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PERFORMANCE EVALUATION OF SMALL-SCALE PAPER RECYCLING SYSTEM

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Abstract

In a bid to address the challenge of raw materials scarcity and high cost of pulp production from the log, the recycling of waste paper is drawn into focus. The design and fabrication of a hydropulper and agitator unit had been carried out earlier. This study however limits its scope to the performance evaluation of the various units and production of pulp sheets from waste paper using the fabricated machines. It required about 16litres of water to disintegrate 1kg of wastepaper. Performance tests showed that 50mins was adequate for effective fibre disintegration. Fibre length at the end of 50mins was 1.8mm.The fibre thickness was 0.03mm at the end of 50mins.The units can produce about 3.8kg of recycled paper from 5kg of waste paper. The consistency of slurry employed for sheet formation was between 2-3%.The average thickness of pulp sheets produced was 2mm.The properties of the slurry from the hydropulper were similar to those from the paper mill factory. Average weight of pulp sheets produced without a screw press was 215g.The performance of the machines was considered to be satisfactory.

Keywords: Pulp slurry, fibre length, Hydropulper, Agitator,Waste paper

INTRODUCTION

Recycling waste paper to produce paper has alleviated the problem of raw materials to an extent. Hence the objective of this study was to evaluate the performance of paper recycling machines designed and fabricated in Nigeria. Ahydropulper and agitator that had beendesignedearlier were used to generate slurry from waste paper. Pulp sheets were then produced from the slurry generated.

Most industrialized nations practise paper recycling with the United States recycling about 47 billion kilogrammes annually. This means that there is about 8 billion dollars worth of paper that can be collected and recycled each year (Georgia-Pacific, 2005).Australians use almost 3.3 billion kilogrammes of paper in 1995, with almost 1.4 billion kilogrammes of waste paper collected for recycling (Amcor, 2005). In 1996, over 330,000,000 kilogrammes of old Australian newspapers were recycled both in Australia and overseas into a variety of products including newsprints, cardboard, packaging materials, insulation boards for housing and animal bedding (NRF, 2005). Paper recycling in Nigeria is practiced in the production of tissue paper and serviette. Epesok Paper Mill which commenced operations in 1989 is one of the paper recycling companies in Nigeria and utilizes 70% waste paper as raw materials (Komolafe, 2005).

The Fourdrinier machine comprises the major sheet forming machine normally employed in the manufacture of all grades of paper and board (Wahistrom, 1970).A standard sheet forming machine was used to produce test sheets from pulp in 1958 by the Technical Association of Pulp and Paper Industry (TAPPI, 1958). Ologunleko and Onilude (1998) fabricated a laboratory sheet forming machine to form handsheets for physical properties tests of paper. The machine has a top cylinder funnel, grid plate, stirrer and drainage pipe. The sheet former employed in this study was similar.The disintegration of waste paper to form slurry takes place during stock preparation and various equipments have been designed and modified over the years. (UNIDO,1986).

The paper breaker originally first built in 1600 Holland was a high density pulping machine (GIT, 2004).The operation involves the breaker being filled with water to a given level and the roll is revolved. The projecting blades of the rotor create turbulence which breaks up the pulp or waste paper (GIT, 2004). The more common and widely used disintegrator is the hydropulper which consists of an open cylinder in which an impeller revolves. The impeller has projecting blades on the surface which creates maximum turbulence within the vessel. The vessel has a false bottom while the inner bottom has drilled holes which permit the removal of pulp after disintegration. Pulping process for hydropulpers is most efficient at 8% consistently, though emptying is slow (Wahistrom, 1970).Pulping at lower consistencies can be carried out these days.

Modern hydropulpers are fed by mechanical conveyors while more recent development makes use of the secondary pulper, with in-built screens for removal of small rejects (Young, 1980). Hydropulpers are usually vertical but can also be horizontal with capacity range 10-300,000 kilogrammes per day. Both batch and continuous pulping are carried out with great assurance of uniform disintegration (Young, 1980).

The Technical Association of Pulp and Paper Industry (1958) employed a standard disintegrator which comprised a propeller shaft with three blades driven by an electric motor. This was used to produce slurry later formed into handsheets for physical tests of pulp.

A variety of process functions are carried out in vessels stirred by rotating impellers. One of these is the suspension or dispersion of particulate solids in a liquid to produce uniformity, promote mass transfer (such as dissolution), or to create and assist chemical reactions (Perry and Green, 1997). The mixing equipment could be axial-flow impellers or radial-flow impellers. Axial flow impellers include all impellers in which the blade makes an angle of less than 90 degrees with the plane of rotation. Propellers and pitched-blade turbines are examples (Perry and Green, 1997). Paper recycling machines designed by Aperebo et al. (2016) had the pitched-blade turbine adapted for the mixing equipment (agitator).

