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# A Simple Method for the Measurement of the Concentration of pulp Solutions

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**Abstract**

A simple and handy method determining the concentration of pulp solutions is described; pouring a definite quantity of this solution into a beaker, which was rotated by a propeller, time was measured from the instant at which this propeller was drawn out from this liquid, till this liquid came to standstill.

This time was taken as the measure of the concentration.

Some factors governing this time, say, dimension of the beaker, quantity of solution used, initial speed of rotation etc. were also considered.

## I Introduction

It is well known that concentration of pulp solutions has considerable effects on the processes of bleaching, sizing and the making-into-paper process in a papermill. Consequently, it should be fairly important how the measurement of the concentration can be made simply, exactly and quickly.

The measuring method now in use is as follows: a determined amount of pulp solution is taken out and, after squeezing out of water, is placed in a drying oven to attain an absolutely dried state. The percentage of the concentration is determined by weighting the dried pulp. This way of measurement lacks the speediness, though it may be exact. The authors' way is exceedingly simple and has an exactness tolerable for practical purposes. Especially its speediness exceeds that of the above drying method greatly. As this method is supposed to be of valuable use in practice, we wish to describe the details in the following sections.

## II Principles of Measurement

A determined amount of sample of unknown concentration is taken into a beaker and is rotated at a constant speed by a stirring propeller dipped in the solution.

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After the state of the rotation of the solution has become steady, the stirrer is pulled out from the solution and the time interval from that instant to the halt of the solution is measured by a stop-watch. The time depends on the concentration as well as on the size of the vessel, the form of the stirrer and the number of the stirrer and the number of revolutions per minute. Therefore, the concentration can be determined by the measurement of the time required, as long as the size of the vessel and the conditions of the stirring are kept constant.

For this method of measurement it becomes necessary to get beforehand informations on the relation between the concentration and the time by the execution of the above process on samples of known concentrations. This relationship can be represented by a smooth curve of second degree. Thus, after the relation between the concentration and the time has been plotted on a curve under a pre-determined experimental condition for each species of pulp, the concentration of an unknown sample will be measured at once by measuring the time under the same condition.

Incidentally, when the concentratsion is too high, the sample comes to stop almost instantaneously with the pulling out of the stirrer from the solution, reducing the measurement of the time very difficult. To avoid this difficulty, the solution is diluted to a volume of several times by the addition of water, the limits of the measurement being thus removed. In the second place, when the concentration is low the rotating fibre-like pulp may sedimentate by its own weight, which occured in the present experiment when the concentration was below 0.2%, and the sample in the beaker deviates from a homogeneous state. Therefore, when the concentration is too low the water is extracted from the sample to come into measurable concentrations and thus the limit is also removed.

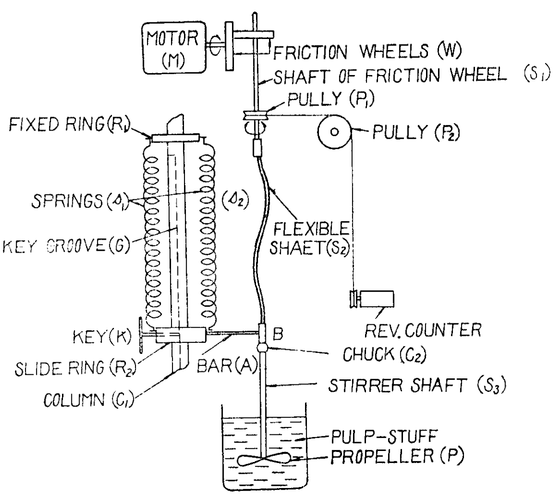


Fig.1. Apparatus

Now, a brief description of the apparatus will be given. Fig. 1. shows the sketch.

The torque needed by the stirrer ($P$) is transmitted from the motor ($M$) through the friction disc ($W$), while the shaft ($S_1$) and the stirring rod ($S_3$) are connected to each other by a flexible shaft which allows the free vertical movement of the stirrer.

The rotation of the stirrer is regulated by a relative displacement of the controller which is attached to the motor and also by the friction disc. The r. p. m. at any instant is read by a revolution counter.

As for the stirrer a glass one was used to avoid the entanglement of the pulp fibres and also its rusting.

