Oil palm frond fibers pulp from kraft pulping process–effect of beating

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Abstract. The main objective of this research is to determine the effect of beating to physical, mechanical and optical properties of the paper. The pulp that is used in this research is pulp from Oil Palm Frond (OPF). Pulping method that was carried out in this research is the kraft pulping which was undergo in 4 different conditions (20% NaOH: 20% Na_2S; 20% NaOH, 30% Na_2S; 30% NaOH, 20% Na_2S and 30% NaOH, 30% Na_2S). The beating process is carried out using PFI Mill Beater and five amounts of beating were imposed to each pulp (0, 250, 500, 750 and 1500 rotations). From the result obtained, the freeness (CSF) of the pulp was decreased against the increasing amount of beating. The optimum amount of beating is at 1500 rotations for tensile strength (5981.1 N/m), bursting strength (660.72 kPa) and folding endurance (915). For tearing resistance (730.23 mN), the optimum amount of beating is at 250 rotations. Beating also contributes to reduce the brightness and the opacity too. The result show that suitable beating stage for kraft OPF pulp is at 1500 rotations, because almost all testing give optimum or closely to optimum result at this amount of beating.

Key words: Oil palm frond fibers, Kraft pulping, yield, tensile index, tear index, brightness.

Introduction

In the past decade the global consumption of paper and board augmented from 237.11 million tones in 1990 (Anon, 1991) to 323.38 million tones in 2000 (Anon, 2001), an increase of 86.27 million tones. This figure is expected to rise further with the increasing world population, and improved literacy and quality of life worldwide. The continued high growth in paper consumption will lead to increased demand for fiber, creating additional pressure on the world's diminishing forest resources. Meanwhile, the paper industry is also constantly facing mounting resistance from the conservationists and environmental groups. To maintain the paper industry growth, governments as well as industry executives have to establish and implement policies and plans to ensure a sustainable fiber supply, including reforestation program, plantation management, recycling, and development of non-wood fibers.

The ever-increasing manufacturing costs and uncertainty in wood supply in some regions due to restrictions on logging and inadequate forest resources have caused increasing concerns over future fiber supplies. Many North American and European papermakers are searching for alternative fiber sources such as non-wood plant fibers. Within the mixed portfolio of non-wood fibers, oil palm (*Elaeis guineensis*) is one that shows great potential as a papermaking raw material, particularly for Indonesia and Malaysia (Fuad et al., 1999). Oil palm is vastly cultivated as a source of oil in West and Central Africa, where it originated, and in Malaysia, Indonesia and Thailand. In Malaysia, oil palm is one of the most important commercial crops.

The explosive expansion of oil-palm plantation in these countries has generated enormous amounts of vegetable waste, creating problems in replanting operations, and tremendous environmental concerns. It is reported that Malaysia alone produced during the recent past years about 30 million tones annually of oil-palm biomass, including trunks, fronds, and empty fruit bunches (Anon., 1997). Estimation (Lim, 1998) based on a planted area of 2.57 million ha, and a production rate of dry oil-palm biomass of 20,336 kg/ha/yr, shows that Malaysian palm oil industry produced approximately 52.3 million tones of lignocellulosic biomass in 1996.

This figure is expected to increase substantially when the total planted hectarage of oil palm in Malaysia could reach 3.151 million ha in 2000 (Chan, 1999), whilst in Indonesia the projected availability of oil-palm solid wastes for 2000 was about 24.5 million tones (Lubis et al., 1994). Malaysia, in 2000, produced an estimated 56.9 million tones of oil-palm biomass (Chan, 1999). Taking into account the proportion of useful fibrous elements that can be extracted from various oil-palm components, an overall recovery rate of 75% and a pulp yield of 45%, the net useful pulp would amount to about 14.8 million tones. The purposes of this research is to study the effect of beating in papermaking process to the properties of paper. to compare the effect of beating in papermaking process by divided the sample (pulp) into 5 different beating conditions (0, 250, 500, 750 and 1500 rotations). to produce paper from Oil Palm Frond (OPF).

Materials and Methods

Materials

Oil palm frond samples were obtained from the palm oil mill PT Fajar Baizury, Aceh Indonesia. These fronds were cut at an approximate length of 2 inch and were dried before used.