MATERIALS AND METHOD

The waste paper recycling units making up the system are the hydropulper, the agitator (mixing equipment) and the sheet former but only the first two were fabricated as a sheet former was available. Mild steel was the major construction material.

The hydropulper was loaded with waste paper and water to test its efficiency. A maximum load of 20kg of waste paper was converted to slurry in one batch process. The degree of disintegration and time it took to achieve desirable disintegration was observed and recorded.To achieve the above, the hydropulper was loaded and operated at various time intervals. At the end of each run, the slurry produced was brought out to ascertain the level of dispersion of the fibres which will give an indication of the degree of disintegration achieved. This was done after 10mins, 20mins, 30mins, 40mins, 50mins, and 60mins.

Also, the mass of load was also varied to obtain the amount of waste paper that will produce the best results – efficient conversion to slurry in a given time; 5kg, 10kg, 15kg, and 20kg were loaded into the machine. The volume of water required to defibrillate 1kg of waste paper was also investigated. The consistency of the slurry produced was determined using oven-dry method. The agitator was operated after slurry was produced in the hydropulper. Its performance was satisfactory.

The sheet former was used to produce pulp sheets from the slurry generated. The average thickness of the sheets produced was measured. The fibre length and thickness of the fibres making up the slurry were measured for each time interval using a photomicroscope after slides were prepared. The average weight of the pulp sheets produced was also measured. Slurry and virgin pulp *Eucalyptus spp* was procured from the industry (Epesok Paper Mill, Lagos) to compare fibre lengths and thickness with those from the hydropulper slurry. The sheets produced were then pressed manually or using a screw press before been dried employing solar energy.

RESULTS AND DISCUSSION

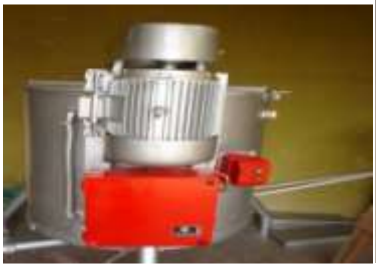


Plate 1. The hydropulper Plate 2.The hydropulper shaft and impellers


Plate 3. The Agitator Plate 4.The agitator shaft and blades

Table 1. Hydropulper and agitator specifications

Feature	Hydropulper	Agitator
Volume	$0.4217m^3$	$0.3947m^3$
Cylindrical vat diameter	835mm	760mm
Cylindrical vat height	910mm	870mm
Electric motor speed	1440rpm	1440rpm
Motor power rating	7.5HP	1HP
V-belt type	A	A
Shaft length	1100mm	1000mm
Number of v-belts	2	2

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Figure 1 is the graph showing fibre length values plotted against disintegration time. The values are those in Table 2. The resultant graph shows a reduction in the fibre length as the disintegration time is increased. This implies that at the end of 60 minutes, the fibre length of the fibres in the slurry produced which is used for sheet formation is 1.8mm as against 2.6mm after 10 minutes of disintegration action. There is no apparent change in the fibre length after 50 minutes of disintegration action and 60 minutes of such action as the value remains 1.8mm. Hence 50 minutes can be considered adequate time for disintegration of fibres before use in sheet formation.

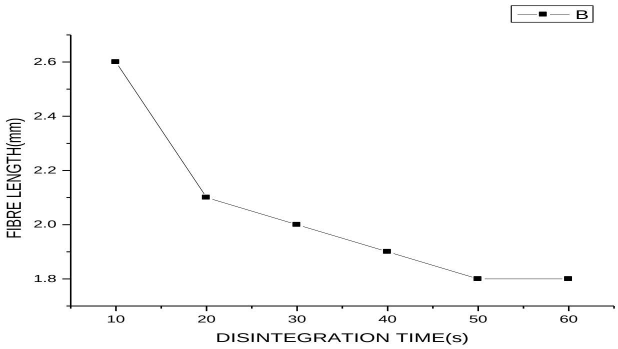

Figure 1. Effect of disintegration time on fibre length

The graph in Fig. 2 shows fibre thickness against disintegration time. From the graph, the fibre thickness remains unchanged after 30 minutes of disintegration aside the initial reduction which takes place after 20 minutes. This implies that the disintegration action alters the fibre length more than the fibre thickness. From Table 3, the weight of eighteen sheets produced from 5kg of waste paper can be seen. The mold with which they were produced had dimensions 600mm by 600mm by 190mm. The sheets did not go under a press during production and had an average thickness of 2mm. Most of the sheets were produced without going under the screw-press. Thus, some sheets were produced using the screw-press so they could be compared with those produced manually. The average weight of five sheets produced with the screw-press was 704g.Five samples were drawn at random from the sheets which did not go under the press and an average weight of 215g was obtained. The difference in the weight is a result of an increase in the volume of slurry used.

