Vapor Phase Cooking of Aspen Chips Pretreated with Sodium Sulfite and/or Non-Sulfur Chemicals

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ABSTRACT

The effects of pretreatment solution consisting of Na_2SO_3, Na_2SO_3 + NaOH, NaOH or NaOH + AQ on the properties of pulp obtained by vapor phase cooking of pretreated chips in the temperature range 128 to 190 °C have been studied. The pulp yield varied from 85 to 96% depending on cooking time, temperature and impregnation solution. The effects of pretreatment chemicals on resulting pulp quality were greatly influenced by cooking conditions. Pulp obtained with pretreatment solution containing 8% Na_2SO_3 or 8% Na_2SO_3 + 0.5% NaOH showed superior paper properties at high temperature (190°C) cooking conditions, whereas those obtained with pretreatment solutions containing 1% NaOH or 1% NaOH + 0.1% AQ showed superior paper properties at low cooking temperature (150 or 128 °C) conditions. Sodium sulfite with or without NaOH in pretreatment solution improved the paper bonding properties, whereas NaOH with or without AQ improved the tear properties. The refining energy consumption of a pulp was greatly influenced by pretreatment solutions as well as cooking temperature. Sodium sulfite in pretreatment solution preserves the pulp brightness, whereas sodium hydroxide with or without the anthraquinone darkens the pulp at SEP, CMP and CTMP conditions.

INTRODUCTION

Research in pulp and paper intending to minimise the pollution problem to meet the current environmental regulation has got a priority in recent years. Research aimed at the utilisation of O_2 for replacing the sulfur base chemicals used in conventional pulping processes has received much attention in major pulp and paper producing countries (1-4). The useful application of soda-oxygen process in pulping of non-woody material was discussed in the literature (5,6). The soda--AQ process has also received a research importance after the disclosure of catalytic action of AQ in alkaline pulping (7-10) A. research work involving the utilisation of inorganic salts, metal or iodide ions in oxygen pulping was also reported (11, 12). A systematic study of the organic chemical accelerators for alkaline pulping was published by Clayton and Fleming (13). It was previously observed (14) that the wood chips pretreated with magnesium salt and cooked in soda process resulted in higher pulp yield than those directly obtained by soda process. All these research activities were mainly concentrated to low yield chemical pulping with the objective of replacing the well-known Kraft pulping.

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Until now, no substantial research effort has been reported to replace the sulfur based chemicals used in high-yield and ultra-high-yield pulping process. We have previously discussed our preliminary effort in this direction (15,16). Among the ultra-high-yield pulping processes, RMP and TMP require no chemical and thus create lowest pollution problems. However, these processes yield pulp of inferior quality in comparison to those obtained by using CMP, CTMP and steam explosion pulping (SEP) processes. The sulfur base chemical such as Na_2SO_3 applied in CTMP, CMP and SEP processes give pulps of good physical and optical properties. The negatively, sulfur base chemical is one of the many reasons for pollution in pulp and paper mills.

The objective of this research work is to prepare ultra-high-yield pulp from aspen chips pretreated with NaOH or NaOH + AQ solutions by applying CTMP, CMP and SEP (17) pulping processes. The characteristics of the resulting pulps are then compared with those of CTMP, CMP and SEP pulps, where Na_2SO_3 with or without the presence of NaOH was used in pretreatment solutions.

EXPERIMENTAL

Material

Aspen used in this study, supplied in log form, was debarked, chipped and screened at << La Station Forestiere Duchesnay, Quebec. >>. The chips were shredded in << Centre de Recherche et Development, Consolidated-Bathurst Co., Grand-Mere, Quebec >>. The Chips were shredded for better penetration of impregnation liquor. The average chip size after screening was the following: length = 2.5-3.7 cm, width = 1-2 cm, thickness = 1-9 mm with maximum distribution at 5 mm.

Impregnation

150g of chips (50% humidity) were mixed in a plastic bag with 375g of solution made up of 8% Na_2SO_3, 8% Na_2SO_3 + 0.5% NaOH or 1% NaOH. For soda-AQ pretreatment process, 0.1% AQ (based on o.d. chips) was dissolved in acetone, then mixed up with the chips and allow sufficient time to evaporate the excess acetone. The solution of 1% NaOH was then added to make liquor/chips ratio, L/C=6. The pretreatment of chips with of 8% Na_2SO_3, 8% Na_2SO_3 +0.5% NaOH was carried out at 60 ^{0}C for 24h, whereas pretreatment with 1% NaOH or 1% NaOH + 0.1% AQ was performed at 60 ^{0}C for 3h.

Cooking

Cooking was performed by using saturated steam in a laboratory batch reactor built by Stake Tech. Ltd. Steam explosion pulping: The pretreated chips were cooked with saturated steam at 190 ^{0}C for 4 min. Cooking was preceded by 1 min steam flushing at atmospheric pressure. After cooking, the pressure was released instantaneously and the chips which exploded into the release vessel were washed in a washing machine with tap water. Sufficient washing was done to be sure that the chips contain no initial chemical or chemical products. The washed exploded chips were then stored in a cold room and refined later on.

Simulated CTMP of aspen was obtained by cooking the impregnated chips with steam at 128 ^{0}C for 10 min in a Stake batch reactor. In the same reactor simulated CMP was prepared by cooking the impregnated aspen chips with steam at 150 ^{0}C for 30 min. In both cases, cooking was preceded by 1 min steam flushing at atmospheric pressure. The chips after cooking were processed following the procedure applied for exploded chips.

