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(54) **PAPERMAKING METHOD**

(57) There is provided a method of producing a paper on a paper machine, comprising the steps of:
a) providing a pulp, such as a mixture of hardwood pulp and softwood pulp;
b) adding cationic glyoxylated polyacrylamide (G-PAM) to the pulp;
c) forming a web from the pulp in a forming section comprising a head box;
d) pressing the web in a press section;
e) drying the web in a drying section; and
f) optionally calendering the web in a calender.

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to the field of papermaking.

BACKGROUND

[0002] In the field of papermaking, it is difficult to achieve certain combinations of paper properties. As an example, it is generally challenging to produce a paper of high bending resistance that, at the same time, has smooth surfaces. This is because the calendering operation that is normally used to smoothen the surfaces also densifies the paper and thereby makes it floppy. Another example of conflicting properties are wet strength and recyclability since the latter requires repulping of the paper, which is typically hampered by the wet strength. Yet another example is that there is often a conflict between low porosity and good formation. This is because low porosity typically requires highly refined pulp that is often difficult to dewater. To overcome the dewatering problem, the headbox consistency may be increased and/or more retention chemicals may be added. Both these measures are however known impair formation.

SUMMARY

[0003] An objective of the present disclosure is to provide a method of producing a recyclable paper having relatively high wet strength. In some embodiments, it is also an objective that the paper exhibits at least one and preferably all of the following properties: good formation; low porosity; and low surface roughness without increasing the density too much.

[0004] Accordingly, the following itemized listing of embodiments of the present disclosure is provided:

1. A method of producing a paper on a paper machine, comprising the steps of:

    a) providing a pulp;
    b) adding cationic glyoxylated polyacrylamide (G-PAM) to the pulp;
    c) forming a web from the pulp in a forming section comprising a head box;
    d) pressing the web in a press section;
    e) drying the web in a drying section; and
    f) optionally calendering the web in a calender.

2. The method of item 1, wherein the pulp is a mixture of hardwood pulp and softwood pulp.

3. The method of item 1 or 2, wherein the pulp is bleached.

4. The method of any one of the preceding items, wherein the pulp is a kraft pulp, such as a mixture of a bleached hardwood pulp and a bleached softwood pulp.

5. The method of any one of the preceding items, wherein the pulp is refined, e.g. such that the Schopper-Riegler number measured according to ISO 5267-1:1999 of the pulp in the head box is 20-30, preferably 22-30, such as 23-28.

6. The method of item 5, wherein said refining comprises low consistency (LC) refining.

7. The method of any one of the preceding items, wherein the pH of the pulp is in the range of 4.8-5.5 when the cationic G-PAM is added.

8. The method of any one of the preceding items, wherein the consistency of the pulp is in the range of 1.5-3.0 % when the cationic G-PAM is added.

9. The method of any one of the preceding items, wherein the pulp is not subjected to refining after the G-PAM addition.

10. The method of any one of the preceding items, wherein cationic G-PAM is added in a total amount of 1.5-3.0 kg/tonne dry fibre, preferably 2.0-3.0 kg/tonne dry fibre, more preferably 2.5-3.0 kg/tonne dry fibre.

11. The method of any one of the preceding items, further comprising adding an anionic polymer to the pulp.

12. The method of item 11, wherein the anionic polymer is anionic polyacrylamide (A-PAM).

13. The method of item 12, wherein the A-PAM is added in a total amount of 0.20-1.00 kg/tonne dry fibre, preferably 0.25-0.75 kg/tonne dry fibre, more preferably 0.35-0.55 kg/tonne dry fibre.

14. The method of any one of items 11-13, wherein the anionic polymer is added before the cationic G-PAM is added.

15. The method of any one of items 11-14, wherein the pH of the pulp is in the range of 6.5-8.0 when the anionic polymer is added.

16. The method of any one of items 11-15, wherein the pulp is subjected to LC refining after the addition of the anionic polymer.

17. The method of any one of the preceding items, further comprising adding at least one hydrophobic size to the pulp.

18. The method of item 17, wherein the at least one hydrophobic size comprises rosin size.

19. The method of item 18, wherein said rosin size is added in a total amount of 1.0-4.0 kg/tonne dry fibre, preferably 1.5-3.0 kg/tonne dry fibre, more preferably 1.5-2.5 kg/tonne dry fibre.