Pulping

All cooks were carried out in a 4-liter stationary stainless steel digester (without external circulation mixing) manufactured by NAC Autoclave Co. Ltd., Japan, fitted with a computer-controlled thermocouple. Pulping method that was carried out in this research is the kraft pulping which was undergo in 4 different conditions (20% NaOH: 20% Na_2S; 20% NaOH, 30% Na_2S; 30% NaOH, 20% Na_2S and 30% NaOH, 30% Na_2S). The beating process is carried out using PFI Mill Beater and five amounts of beating were imposed to each pulp (0, 250, 500, 750 and 1500 rotations).

Results and Discussion

Analysis of physical properties of paper

Density is an important basic parameter to determine the paper properties. It influence by the porosity, rigidity and the mechanical properties of the paper. Because paper is composed of a randomly felted layer of fiber, it follows that the structure has a varying degree of porosity. Thus, the ability of fluids, both liquid and gaseous, to penetrate the structure of paper becomes a property that is both highly significant to the use of paper. Since the thickness have great influence to the density, the greater the beating rates, the lower the thickness thus the higher density for the beaten pulp. Figure 1 below show the density of paper produced.

Referring from Figure 1, it shows that density of paper produced is increase as the beating increase. Paper with no beating has the lowest density and paper which undergoes 1500 beating has the highest density.

Density will increase if there are more bonds between the fibers. Beating makes the fibers become shorter and finer. These short fibers will bond one with another easily because of more surface area, so that paper that produced becomes denser and pack. The existence of fines will fill the porosity between the fibers that increase the bonding between the fibers and also increase the density.

Analysis of mechanical properties of paper

Analysis of tensile strength

Tensile strength is determined by measuring the force required to break a narrow strip of paper where both the length of the strip and the rate of loading are closely specified. The amount of stretch at rupture may be determined at the same time. The tensile strength need to covert to tensile index by divide the strength with grammage, so that we get more accurate value without influence by different grammage of handsheet.

The testers provide a plot of the stress/strain curve and compute the area under the curve which is referred to as tensile energy absorption (TEA), a measure of paper toughness. TEA can be increased by increasing the tensile or increasing the stretch. Figure 2 below show the tensile strength of paper produced.

According to Figure 2, we can see that tensile strength of paper produced is increase as the beating increase. Paper with no beating has the lowest tensile strength and paper which undergoes 1500 beating has the highest tensile strength.

Tensile strength increases because there is more amount of bonding between the fibers. Increased bonding caused by increased beating will increase the tensile strength. There is a linear relation between the tensile strength of paper and the area of fibers in optical contact in the early stages of beating. The relation is the same regardless of whether the area of fiber contact is varied by increased beating, thus indicating the fundamental importance of fiber bonding.

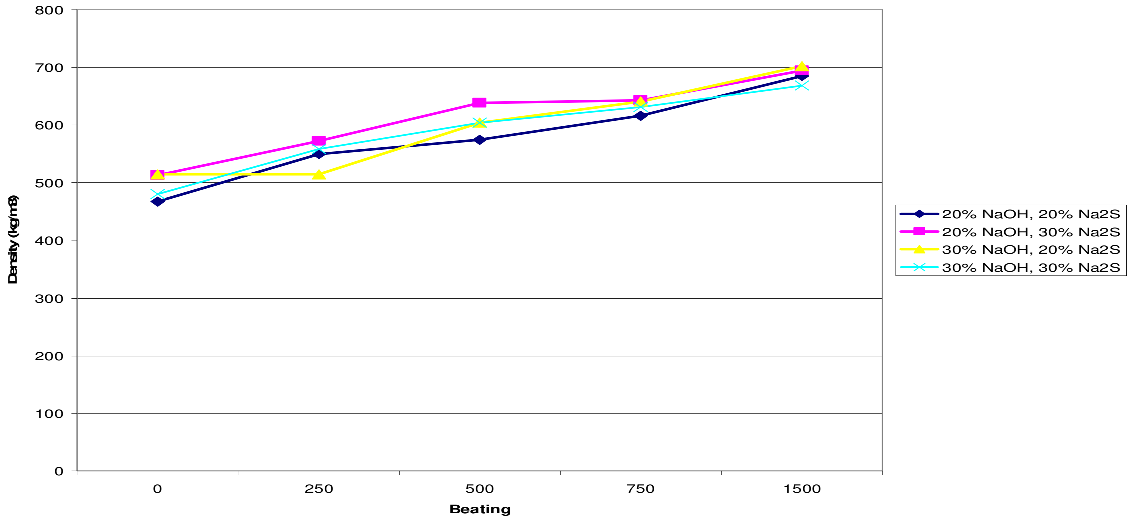

Figure 1. Graph of density versus beating condition.