Yield measurement

Exploded or cooked chips obtained from 75g (oven dry basis) of initial chips were washed with 1 L of tap water and subsequently defibrated for 90s in a laboratory blender at 2% consistency. The obtained pulp was washed again with water until the releasing water was visually found clear, then dried in an oven at 105 ^{0}C to constant weight and the resulted weight was compared to the initial oven dry weight of chips.

Refining

Laboratory refining was done using a domestic blender Osterizer B-8614 at 2% consistency level. Defibration and refining energy were measured using a Wattmeter EW-604. Specific refining energy was calculated by subtracting the blending energy of fully beated pulp from the total energy needed to defibrate, refine and blend the fiber suspension (18).

Property evaluation

Paper sheets were prepared and tested according to Standard CPPA testing methods on 1.2g sheets. Brightness was evaluated on sheets prepared by using tap water.

RESULTS AND DISCUSSION

Figure-1 demonstrates the influence of impregnation solution on pulp yield obtained at SEP (steam explosion pulping), CMP and CTMP conditions. The pulp yields drop from 96% at CTMP conditions to 88.5% at SEP conditions when the impregnation solutions consisting of 8% Na_2SO_3. Addition of 1% NaOH with 8% Na_2SO_3 in impregnation solution drastically reduces the pulp yield to 85% level through the hydrolytic action caused by high temperature (190 °C for SEP and 150 °C for CMP) conditions.

The degradation reactions are less severe at low temperature conditions (128 °C for CTMP) resulting in 94.7% pulp yield. When the impregnation solution consisting of 1% NaOH, the pulp yields are 89.2%, 90.4% and 94.4% at SEP, CMP and CTMP conditions respectively. The results indicate that the impregnation solution consisting of 1% NaOH is less severe than that of solution consisting of 8% Na_2SO_3 + 1% NaOH. But the presence of 0.1% AQ with 1% NaOH in impregnation solution sharply reduces the pulp yield at SEP and CMP conditions due to the catalytic action of AQ in degradation reactions at high temperature. A synergetic effect of two chemicals in pretreatment solution is reflected in pulp yield obtained in three processes.

The influence of pretreatment solution and cooking temperature on the relation of pulp yield versus specific refining energy is shown in **Figure-2.** The specific refining energy demand of the pulp decreases from 4.5 to 3.6 MJ/kg (i.e. a reduction of 20%) with the rise in cooking temperature from 128 to 190 °C for the treatment solution consisting of 8% Na_2SO_3. The pulp yield decreases from 94.5 to 89.2% with increasing cooking temperature. The effect of pretreatment solution consisting of 1% NaOH is contrary to that of 8% Na_2SO_3 in the pretreatment solution. The specific refining energy of the pulp

