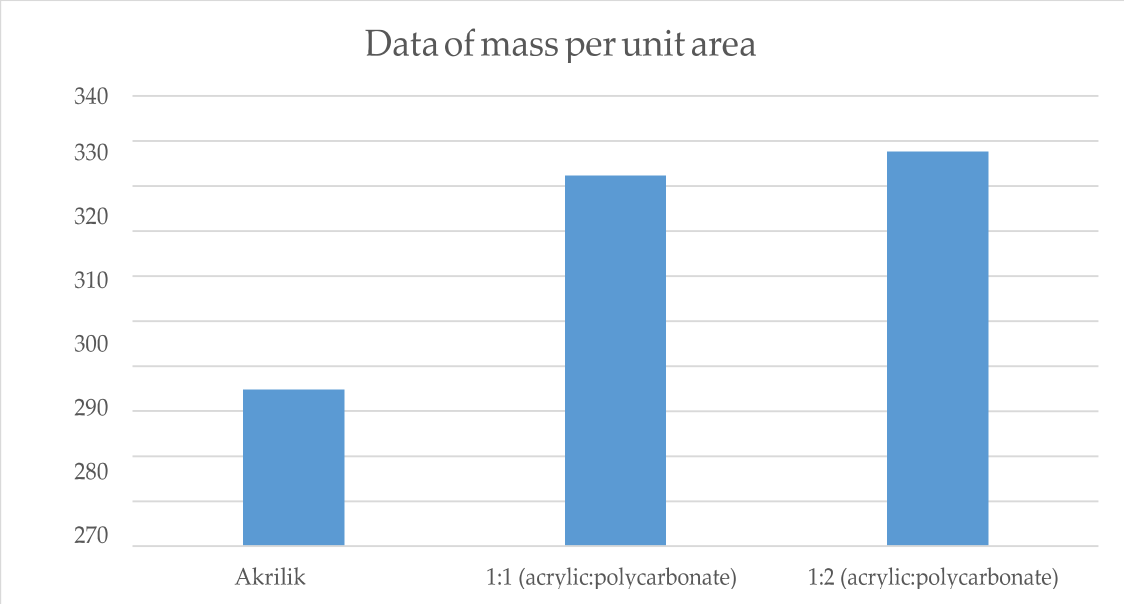

Figure 6. Chart of mass per unit area

4.3. Termography Test

In Figure 7 can be seen that the more fiber is inserted, the greater the temperature is reduced. Following the literature according to Iman Mujiarto polycarbonate has low flammability (Mujiarto, 2005). Polycarbonate (polycarbonate) is an engineering plastic made from a condensation reaction of bisphenol A with phosphorus (phosgene) in alkaline media. (Mujiarto, 2005). Bisphenol A (BPA) is one of the highest production chemicals in the world. BPA is found mainly in polycarbonate plastic containers and aluminum can epoxy resin layers (Groff, 2010).