The quantity and the amount of the fiber bonding are the most important factors that affecting the tensile strength of the hand sheet. The tensile strength increases with the increasing of the fiber bonding. The tensile strength has a linear relationship with the optical contact of fiber. The increase of beating make the fibers become more flexible and conformable which in turn provides for more area to be developed for bonding along the fiber’s length. Therefore, tensile strength, being dependent upon the formation of fiber-to-fiber bonds, is greatly influenced by fiber length and cell wall thickness. That is, in the unbeaten sheet the bonded areas formed are fewer and weaker than those formed in a sheet from beaten fibers. The bonds are, however, sufficient to hold the fibers while the fibers themselves stretch by an amount dependent on fibril angle to a point at which the load can no longer be maintained by the bonded network. In a beaten sheet a greater number of bonded areas and bonds are formed than in an unbeaten sheet.

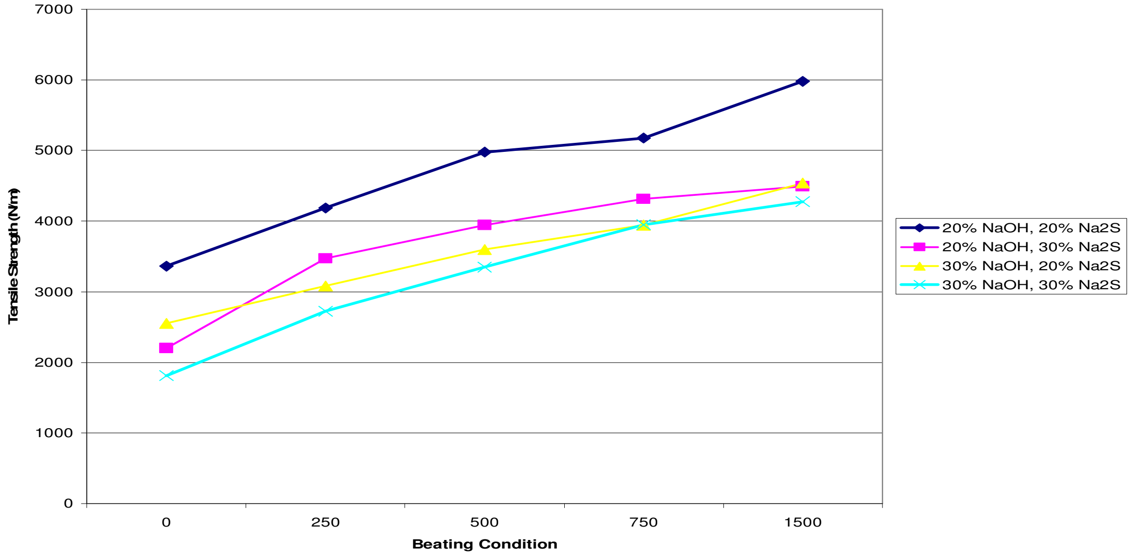

Figure 2. Graph of tensile strength versus beating condition.

Analysis of bursting strength

Bursting strength tells how much pressure paper can tolerate before rupture. It is important for bag paper. Bursting strength is measured as the maximum hydrostatic pressure required to rupture the sample by constantly increasing the pressure applied. Bursting strength depends on basis weight of paper. Figure 3 below show the bursting strength of paper produced.