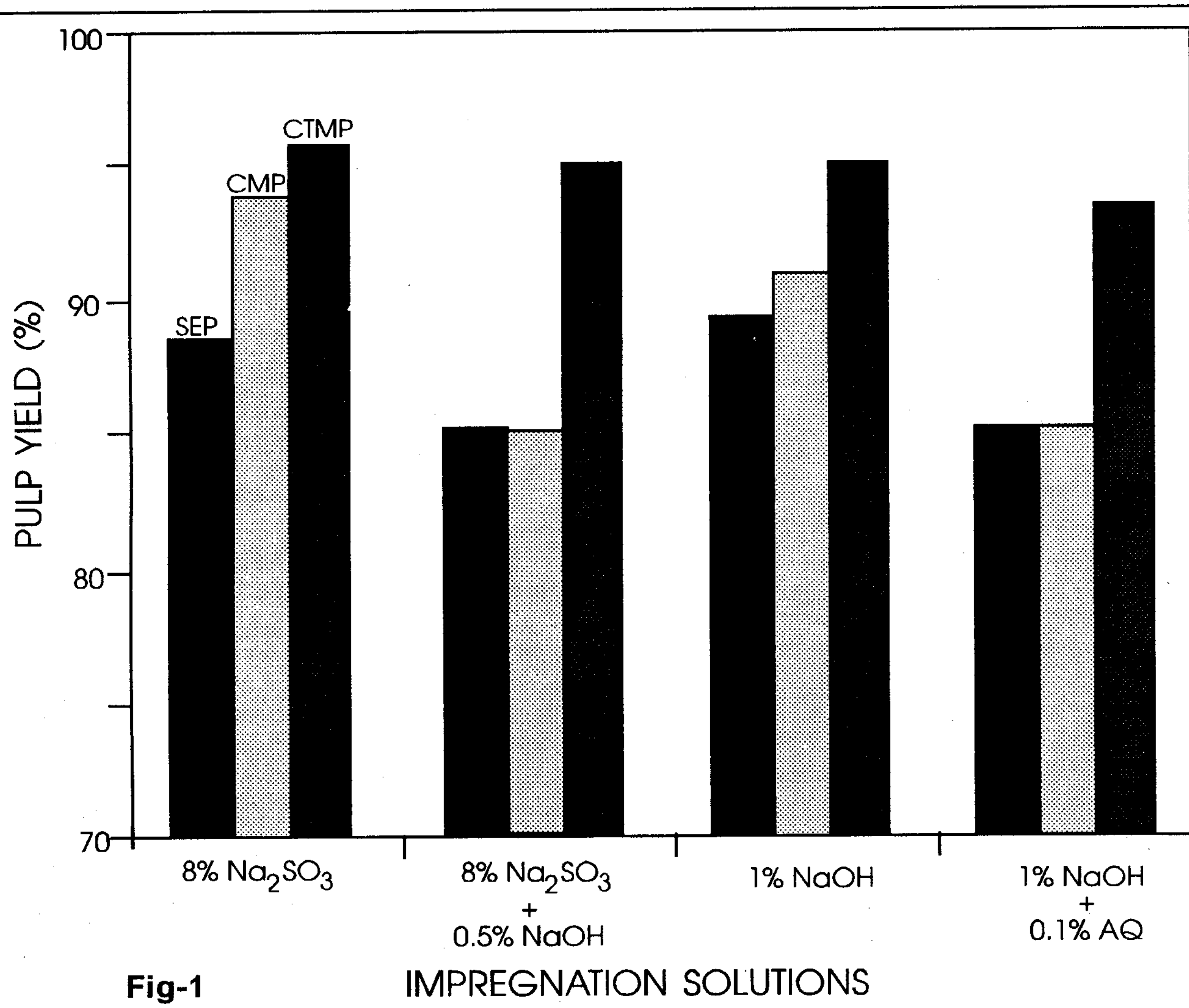

Fig-1

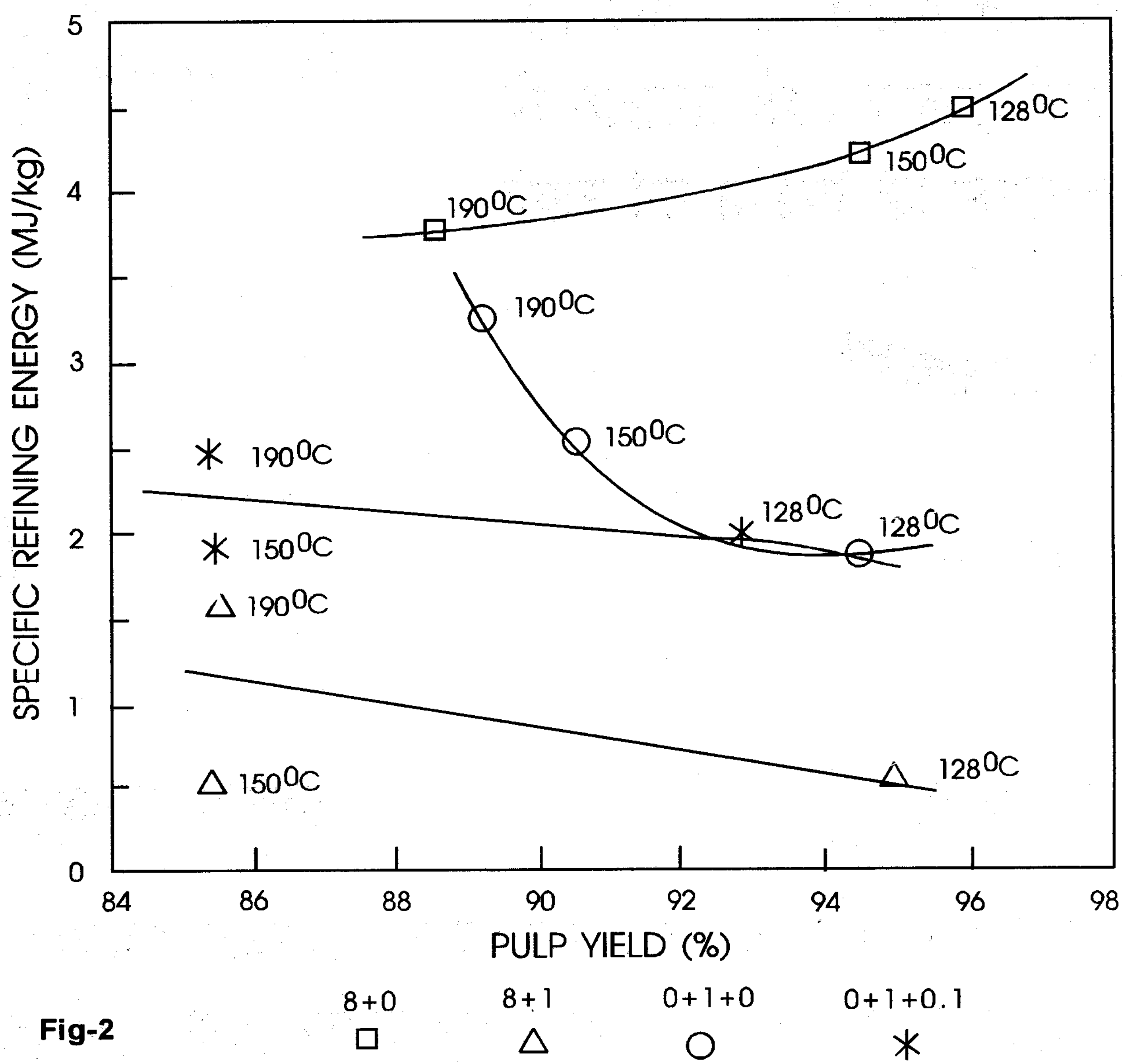

Fig-2

increases from 1.65 to 3.3 MJ/kg (i.e. an increase of 100%) with the rise of cooking temperature from 128 to 190 °C. The pulp yield decrease from 94.5% at 128 °C to 89.2% at 190 °C.