20. The method of any one of items 17-19, wherein the at least one hydrophobic size comprises ASA or AKD, preferably AKD.

21. The method of item 20, wherein said AKD is added in a total amount of 0.3-2.0 kg/tonne dry fibre, preferably 0.4-1.5 kg/tonne dry fibre, more preferably 0.4-1.0 kg/tonne dry fibre.

22. The method of any one of 17-21, wherein the pH of the pulp is in the range of 4.8-5.5 when the at least one hydrophobic size is added.

23. The method of any one of 17-22, wherein the consistency of the pulp is in the range of 1.5-3.0 % when the at least one hydrophobic size is added.

24. The method of any one of 17-23, wherein the pulp is not subjected to refining after the addition of the at least one hydrophobic size.

25. The method of any one of items 17-24, further comprising adding alum to the pulp.

26. The method of item 25, wherein said alum is added in a total amount of 2.0-8.5 kg/tonne dry fibre, preferably 2.5-5.5 kg/tonne dry fibre, more preferably 2.5-4.5 kg/tonne dry fibre.

27. The method of item 25 or 26, wherein said alum is added before said at least one hydrophobic size.

28. The method of any one of the preceding items, wherein the consistency of the pulp in the head box is 0.20-0.60 %, preferably 0.30-0.55 %, more preferably 0.35-0.50 %.

29. The method of any one of the preceding items, wherein pH of the pulp in the head box is in the range of 4.8-5.5, preferably 5.0-5.5.

30. The method of any one of the preceding items, wherein clay is added to the pulp.

31. The method of item 30, wherein said clay is added in such an amount that the ash content of the paper is in the range of 2.0-5.5 %, such as 3.0-5.0 %.

32. The method of item 30 or 31, wherein the point of addition of said clay is in the short circulation.

33. The method of any one of the preceding items, further comprising adding a dry strength agent to the pulp.

34. The method of item 33, wherein the dry strength agent is starch, preferably cationic starch.

35. The method of item 34, wherein said starch is added in a total amount of 2.0-7.0 kg/tonne dry fibre, preferably 3.5-6.0 kg/tonne dry fibre.

36. The method of any one of the preceding items, wherein the forming section comprises a wire shaker.

37. The method of any one of the preceding items, wherein the cross directional dry content of the web is controlled by a steam box arranged at the downstream end of the forming section.

38. The method of any one of the preceding items, wherein the press section comprises a shoe press.

39. The method of item 38, wherein the shoe press is operated at a line load of 650-950 kN/m, such as 750-900 kN/m.

40. The method of item 38 or 39, wherein the press section further comprises at least one press nip upstream the shoe press.

41. The method of any one of the preceding items, wherein the calender is a soft nip calender.

42. The method of item 41, wherein the line load of the soft nip calender is in the range of 60-170 kN/m, preferably 80-140 kN/m, such as 100-140 kN/m.

43. The method of item 41 or 42, wherein the hard roll of the soft nip calender is heated, preferably to a temperature in the range of 100-200 °C, such as 120-180 °C.

44. The method of any one of the preceding items, wherein the grammage measured according to ISO 536:2019 of the paper is at least 100 g/m^2.

45. The method of any one of the preceding items, wherein the specific formation number measured according to SCAN-P 92:09 of the paper is below 1.00 $\sqrt{g/m}$, such as below 0.90 $\sqrt{g/m}$, such as below 0.85 $\sqrt{g/m}$.

46. The method of any one of the preceding items, wherein the Bendtsen roughness measured according to SS-ISO 8791-2:2013 of at least one side of the paper is below 250 ml/min, preferably below 220 ml/min, more preferably below 160 ml/min.

47. The method of any one of the preceding items, wherein the Bendtsen roughness measured according to SS-ISO 8791-2:2013 of both sides of the paper is below 600 ml/min, preferably below 500 ml/min, more preferably below 400 ml/min.

48. The method of any one of the preceding items, wherein the Gurley value according to ISO 5636-5:2013 of the paper is above 50 s, preferably above 60 s, such as above 65 s.

49. The method of any one of the preceding items, wherein the density measured according to ISO 534:2011 of the paper is 600-950 kg/m^3, preferably below 600-920 kg/m^3.

50. The method of any one of the preceding items, wherein the wet tensile strength index measured according to ISO 1924-3:2005 in the machine direction (MD) of the paper is at least 8.0 Nm/g, preferably at least 9.5 Nm/g, more preferably above 11.0 Nm/g.