Onto the supporting rod ($C_1$) a key groove is engraved so that the slide ring ($R_2$) is allowed to move vertically only. The bearing ($B$) is fixed by a bar ($A$) which in turn is connected to the slide ring ($R_2$) and the stirrer shaft is kept at right angle against the bar ($A$) by the chuck ($C_2$). The fixed ring ($R_1$) and the slide ring ($R_2$) are connected to each other by the spring ($s_1$,$s_2$), so that the stirrer may be pulled up rapidly. As soon as the key ($K$) is released, the slide ring ($R_2$) springs upwards quickly.

## III Method of Measurement

Firstly, a certain amount of the pulp solution is taken into a beaker and the key is loosened, the spring is extended and the stirrer is fixed at a determined position in the solution. Positions of the stirrer and the surface of the solution are determined beforehand by the use of marks on the beaker. Secondly, the stirrer is started and the r. p. m. is measured by the reading of the meter while an appropriate control of the rotation is being made. After the above preparations are made, the observer loosens the key to let the stirrer move out of the solution quickly, while at the same time setting into motion a stop-watch. He pushes the watch again at the instant of the halt of the rotation of the solution and measures the time interval. By the comparison of this time interval with the graph representing the relation between the concentration and the time needed at the same r. p. m., the observer finds the concentration at once. When one watches the rotating state near the end of the rotation, he notices that the direction of the rotation at the surface becomes reversed immediately before the perfect stop. Since this phenomenon is easy to observe, we define this instant to be that of the halt of the rotation.

## IV Results

A) Fig. 2 and Table 1 show the effect of the diameter of the stirrer upon the time to the halt under the conditions of a constant amount of solution and the constant r. p. m. When the diameter is too small compared to that of the beaker, the mixing cannot be accomplished completely. The refore there exists a limitin the relative ratio of the diameter of the stirrer against that of the beaker and it is recommended that $\frac{\text{diameter of propeller}}{\text{diameter of beaker}} > \frac{1}{2}$.

In the whole range of concentration, the following formula holds: $C=Kt^n$, where $C$ is the pulp concentration, $t$ time to the halt of the solution and $K$, $n$ are constant depending on the forms the of the vessel and the stirrer as well as on the r· p. m. Fig. 3 shows an example of the results.

Tabl 1.

| Curve No. | Curve Mark | Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | Propeller Revolution per Minute |
|---|---|---|---|---|---|
| I | ● | 13 | 2.000 | 10 | 300 |
| II | ⊙ | 13 | 2.000 | 6 | 300 |

| T(sec) \ C(%) Concentration of Pulp-Stuff | 0.16 | 0.31 | 0.37 | 0.47 | 0.65 | 0.83 | 0.90 | 1.00 | 1.04 | 1.25 | 1.49 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time Untill the Revolving Pulp-Stuff stops | 58.6 | 30.3 | 25.7 | 19.1 | 12.5 | 8.9 | 7.6 | 6.8 | 6.1 | 5.0 | 3.7 |
| | 55.7 | 23.3 | 20.2 | 14.9 | 8.6 | 2.5 | | | | | |

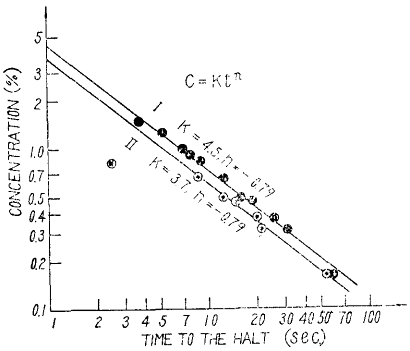


Fig. 3. Relation between " time to the halt " and concentration of pulp, ploted on logarithmic scale