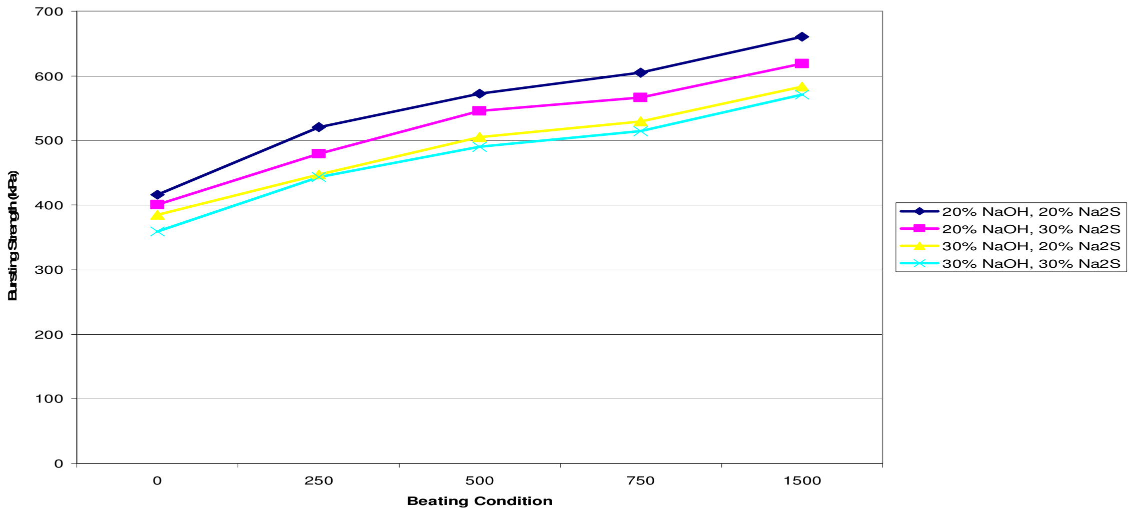

Figure 3. Graph of bursting strength versus beating condition.

From figure 3, it shows that the bursting strength of paper produced is increase as the amount of beating increase. Paper with no beating has the lowest bursting strength and papers which undergo 1500 beating have the highest bursting strength.

Bursting strength of paper produced is increase as the amount of beating increase too. Increased fiber length makes for a higher bursting strength, but bursting strength even more affected by fiber bonding. Beating increases the bursting strength over most of the range. However, a decrease in bursting strength occurs with excessive beating.

Analysis of tearing resistance

Tearing resistance indicates the behavior of paper in various end use situations; such as evaluating web runnability, controlling the quality of newsprint and characterizing the toughness of packaging papers where the ability to absorb shocks is essential. Fiber length and interfiber bonding are both important factors in tearing strength. The fact that longer fibers improve tear strength is well recognized. The explanation is straight forward; longer fibers tend to distribute the stress over a greater area, over more fibers and more bonds, while short fibers allow the stress to be concentrated in a smaller area. High tear strength results from such paper properties as a high fiber length, a low degree of beating, a high grammage, and a high thickness. Tear strength is affected by the grain (fiber orientation) of machine made papers, it being lower in the machine direction than in the cross-machine direction. Figure 4 below show the tearing resistance of paper produced.

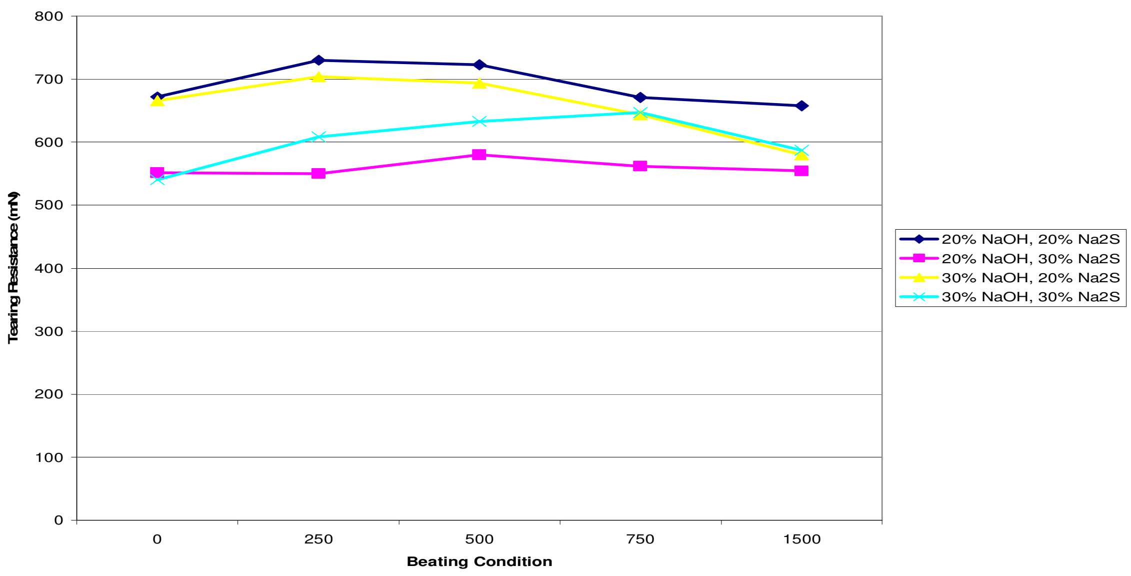

Figure 4. Graph of tearing resistance versus beating condition.

According to Figure 4 we can see that the tearing resistance of paper produced is increase after some of beating amount, but after that, more amount of beating will make the tearing resistance decrease.