51. The method of any one of the preceding items, wherein the wet tensile strength index measured according to ISO 1924-3:2005 in the cross direction (CD) of the paper is at least 5.5 Nm/g, preferably at least 6.5 Nm/g, more preferably at least 7.5 Nm/g.

52. The method of any one of the preceding items, wherein the wet tensile stiffness index measured according to ISO 1924-3:2005 in the machine direction (MD) of the paper is at least 1000 Nm/g, preferably at least 1045 Nm/g, more preferably at least 1200 Nm/g.

53. The method of any one of the preceding items, wherein the wet tensile stiffness index measured according to ISO 1924-3:2005 in the cross direction (CD) of the paper is at least 400 Nm/g, preferably at least 445 Nm/g, more preferably at least 545 Nm/g.

54. The method of any one of the preceding items, wherein mixing of said cationic G-PAM with the pulp is aided by a pump.

55. The method of item 54, wherein the pump is arranged downstream the point of addition of said cationic G-PAM, but upstream a headbox pump.

56. The method of item 55, wherein the pump is arranged upstream a wire pit, which in turn is arranged upstream the headbox pump.

57. The method of any one of the preceding items, wherein the Cobb 60 s value measured according to ISO 535:2014 of at least one side of the paper is below 30 g/m^2, preferably below 25 g/m^2, more preferably below 23.5 g/m^2.

58. The method of any one of the preceding items, wherein the Cobb 60 s value measured according to ISO 535:2014 of both sides of the paper is below 30 g/m^2, preferably below 25 g/m^2, more preferably below 23.5 g/m^2.

DETAILED DESCRIPTION

[0005] There is thus provided a method of producing a paper on a paper machine, comprising the steps of:

a) providing a pulp;
b) adding cationic glyoxylated polyacrylamide (G-PAM) to the pulp;
c) forming a web from the pulp in a forming section comprising a head box;
d) pressing the web in a press section;
e) drying the web in a drying section; and
f) optionally calendering the web in a calender.

[0006] In one embodiment, the pulp preferably a mixture of hardwood pulp and softwood pulp. This embodiment is particularly relevant for bleached pulp. The dry weight ratio of hardwood pulp to softwood pulp may be between 70:30 and 10:90, such as between 60:40 and 25:75, preferably between 60:40 and 30:70, more preferably between 55:45 and 40:60.

[0007] The pulp may be bleached or unbleached. When it is unbleached, it may be a 100% softwood pulp.

[0008] The pulp is preferably a kraft pulp. For example, it may be a mixture of a bleached hardwood sulphate pulp and a bleached softwood sulphate pulp.

[0009] Broke pulp is typically added, e.g. in a proportion of 5-30% (w/w). The broke pulp is preferably obtained from the same method. The broke pulp is typically added downstream a refining step. However, the broke pulp may be added upstream the addition of the anionic polymer (discussed below). In one embodiment, broke pulp is added downstream a refining step, but upstream of all additions of papermaking chemicals.

[0010] The method preferably comprises refining of the pulp, e.g. to such a degree that a Schopper-Riegler (SR) number of 20-30, preferably 22-30, such as 23-28. Refining can be carried out in different positions between the cook and the headbox. In any case, the SR number ranges given herein relate to the pulp in the head box. In the context of the present disclosure, SR numbers are measured according to ISO 5267-1:1999.

[0011] The refining normally comprises low consistency LC refining, e.g. refining at a consistency of 2-5 %, such as 3-4 %. In some embodiments comprising LC refining, no high consistency (HC) refining is carried out.

[0012] When the cationic G-PAM is added to the pulp, the pulp preferably has a pH in the range of 4.8-5.5, such as 5.0-5.5.

[0013] Further, the consistency of the pulp is preferably in the range of 1.5-3.0 % when the cationic G-PAM is added.

[0014] Preferably, refining is only carried out before the addition of the cationic G-PAM. Accordingly, in one embodiment of the method, the pulp is not subjected to any refining after the addition of the cationic G-PAM.

[0015] The total amount of cationic G-PAM added to the pulp may be 1.5-3.0 kg/tonne dry fibre, preferably 2.0-3.0 kg/tonne dry fibre, such as 2.5-3.0 kg/tonne dry fibre.

[0016] As an example, the cationic G-PAM may be added to the pulp in the piping leading from the machine chest to the wire pit of the paper machine.