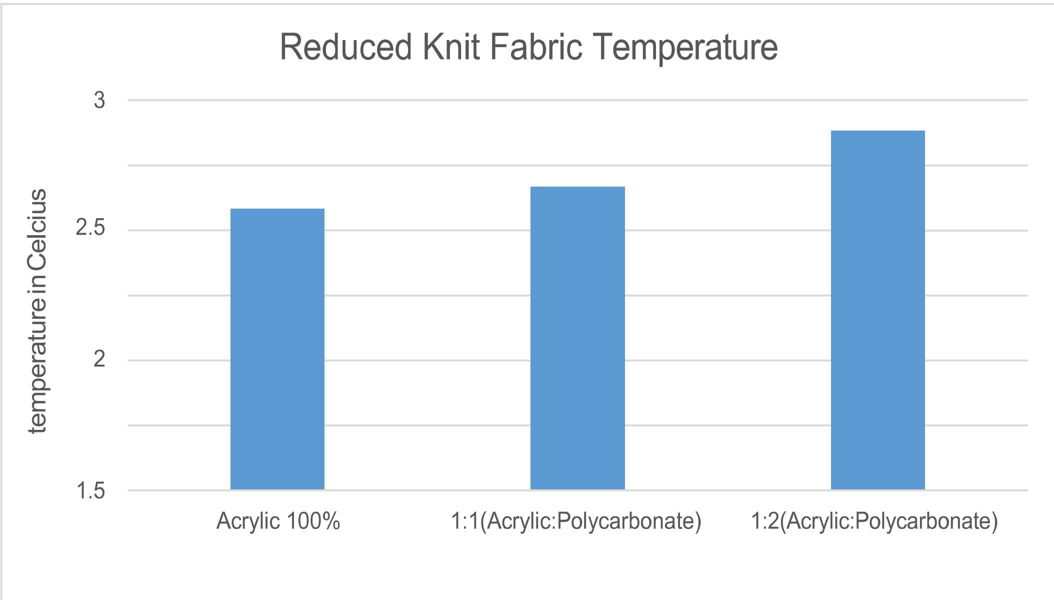

Figure 7. Chart of reduced knit fabric temperature

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4.4. Bursting Strength Test

In bursting strength test is to determine the maximum pressure needed to break down the knit fabric. In the test, the results of the test are obtained with the chart in Figure 8. In Figure 8 it can be seen that the more fiber insertion in the knit fabric, the greater the power needed to break down the knit fabric. This is caused by the presence of polycarbonate fibers that are between the entanglement of knit fabrics. According to Mujiarto polycarbonate has good impact strength properties (Mujiarto, 2005).

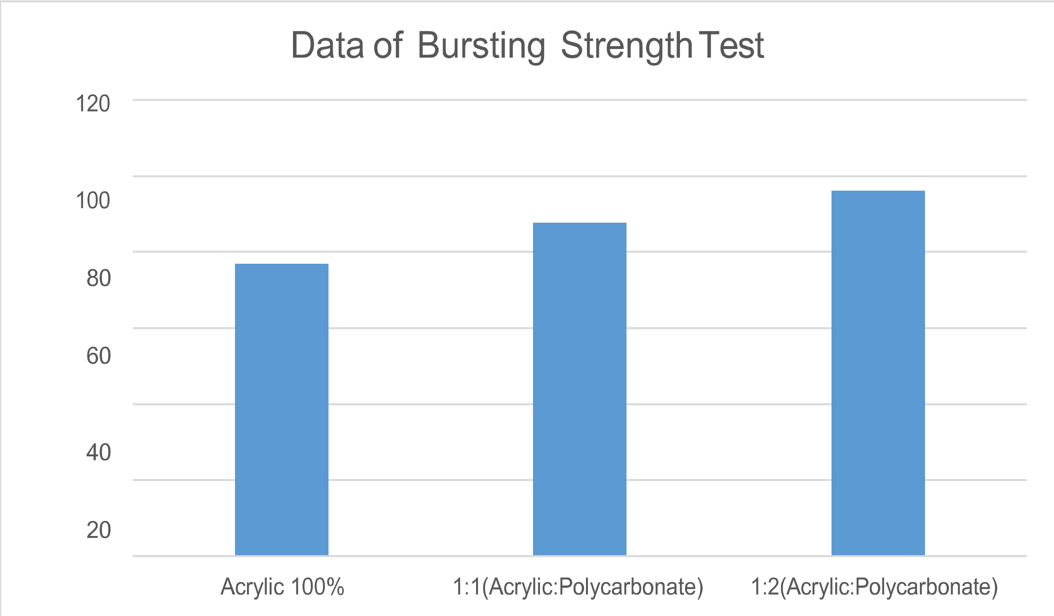

Figure 8. Chart of reduced knit fabric temperature

5. Conclusion

Knitted fabrics made of acrylic yarn can be inserted polycarbonate monofilament during the knitting process using a flat knitting machine. The knit fabric is carried out for moisture content & regain test, mass per unit area test, and also bursting strength test to give the information of humidity, mass, and strength of the fabric. The thermography test is to prove the character of the polycarbonate monofilament. The visual result of the thermography test is the more polycarbonate monofilament was inserted on the fabric the darker the result was. The result of reduced temperature is the more polycarbonate monofilament was inserted on the fabric temperature will more reduce.

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