The results obtained during the performance evaluation are presented in the tables below: the fibre length and thickness after varying periods of disintegration and the weights and thickness of pulp laps formed without going under the screw-press.

Table 2. Fibre length and thickness after different periods of disintegration action

Disintegration duration (mins)	Fibre length (mm)	Thickness (mm)
10	2.6	0.04
20	2.1	0.04
30	2.0	0.03
40	1.9	0.03
50	1.8	0.03
60	1.8	0.03

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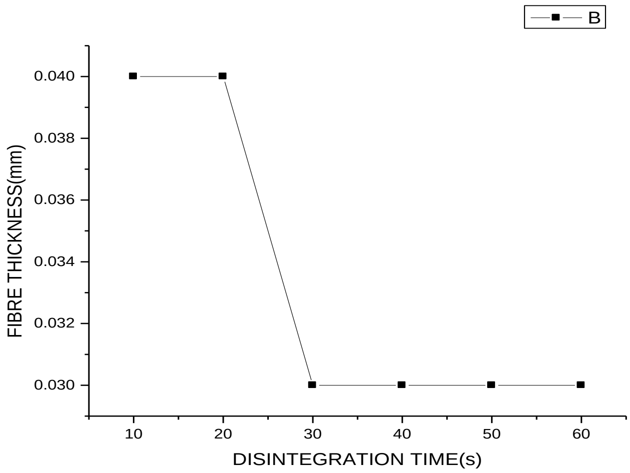

Figure 2. Effect of disintegration time on fibre thickness

The thickness is also increased and the uniformity of the shape of the sheet is guaranteed when a press is employed. Plate 5 shows pulp sheets produced without the screw-press and Plate 6 shows pulp sheets produced with the screw-press.

Table 3. Weight and thickness of pulp sheets produced without employing the screw-press

No.	Weight (g)	Thickness (mm)	No.	Weight (g)	Thickness (mm)
1	234	3.0	10	215	2.0
2	218	3.0	11	233	2.5
3	194	2.0	12	232	2.0
4	232	2.5	13	195	2.0
5	217	2.0	14	215	2.5
6	195	2.0	15	192	2.0
7	234	2.5	16	214	2.0
8	216	2.5	17	213	2.0
9	215	2.5	18	191	2.0

After testing of the machine and production of samples; the need for the unbiased assessment of the machine’s performance required that it be compared against a standard. Virgin pulp of *Eucalyptus spp* and slurry from the tanks-before it is pumped to the headbox of the Fourdrinier machine were obtained from the factory: Epesok Paper Mill, Alausa, Lagos. Table 4 shows that the fibre length of fibres from the virgin pulp is 2.7mm while that of fibres from the slurry obtained from the factory is 1.8mm.

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Plate 5.Pulp sheets produced without the screw-press

Plate 6. Pulp sheets produced with the screw-press

The fibre length of slurry produced from the hydropulper fabricated is 1.8mm. The performance of the hydropulper is therefore considered satisfactory.

Table 4. A comparison of various fibre lengths: virgin pulp, factoryslurry and experimental slurry.

Source	Fibre length (mm)
Virgin pulp	2.7
Factory slurry	1.8
Experimental slurry	1.8

The consistency of slurry employed for sheet formation was between 2-3% and it required 16litres of water to disintegrate 1kg of waste paper. About 3855g of recycled paper can be produced from 5000g of waste paper. The colour of the sheets produced was bright though the raw material was mainly waste paper generated from photocopy centres with a lot of ink. Deinking was however observed to take place by sedimentation when the slurry was allowed to remain in a drum for 24hours before the sheets were formed.

CONCLUSIONS AND RECOMMENDATIONS

The pulp sheets produced are similar to those imported hence they could be packaged for export. They will require less energy to disintegrate when theyare employed in the subsequent production of paper, serviette et al. It is hereby concluded that the recycling machines designed and fabricated under review performed satisfactorily.

It is recommended that the system be compared to a laboratory scale mixer(planetary mixer used in kitchen) and data obtained on the mass fraction of flakes versus specific energy consumption. Measurement of flake content by Somerville screen using 0.10mm slotted screen should also be concluded. Theconstraint oftime assigned for this phase of the study did not allow for those activities to be concludedat the time of this report.

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