For the impregnation solution containing 8% Na_2SO_3 + 1% NaOH, the specific refining energy demand obtained at 128 and 150 °C remains virtually same (0.6 MJ/kg) whereas for the pulp obtained at 190 °C is around 1.6 MJ/kg. However, the pulp yield obtained at 150 and 190 °C is almost the same. The specific refining energy shows little variation for the pulp yield varying from 93 to 85% with the increase in cooking temperature from 128 to 190 °C, when the impregnation solution consisting of 1% NaOH + 0.1% AQ. Heitner et al (19) have demonstrated that specific refining energy demand is a function of pulp yield. Our results demonstrate that the refining energy of high-yield pulp is not a function of pulp yield only, rather a function of treatment temperature and impregnation chemicals. The presence of NaOH in pretreatment solution alone or along with 5% Na_2SO_3 or 0.1% AQ helps to swell the fiber and softens the chips during cooking, resulting in easy defibration and defibrillation through refining thus consuming less refining energy.

The influence of treatment temperature and impregnation chemicals on the relation between pulp yield and breaking length is depicted in **Figure-3.** The breaking length of the pulp obtained with pretreatment chemicals 8% Na_2SO_3 increases from 3.7

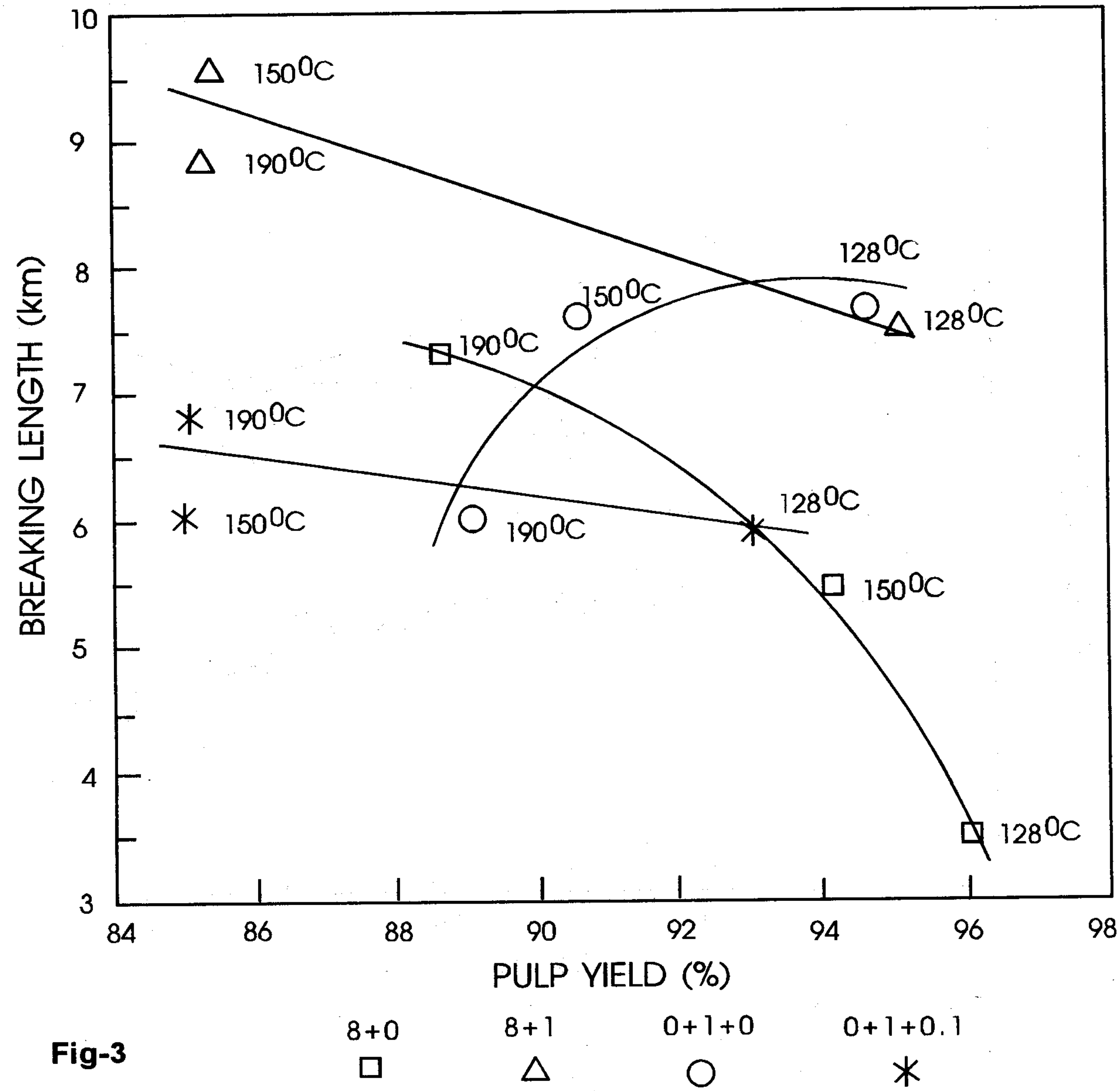

Fig-3

to 7.4 km (i.e. 100% increase) with the rise in cooking temperature from 128 to 190 °C. This increase in breaking length values is accompanied by a significant drop in pulp yield. At low temperature cooking such as 128 and 150 °C, the pulp yield varies from 94-96% with a corresponding breaking length of 2.74-4.6 km. When the pretreatment solution contains 1% NaOH in addition to 8% Na_2SO_3, the pulp's breaking length (7.75 km) is improved remarkably at low temperature (128 °C) conditions along with high pulp yield (94.7%). The pulp yield drops drastically at temperature 150 or 190 °C to a level of around 85% having a breaking length of 9-10 km. In case of impregnation solution consists of 1% NaOH, the CTMP condition shows the advantages over the other processes in terms of both a breaking length and a pulp yield.