[0017] Mixing of said cationic G-PAM with the pulp may be aided by a pump. The pump is preferably arranged upstream a headbox pump (and, of course, downstream the point of addition of said cationic G-PAM). In one embodiment, the pump is arranged upstream a wire pit, which in turn is arranged upstream the headbox pump.

[0018] An embodiment of the method further comprises adding an anionic polymer to the pulp, i.a. to balance the charge of the pulp. The anionic polymer may for example be anionic polyacrylamide (A-PAM). The total amount of A-PAM added to the pulp may be 0.20-1.00 kg/tonne dry fibre, preferably 0.25-0.75 kg/tonne dry fibre, more preferably

0.35-0.55 kg/tonne dry fibre. The anionic polymer is preferably added to the pulp before the cationic G-PAM is added is added to the pulp. The pH of the pulp may be in the range of 6.5-8.0 when the anionic polymer is added. In one embodiment, LC refining is carried out before and after the addition of the anionic polymer. In such case, the amount of LC refining (measured as kWh/tonne dry fibre) may be higher before than after the addition of the anionic polymer.

[0019] The method may further comprise adding at least one hydrophobic size to the pulp, thereby reducing the water absorption of the paper and thus improving its durability in wet or humid conditions.

[0020] The at least one hydrophobic size preferably comprises rosin size. Rosin size may be added to the pulp in a total amount of 1.0-4.0 kg/tonne dry fibre, preferably 1.5-3.0 kg/tonne dry fibre, more preferably 1.5-2.5 kg/tonne dry fibre.

[0021] Further, the at least one hydrophobic size may comprise Alkenylsuccinic anhydride (ASA) or Alkylketene dimer (AKD), preferably AKD. AKD may be added to the pulp in a total amount of 0.3-2.0 kg/tonne dry fibre, preferably 0.4-1.5 kg/tonne dry fibre, more preferably 0.4-1.0 kg/tonne dry fibre.

[0022] Preferably, the at least one hydrophobic size comprises both rosin size and AKD.

[0023] When the at least one hydrophobic size is added, the pH of the pulp is preferably in the range of 4.8-5.5 and the consistency of the pulp is preferably in the range of 1.5-3.0 %.

[0024] In an embodiment, the pulp is not subjected to refining after the addition of the at least one hydrophobic size.

[0025] The at least one hydrophobic size is preferably added after the addition anionic polymer discussed above. As an example, the at least one hydrophobic size may be added to the pulp in the piping leading from the machine chest to the wire pit of the paper machine.

[0026] An embodiment of the method further comprises adding alum to the pulp, e.g. in a total amount of 2.0-8.5 kg/tonne dry fibre, preferably 2.5-5.5 kg/tonne dry fibre, more preferably 2.5-4.5 kg/tonne dry fibre. Alum is preferably added to the pulp before any hydrophobic size is added to the pulp.

[0027] In the method, the headbox consistency of the pulp may be 0.20-0.60 %, such as 0.30-0.55 %, such as 0.35-0.50 %, in particular when the grammage is above 100 g/m^2. The present inventors have managed to obtain good formation at this headbox consistency, also when the pulp is subjected to LC refining and papermaking chemicals are added.

[0028] To improve the formation, the forming section of the paper machine may comprise a wire shaker.

[0029] In an embodiment of the method, the cross directional dry content of the web is controlled by a steam box arranged at the downstream end of the forming section.

[0030] The pH of the pulp in the head box may be in the range of 4.8-5.5, preferably 5.0-5.5.

[0031] In an embodiment of the method, inorganic filler, such as clay, is added to the pulp. Inorganic filler may be added in such an amount that the ash content of the paper is in the range of 2.0-5.5 %, such as 3.0-5.0 %. The addition of inorganic filler typically improves surface properties of the paper. A drawback of adding inorganic filler may however be lower strength properties. Also, addition of inorganic filler typically increases the density of the paper. Still, the present investors have managed to keep the density of the paper below 915 kg/m^3 (in full scale trial 1 even below 890 kg/m^3) while obtaining relatively high wet strength properties at an ash content of 4% (see table 1).

[0032] Clay is preferably added in the short circulation of the paper machine.

[0033] An embodiment of the method further comprises adding a dry strength agent to the pulp. The dry strength agent may be starch, preferably cationic starch. The total amount of starch that is added to the pulp may be 2.0-7.0 kg/tonne dry fibre, preferably 3.5-6.0 kg/tonne dry fibre.