The tearing resistance of paper made from an unbeaten pulp is almost entirely due to work involved in overcoming the frictional resistance of the fibers being pulled from the paper; there is practically no tearing of the fibers, and since the total area of fiber contact is small the frictional resistance is low. After a slight amount of beating, interfiber bonding is increased and the tearing resistance is greater because of the increased frictional resistance in pulling fibers out of the paper.

As beating is further increased, the fibers no longer slip past one another readily; consequently, there is an increase in the number of fibers that are ruptured in tension. The action then becomes more nearly a shearing action than a pulling one, and since the work involved in rupturing a fiber is much less than the energy involved in pulling a fiber out of the sheet, the energy required to tear the sheet decreases. Stated differently, the sheet increases in cohesion and stiffness as a result of beating, and this tends to concentrate the tearing force into a smaller area, with the result that lower tearing values are obtained. This explains why tearing resistance steadily decreases on beating after an initial increase.

Analysis of optical properties of paper

Analysis of brightness

Brightness is defined as the percentage reflectance of blue light only at a wavelength of 457 nm. Brightness is not whiteness. However, the brightness values of the pulps and pigments going into the paper provide an excellent measure of the maximum whiteness that can be achieved with proper tinting. Brightness is usually reflected as the lightness or the reflectivity of paper. Figure 5 below show the brightness of paper produced.

From figure 5 it shows that the brightness of paper produced is decrease as the amount of beating increase. Paper with no beating has the highest brightness and paper which undergoes 1500 beating has the lowest brightness.

This maybe is due to the increasing of density from increase the beating process, so that results the fibers are more pack together. But every fiber's brightness is different because their lignin content is different. Because paper is composed of a randomly felted layer of fiber it follows that the structure has a varying degree of porosity. Thus, this will influence the ability of the reflectance of light from white paper or almost white at a single wavelength in blue region of visible spectrum.

As we know, the brightness of pulp is an important factor. So that the uneven whiteness of fibers pack together will reduce the brightness of papers when increasing of density, unless every fiber has the same whiteness, then it will increase the brightness. This due to the brightness is sometimes used as measure of whiteness. Although the whiteness is dependent on both the total reflectance and the uniformity of the reflectance, the uniformity of whiteness is much more important than the total reflectance.

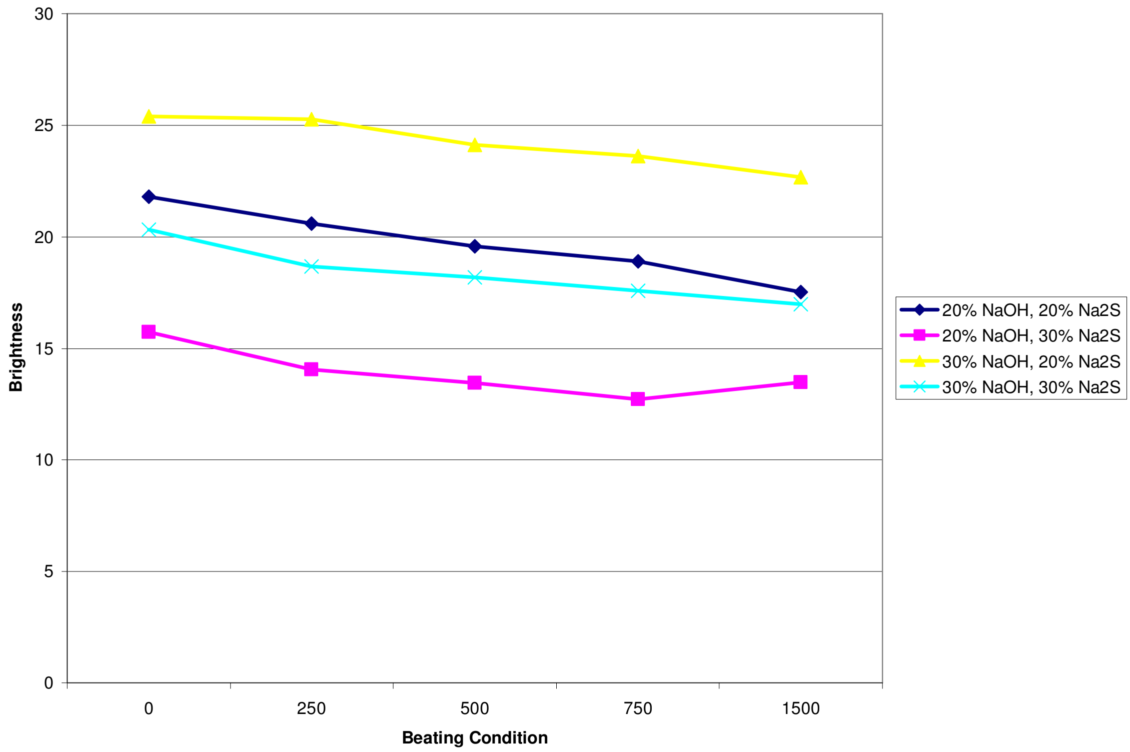

Figure 5. Graph of brightness versus beating condition.