The pulp yield and breaking length values at CTMP conditions are 94.5% and 7.7 km respectively. The pulp's breaking length decreases significantly at SEP conditions and this is accompanied by a drop in pulp yield. The presence of 0.1% AQ with 1% NaOH is not helping to achieve high breaking length and pulp yield. At CTMP conditions, the pulp yield is around 93% and the breaking length 5.7 km. AT SEP and CMP conditions, the pulp breaking length increases to 6-6.8 km with a simultaneous drop in pulp yield at a level of 85%. The results clearly show that a breaking length of the pulp depends on im-

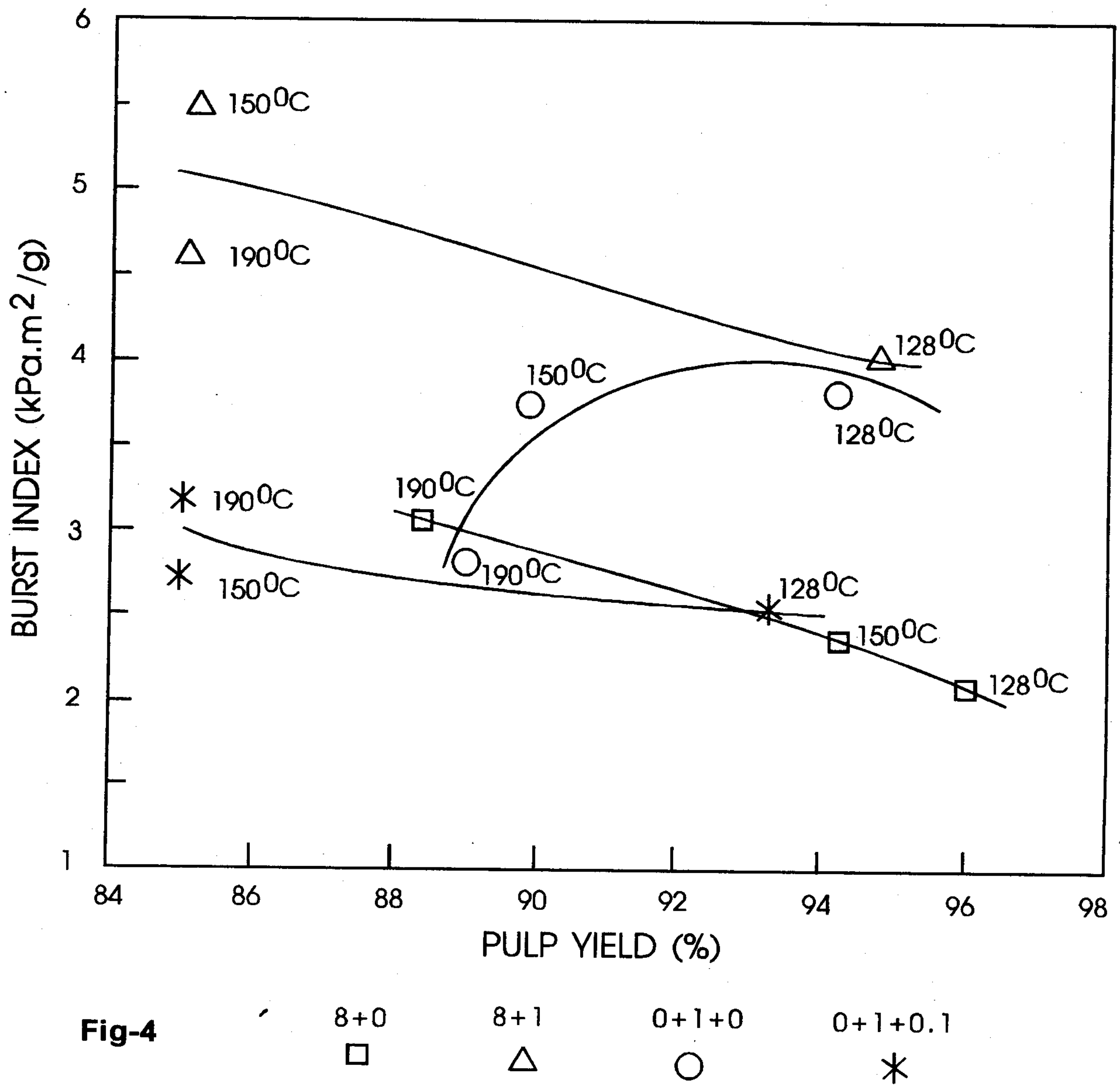

Fig-4

pregnation chemicals as well as on the treatment temperature.