[0034] The press section of the paper machine may comprise a shoe press, which may be operated at a line load of 650-950 kN/m, such as 750-900 kN/m. Upstream the shoe press, there may be at least one additional press nip, such as two additional press nips. The first of these may be operated at a line load of 40-90 kN/m, such as 50-70 kN/m, whereas the second may be operated at a line load of 50-100 kN/m, such as 60-90 kN/m. Hence the line load of the first press nip is preferably lower than the line load of the second press nip.

[0035] The calendering of step f) is carried out when low surface roughness is desired. The calender of step f) is preferably a soft nip calender, which may be operated at a line load of 60-170 kN/m, preferably 80-140 kN/m, such as 100-140 kN/m. The hard roll of the soft nip calender may be heated, preferably to a temperature in the range of 100-200 °C, such as 100-150 °C or 120-180 °C. The moisture content of the web may be 7.0-8.5 % when entering the calender of step f).

[0036] The method of the present disclosure facilitates the production of a paper having certain properties:

[0037] The grammage of the paper is typically 50-200 g/m^2, such as 70-160 g/m^2. The method of the present disclosure is particularly beneficial in case of a grammage of at least 100 g/m^2, such as at least 120 g/m^2. The papers produced in the full-scale trials 1-3 described below all had a grammage above 120 g/m^2 (see table 1). According to the present disclosure, grammage is measured according to ISO:536:2019.

[0038] The Bendtsen roughness of at least one side of the paper is preferably below 250 ml/min, preferably below 220 ml/min, more preferably below 160 ml/min. In one embodiment, the Bendtsen roughness of both sides of the paper is below 600 ml/min, such as below 500 ml/min, such as below 400 ml/min. In the context of the present disclosure, Bendtsen roughness is measured according to SS-ISO 8791-2:2013. To obtain low Bendtsen roughness values, step f) is carried out.

[0039] The density (measured according to ISO 534:2011) of the paper is preferably below 950 kg/m^3, more preferably below 920 kg/m^3. At the same time, the density is normally above 600 kg/m^3, more preferably below 650 kg/m^3. The present method is not intended for tissue paper or similar lightweight paper.

[0040] As shown in table 1 below, a paper having a Bendtsen roughness of below 160 ml/min on the printing side and below 400 ml/min on the reverse side as well as a density below 920 kg/m^2 was produced in full scale trial 2.

[0041] In some embodiments, the specific formation number of the paper is preferably below 1.00 √g/m, such as below 0.90 √g/m, such as below 0.85 √g/m. The specific formation number is measured according to SCAN-P 92:09, preferably using an Ambertec Beta Formation Tester

[0042] In some embodiments, the Gurley value (measured according to ISO 5636-5:2013) is preferably above 50 s, more preferably above 60 s, such as above 65 s. A typical upper limit may be 150 s or 100 s. Higher Gurley values are obtained by a relatively high degree of refining, in particular LC refining, and/or calendering.

[0043] As shown in table 1 below, the papers produced in full scale trials 1-3 had specific formation numbers below 0.85 √g/m and Gurley values above 65 s.

[0044] Preferably, the wet tensile strength index in the machine direction (MD) of the paper is at least 8.0 Nm/g, more preferably at least 9.5 Nm/g, such as above 11.0 Nm/g. In the cross direction (CD), the wet tensile strength index of the paper is preferably at least 5.5 Nm/g, more preferably at least 6.5 Nm/g, such as at least 7.5 Nm/g. Wet tensile strength index is sometimes referred to as only "wet tensile index". Wet tensile strength index is measured according to the standard ISO 1924-3:2005, which specifies a wetting time of 10 min.

[0045] Preferably, the wet tensile stiffness index in the machine direction (MD) of the paper is at least 1000 Nm/g, more preferably at least 1045 Nm/g, such as at least 1200 Nm/g. In the cross direction (CD), the wet tensile stiffness index of the paper is preferably at least 400 Nm/g, more preferably at least 445 Nm/g, such as at least 545 Nm/g. Wet tensile stiffness index is measured according to the standard ISO 1924-3:2005, which specifies a wetting time of 10 min.

[0046] As shown in table 1 below, a paper having a wet tensile strength index above 11.0 Nm/g in MD and above 7.5 Nm/g in CD as well as a wet tensile stiffness index above 1200 Nm/g in MD and above 545 Nm/g in CD was produced in full scale trial 1. This paper was also recyclable.