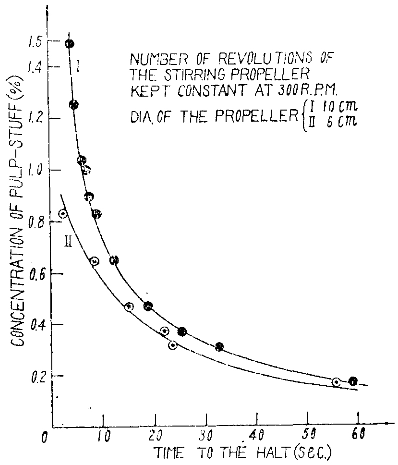


Fig. 2. Effect of the diameter of stirring Propeller

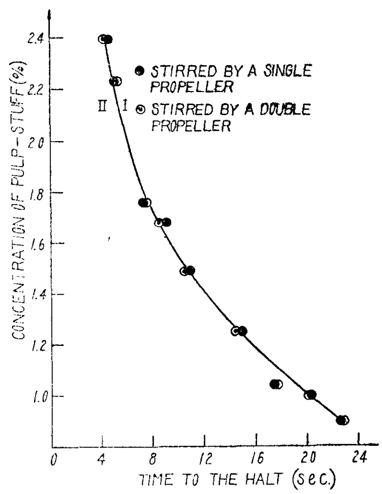


Fig. 4. Stirring with single and double propeller

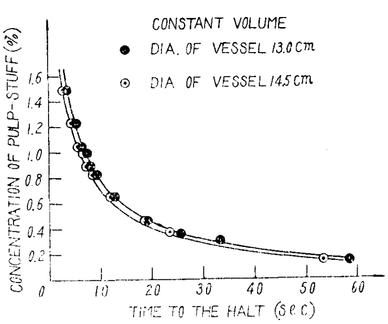


Fig. 5. Effect of the diameter of vessel

B) Fig. 4 and Table 2 show the effects of the number of the blades of the propeller upon the time to the halt when the stirring is done with a constant amount of the solution and under a determined r. p. m. The figure shows that the time is not affected almost to the number of blades as long as $\frac{\text{diameter of propeller}}{\text{diameter of beaker}} > \frac{1}{2}$.

Table 2.

| Curve No. | Curve Mark | Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | Propeller Revolution per Minute |
|---|---|---|---|---|---|
| I | ● | 19 | 4.000 | 10 | 300 |
| II | ⊙ | 19 | 4.000 | 10 | 300 |

| T(sec) \ C(%) Concentration of Pulp-Stuff | 0.90 | 1.00 | 1.04 | 1.25 | 1.49 | 1.68 | 1.71 | 1.76 | 2.23 | 2.39 |
|---|---|---|---|---|---|---|---|---|---|---|
| Time untill the Revolving Pulp-Stuff stops | 22.6 | 20.4 | 17.4 | 15.0 | 10.7 | 8.9 | 8.7 | 7.2 | 4.9 | 4.5 |
| | 22.7 | 20.1 | 17.6 | 14.3 | 10.3 | 8.5 | 8.4 | 7.4 | 5.1 | 4.2 |

C) In Fig. 5 and Table 3 are shown the effects of the diameter of the beaker upon the time to the halt in the case of a certain type of the stirrer and a certain r. p. m. As the difference between the diameters of the two beakers was small in the present experiment, the effect of the diameter of the beaker was hardly perceptible as is shown in Fig. 5.

Table 3.

| Curve No. | Curve Mark | Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | Propeller Revolution per Minute |
|---|---|---|---|---|---|
| I | ● | 13 | 2,000 | 10 | 300 |
| II | ⊙ | 14'5 | 2,000 | 10 | 300 |

| T(sec) \ C(%) Concentration of Pulp-Stuff | 0.16 | 0.13 | 0.37 | 0.47 | 0.65 | 0.83 | 0.90 | 1.00 | 1.04 | 1.25 | 1.49 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time untill the Revolving Pulp-Stuff stops | 58.6 | 30.3 | 25.7 | 19.1 | 12.5 | 8.9 | 7.6 | 6.8 | 6.1 | 5.0 | 3.7 |
| | 53.0 | 27.6 | 23.6 | 18.8 | 12.0 | 8.6 | 7.1 | 6.4 | 5.5 | 4.9 | 2.3 |

Table 4.

| Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | Propeller Revolution Per Minute | T(sec) \ C(%) Concentration of Pulp-Stuff | 1.76 | 2.23 | 2.37 | 2.39 | 2.58 |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 1.000 | 6 | 300 | Time untill the Revolving Pulp-Stuff stops | 7.0 | 3.1 | 4.5 | 3.9 | 5.3 |

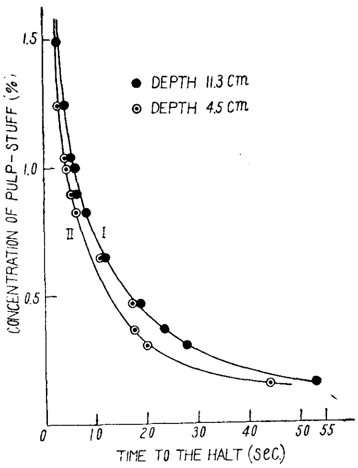


Fig. 6. Effect of pulp column

In the case when the diameter is too small, however, the rotation ceases in a very short time causing the inexactness of the measured values.

We know, therefore, that there is also a limit in the choice of the diameter of the beakers.