The influence of impregnation solution, treatment temperature and pulp yield on the burst index of the pulp is depicted in **Figure-4.** The variation of burst index with pulp yield for various impregnation solutions at different treatment temperature follows the same pattern as observed in Figure 3 where the breaking length is plotted as a function of a pulp yield. After all, both the breaking length and the burst index are adhesion based properties.

The effects of impregnation solution and treatment temperature on the relation between pulp yield and tear values are presented in **Figure-5.** The Pulp obtained with 8% Na_2SO_3 solution at 190 °C shows tear values of 5.7 mN.m²/g which are substantially higher than those found for the pulp obtained at 128 °C or 150 °C. This increase in tear values is accompanied by a reduction in pulp yield from 96 to 88%. Impregnation solutions 8% Na_2SO_3 + 1% NaOH are very effective to improve the adhesion properties at the expense of tear values. The reduction in tear values are probably due to fiber damage during pulping and refining.

The tear values of the pulp obtained at 128 °C and 150 °C increase sharply in comparison to the pulp obtained at the same conditions with 8% Na_2SO_3

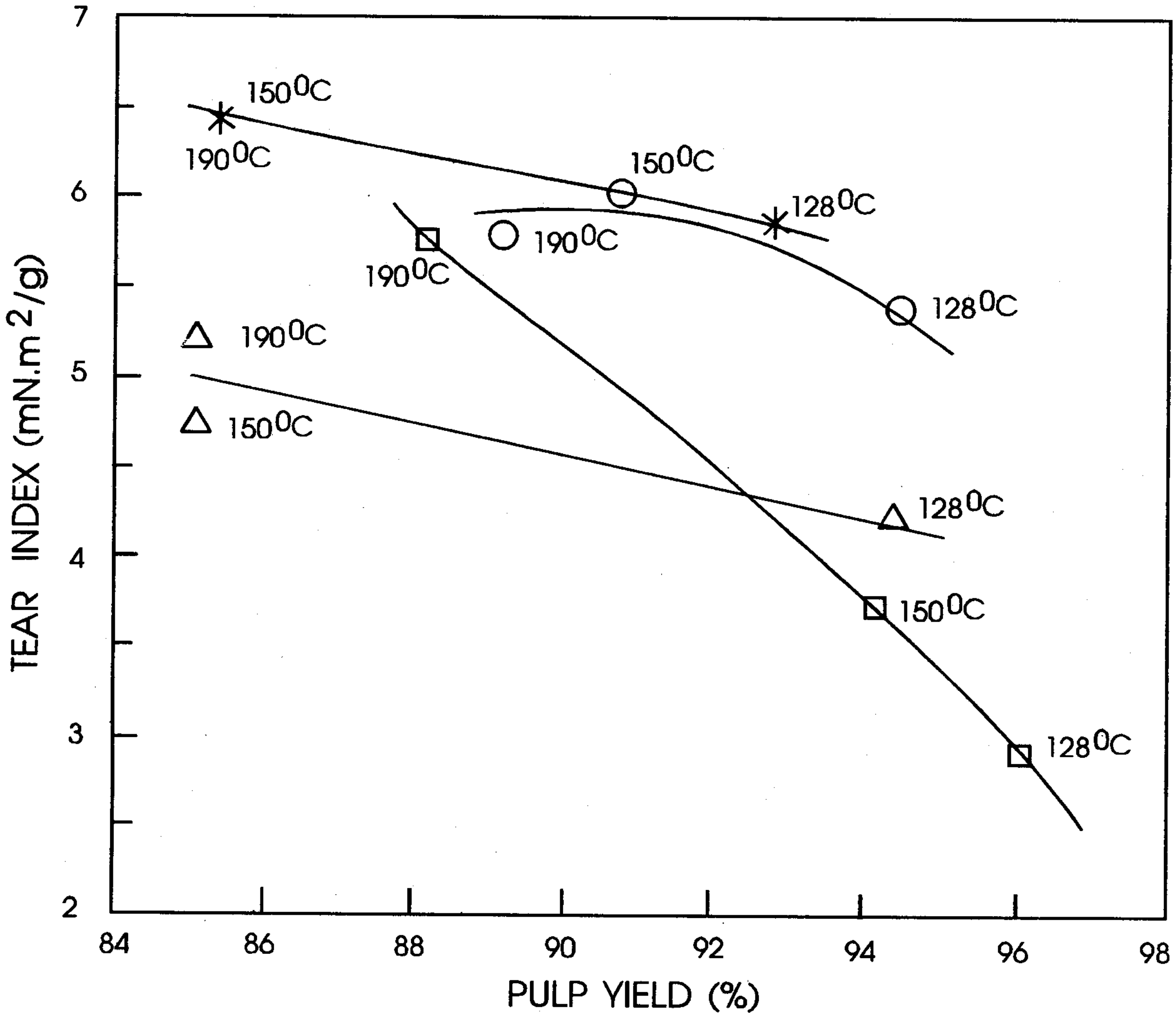

Fig-5 8+0 □ 8+1 △ 0+1+0 ○ 0+1+0.1 ✱

pretreatment solutions. The pulp yield drops from 94% at 128 °C to around 85% at 150 °C or at 190 °C without significant improvement in tear values. However, tear values of pulp obtained with 1% NaOH solution shows slight improvement in tear values with the increase in the temperature. However, the pulp yield drops about 4%. The overall tear values of the pulp are