Actually the amount of beating is less effect on the brightness of paper, unless the addition of filler needs high beating level to produce the higher brightness.

Analysis of opacity

Opacity is calculated as the ratio of the apparent reflectance of one sheet of paper with a black backing to the apparent reflectance of the sheet with a white backing. A sample whose reflectance is not changed by changing its backing from white to black will have opacity of 100 and a sample whose reflectance changes from a high value to zero by changing the backing from white to black will have opacity of zero. The opacity of paper is influenced by thickness, amount and kind of filler, degree of bleaching and coating etc. Figure 4.10 below show the opacity of paper produced.

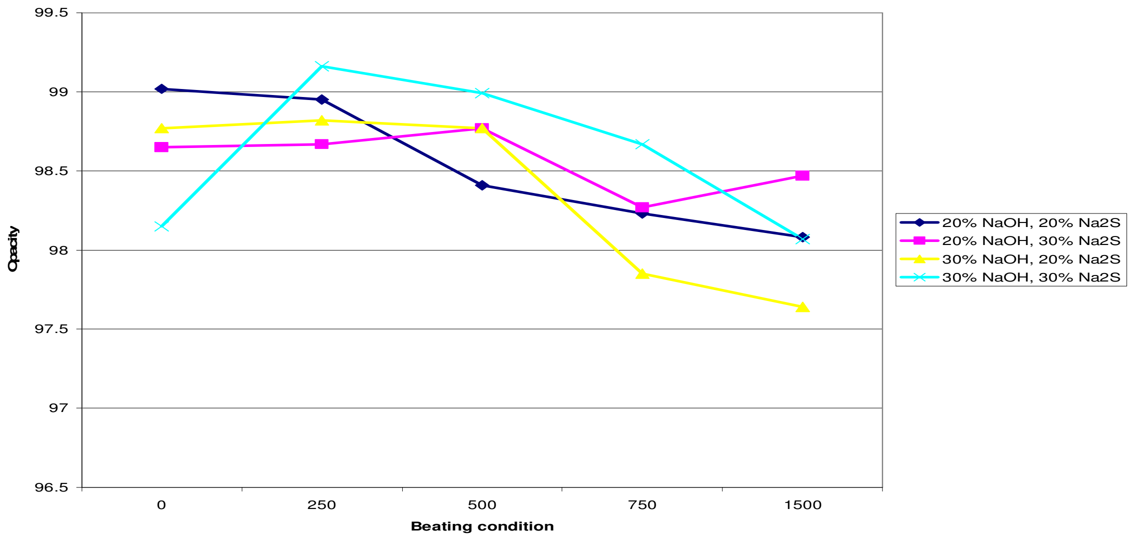

Figure 6. Graph of opacity versus beating condition.

According to Figure 6, we can see that the result of opacity is not in constant line; sometimes it will increase and also decrease. But most of the graph shows that the opacity decrease as the amount of beating increase.

Usually paper is not homogeneous since it made up of individual fibers separated by air spaces although the cellulose can absorbs very little light. Any decrease in scattering indicates an increase in bonding and increase the optical contact. When pulp is beaten, two things occur that have opposite affects on the opacity.

Conclusions

The conclusion from the research is that the beating process will change the properties of paper produced, such as physical, mechanical and optical properties. The beating process makes the paper have a better quality by increasing the strengths of paper from Oil Palm Frond (OPF). But, if the beating process comes to excessive amount, it will make the paper lose its strength (intra-fiber bonding become weaker). This is due to the fibers become too short and can not give any strength to the paper produced. To produce the best quality and properties of paper, the optimum amount of beating should be known.

From the result obtained, it shows that the beating process make changes to physical properties of paper produced For mechanical properties of paper produced, it will increase the tensile strength (5981.1 N/m), bursting strength (660.72 kPa) and folding endurance (915). Exception for tearing resistance (730.23 mN), it will increase until some amount of beating but will decrease if the beating process still continues. It is also found that the brightness and opacity of paper produced is decrease as the amount of beating increase.

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