D) Fig. 6 and Table 5 show the effects of the depth of the solution upon the time to the halt, when a given r. p. m.. As can be seen in the figure, the time needed becomes longer with the increase of the depth. This fact can also be deduced from the constancy of the friction against the basal surface as the same beaker was used throughout.

Table 5.

| Curve No. | Curve Mark | Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter | Propeller Revolution per Minute |
|---|---|---|---|---|---|
| I | ● | 15 | 11.3 | 10 | 300 |
| II | ⊙ | 15 | 4.5 | 10 | 300 |

| T(sec) \ C(%) | 0.16 | 0.31 | 0.37 | 0.47 | 0.65 | 0.83 | 0.90 | 1.00 | 1.04 | 1.25 | 1.49 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time untill the Revolving Pulp-Stuff stops | 53.0 | 27.6 | 23.6 | 18.8 | 12.0 | 8.6 | 7.1 | 6.4 | 5.5 | 4.9 | 2.3 |
| | 44.1 | 17.3 | 20.2 | 16.8 | 10.9 | 6.2 | 5.5 | 4.7 | 3.7 | 3.9 | 2.6 |

E) Table 6 shows the relations between the concentration and the time to the halt for the different multiplying constant in the dilution of the solution in the case of high concentrations. Since when the concentration is too high the measurement becomes difficult, the solution is to be diluted with the addition of water.

Table 6.

| Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | Propeller Revolution Per Minute | Dilution of Pulp-Stuff | T(sec) \ C(%) | 0.16 | 0.31 | 0.37 | 0.47 | 0.65 | 0.83 | 0.9 | 1.00 | 1.04 | 1.25 | 1.49 | 1.68 | 1.71 | 1.76 | 2.23 | 2.39 | 2.58 | 2.77 | 3.01 | 3.23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 2.000 | 10 | 300 | not Diluted | Time untill the Revolving Pulp-Stuff stops | 53.0 | 27.6 | 23.6 | 18.8 | 12.0 | 8-6 | 7.1 | 6.4 | 5.5 | 4.4 | 2.3 | | | | | | | | | |
| 15 | 2.000 | 10 | 300 | twice | | | | | | | | 19.8 | 17.1 | 15.2 | 12.3 | 9.5 | 8.0 | 8.1 | 7.5 | 5.4 | 4.6 | | | | |
| 15 | 2.000 | 10 | 300 | three times | | | | | | | | | | | | | | | 11.6 | 8.6 | 8.0 | 8.2 | 5.6 | 6.0 | 3.0 |

F) Fig. 7 and Table 7 show how the time to the halt of the solution is affected by the r. p. m. of the stirrer when the stirring is done on a given concentration of pulp and by one type of stirrer. Above a certain r. p. m. the time is affected no more by the change of the rotational velocity.

Under the condition given in Table 7. the time to the halt becomes almost constant above 400 r. p. m.

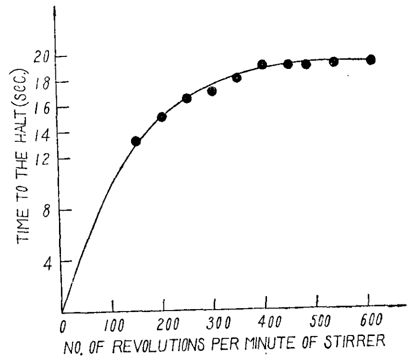


Fig. 7 Time to the halt as a function of stirring speed

Table 7.

| Concentration of Pulp-Stuff (%) | Diameter of Beaker (cm) | Quantity of Pulp-Stuff (c.c) | Propeller Diameter (cm) | C(%) / T(sec) | Number of Revolution per Minute | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 | 540 | 610 |
| 1.17 | 15 | 2.000 | 10 | Time untill the Revolving Pulp-Stuff stops | 3.3 | 13.3 | 15.2 | 16.6 | 17.0 | 18.0 | 19.1 | 19.1 | 19.0 | 19.1 | 19.2 |

## V Conclusions

1) The present method enables the meaurement in the whole range of concentrations of pulp solutions.

2) Relations between the concentration and the time to the halt of the solution depend on the dimension of the vessel and the stirrer and also on the r. p. m. as well.

3) While the time to the halt changes with the increase of the r. p. m., there exists a limit of r. p. m. above which the effect cannot be seen. The limiting r. p. m. depends on the dimension of the vessel and the stirrer.

4) As for the relation between the concentration and the time, the fomula $C=Kt^n$ holds through a wide range.

5) Effects of temperature (0° $C$~100° $C$) is negligible.

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