much higher than those of the pulp obtained with 8% Na_2SO_3 or 8% Na_2SO_3 + 1% NaOH. The effect of 0.1% AQ along with 1% NaOH in pretreatment solution is even more dramatic to improve the tear values of the pulp at all of the three pulping conditions. Pulp obtained at 128 °C shows tear values of 5.7 $mN.m^2/g$ and the corresponding pulp yield is 93%. The tear values increase significantly at 150 and 190 °C with the simultaneous decrease in the pulp yield. The tear values of the pulp obtained with chemicals 8% Na_2SO_3 or 8% Na_2SO_3 + 1% NaOH in impregnation solutions are inferior to that obtained with 1% NaOH alone or with 1% NaOH + 0.1% AQ in pretreatment solution. This suggests that Na_2SO_3 is responsible for bonding properties of the pulp through sulfonation, and NaOH swells and softens the pulp for better defibration preserving fiber length resulting better tear values.

The effects of impregnation solution and treatment temperature on pulp brightness are presented in **Figure-6** as a function of pulp yield. As per expectation, Na_2SO_3 in a pretreatment solution preserves

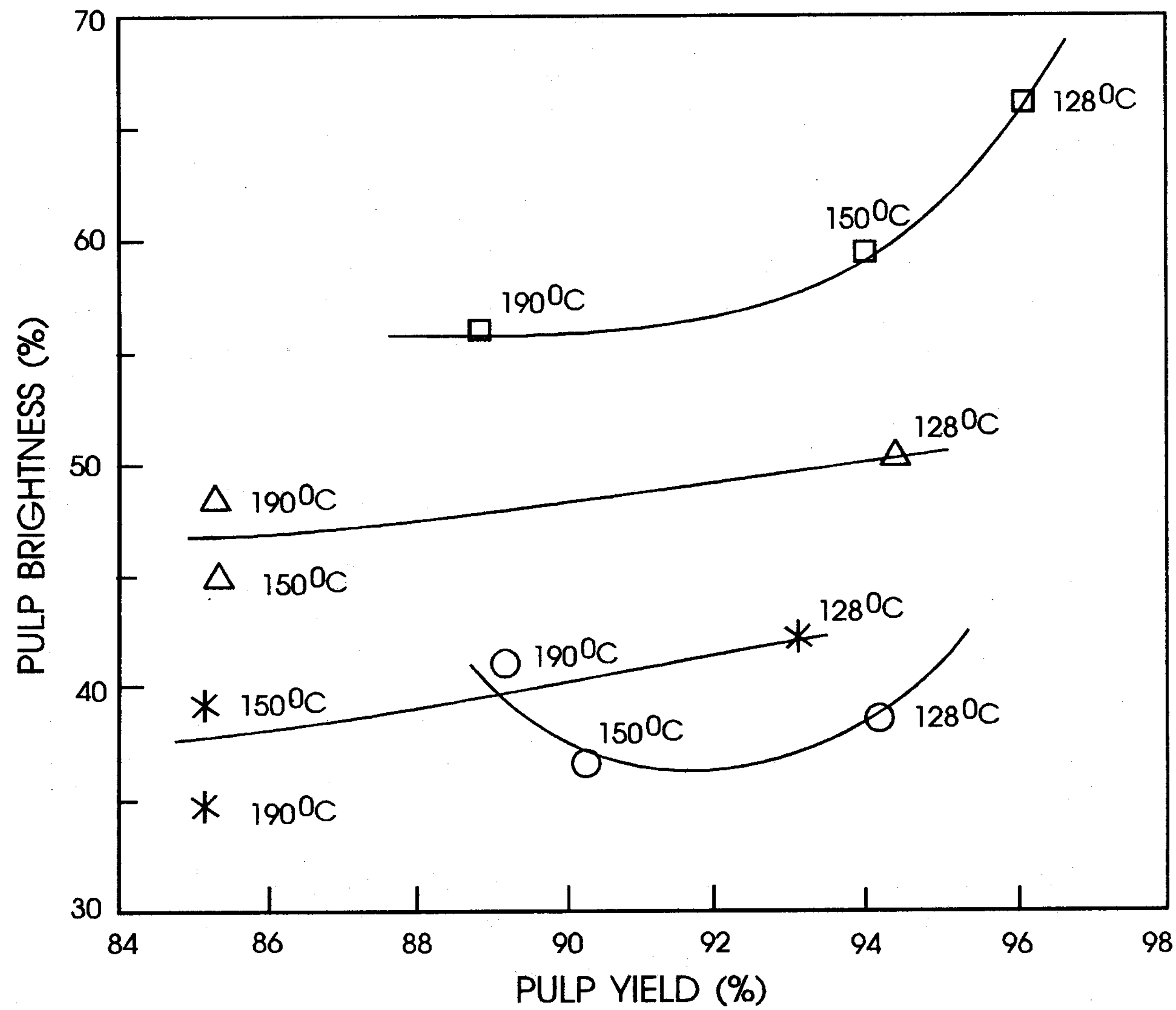

Fig-6

the pulp brightness and NaOH deteriorates the pulp brightness. The Pulp brightness obtained with 8% Na_2SO_3 solution drops from 66 to 55% and pulp yield from 96 to 88% with the rise in cooking temperature from 128 to 190°C. The pulp brightness level further drops in the range of 44-50% when the pretreatment solution contains 1% NaOH in addition to 8% Na_2SO_3. The pulp yield drops simultaneously from 95 to 85% level. The drop in pulp brightness is accelerated when the pretreatment solutions consist of 1% NaOH or 1% NaOH + 0.1% AQ.

CONCLUSIONS

Both impregnation chemicals and cooking conditions have profound effect on resulting pulp yield and properties. Pulp obtained with impregnation solution consisting of 8% Na_2SO_3 + 1% NaOH gives better adhesion based properties at all temperature ranges. However, higher tear values are obtained with the pulp, when impregnation solution consists of 1% NaOH or 1% NaOH + 0.1% AQ. Sodium sulfite in pretreatment solution preserves the pulp brightness, whereas NaOH and AQ in pretreatment solution darkens the pulps. The specific refining energy of the pulp is greatly influenced by pretreatment solution. Pulps obtained with 8% Na_2SO_3 pretreatment solution need highest refining energy and those obtained with 8% Na_2SO_3 + 1% NaOH requiring lowest refining energy.

The breaking length, burst index and tear index increase and a specific refining energy decreases with the rise in the cooking temperature, when the impregnation solution consists of Na_2SO_3 only. In the case of impregnation solution consisting of NaOH only, the breaking length and burst index decrease, and the tear index and the specific refining energy increase with the rise in a cooking temperature from 128 to 190 °C. A cooking temperature above 150 °C has less influence, when the impregnation solution consists of NaOH + AQ or Na_2SO_3 + NaOH. The specific refining energy of the pulp increases with the increase in cooking temperature from 150 to 190 °C for similar pulp yield, when the impregnation solution is NaOH + AQ or Na_2SO_3 + NaOH. Pulp properties depend on impregnation chemicals and cooking temperature, rather than pulp yield alone.

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REFERENCES

1. Grangard, D.H. and Saunders, G.H.: U.S. Patent 3,926114 (1973).

2. Chang, H.-M., Mckean, W.T., Gratzyl, J.S. and Lin, C.K., Tappi, 59(9): 116 (1973).

3. Saukkonen, M. and Palenius, I., Tappi, 58(7): 117 (1975).

4. Chang, H.-M Mckean, W.T., Reeves, R.H. and Stockman, V.E., Tappi, 59(8): 72 (1976).

5. Lachenal, D., De Choudens, C. and Monzie, P., ATIP, 31(4): 131 (1977).

6. EL- Asmavy, A.E. Fadl, M.H., Saleh, T.M. and El-Meadway, S.A., Tappi, 60(6): 109 (1977).

7. Holton, H.H., Pulp Paper Can., 78(10): T218 (1977).

8. Eachus, S.W., Tappi, 66(2): 85(1983).

9. Macleod, J.M. Fleming, B.I. Kubes, G.J. and Bolker, H.I., Tappi, 62(1): 57 (1980).

10. Fullertron, T.J. and Fleming, B.I., Svensk. P., 83(14): 396 (1982).

11. Worster, H.E. and Pudek, M.F., U.S. Patent, 2,926,114 (1960).

12. Ceragioli, G., The role of fundamental research in papermaking; Transactions of the symposium held at Cambridge, Sept. 1981. Vol. 1; ed. J. Brander; Mechanical Engineering publications Ltd. London (1983).

13. Clayton, D.W. and Fleming, B.I., The role of fundamental research in papermaking; Transactions of the symposium held at Cambridge, Sept. 1981. Vol. 1; ed. J. Brander; Mechanical Engineering publications Ltd. London (1983).

14. Chen, R. and Ahmed, A., << Magnesium-Alkaline Pulping of Birch >> AICHE 1989 and 1990 Forest Products Symposium proceedings; pp. 41-47 (1992).

15. Ahmed, A. and Kokta, B.V., << Explosion Steam Cooking of Aspen Pretreated with Methanol-water/alkaline water >> AICHE 1989 and 1990 Forest Products Symposium proceedings; pp. 25-33 (1992).

16. Ahmed, A. and Kokta, B.V., << Effects of pretreatment chemicals in explosion pulping of aspen: Sulfite versus Methanol >>, 6th. ISWPC, P. 97 (1991).

17. Ahmed, A. and Kokta, B.V., Garceau, J.J. and Chen, R., << Progress of Steam Explosion Pulping: Overview >> , Proceedings, CELLUCON 90, Bratislava, Czechoslovakia, August 1990.

18. Shaw, A.C., Pulp Paper Can., 85(6): T152 (1984).

19. Heitner, C., Argyropoulos, D.S., Miles, K.B. Karnis, A. and Kerr, R.B., << Alkaline sulfite ultra-high-yield pulping of aspen chips-A comparison of steam explosion and conventional chemimechanical pulping. >> Proc. Int'l. Mech. Pulping Conf., p. 151, June 2-5 (1991), Minneapolis, Mn.

LIST OF FIGURES

3. The relation between pulp yield and breaking length of pulp obtained with various impregnation solutions and at different treatment temperature.

4. The relation between pulp yield and burst index of pulp obtained with various impregnation solutions and at different treatment temperature.

5. The relation between pulp yield and tear index of pulp obtained with various impregnation solutions and at different treatment.

6. The relation between pulp yield and brightness of pulp obtained with various impregnation solutions and at different treatment.