[0047] To improve performance in wet/humid conditions, it is also preferred that the Cobb 60 s value of at least one side of the paper is below 30 g/m^2, preferably below 25 g/m^2, more preferably below 23.5 g/m^2. In one embodiment, the Cobb 60 s value of both sides of the paper is below 30 g/m^2, such as below 25 g/m^2, such as below 23.5 g/m^2. The Cobb 60 s value is measured according to ISO 535:2014.

EXAMPLES

Full scale trial 1

[0048] A pulp mixture was prepared by mixing never-dried bleached softwood kraft pulp and never-dried bleached hardwood kraft pulp in a 50:50 dry weight ratio. The pH of the pulp mixture was adjusted to about 7 and the pulp mixture was then subjected to low consistency (LC) refining (130 kWh/tonne dry fibre, consistency = about 4%). Broke pulp was added to the LC-refined pulp mixture and the resulting pulp was subjected to thick stock screening. The proportion of broke pulp was about 15% (w/w). A-PAM (Fennobond 85E) was then added to the pulp in an amount of about 0.5 kg/tonne dry fibre. After the addition of A-PAM, the pulp was subjected to post LC refining (21 kWh/tonne dry fibre, consistency = about 3.3%).

[0049] The post LC-refined pulp was routed to the machine chest, in which alum was dosed in an amount of 3-4 kg/tonne dry fibre such that the pH of the pulp was adjusted to about 5.2. Dyes (violet and blue) and cationic starch (Raisamyl 50021, 5 kg/tonne dry fibre) were also added to the pulp in the machine chest. Rosin size (2.5 kg/tonne dry fibre), AKD (0.8 kg/tonne dry fibre) and cationic G-PAM (Fennobond 3150E, 2.8 kg/tonne dry fibre) were added to the pulp in the piping leading from the machine chest to the wire pit. The consistency of the pulp in this position was 2.2%. After the additions of rosin size, AKD and cationic G-PAM, but before the wire pit, the pulp was subjected to pumping.

[0050] Between the wire pit and the headbox pump, "heavier" particles (like sand and metal) were separated from the pulp by means of a hydrocyclones system. Air was removed from the pulp by a Perivac deaerator. Downstream the headbox pump, but upstream the headbox, cationic retention aid (Fennopol K 7526P, 0.15 kg/tonne dry fibre) and anionic retention aid/silica (FennoSil 5000, 0.45 kg/tonne dry fibre) were added. The cationic retention aid was added before machine screens and the silica was added after the machine screens. Kaolin clay was added to the short circulation in such an amount that the ash content of the final paper was about 4%.

[0051] In the headbox, the pH of the pulp was still about 5.2. The SR number of the pulp was 24-28. The headbox consistency of the pulp was about 0.45%. A paper web was formed in a forming section comprising a one-ply fourdrinier wire and a wire shaker. At the downstream end of the forming section, the web was steamed by means of a steam box to obtain an even moisture profile in the cross direction before the press section.

[0052] The press section had three nips: first a single-felted nip operated at a line load of 60 kN/, then another single-

felted nip operated at a line load of 70 kN/m and finally a shoe press nip operated at a line load of 850 kN/m. The web from the press section was dried in a drying section. After the drying section, at a moisture of 7.5-8.0 %, the web was subjected to soft nip calendering at a line load of 103 kN/m. The hard roll of the soft nip calender was heated to 150 °C. The properties of the resulting paper are presented in table 1 below.

[0053] A paper corresponding to that produced in full scale trial 1, but having a basis weight of 120 g/m^2, was tested according to PTS-method PTS-RH:021/97 (Draft Oct 2019) 'Identification of the recyclability of paper and board packages and of graphic print products' - Category II: Paper and board for Recycling (PfR) that are predominantly used in the manufacture of packaging papers. The paper passed all the tests of the method and was thus found to be "Recyclable" (despite the wet strength properties).

Full scale trial 2

[0054] Full scale trail 2 was carried out in the same way as full scale trial 1 with the following exceptions:

- The hardwood pulp was a resuspended marked pulp instead of a never-dried pulp;
- The energy consumption in the first LC refining was 112 kWh/tonne dry fibre instead of 130 kWh/tonne dry fibre;
- The energy consumption in the post LC refining was 19 kWh/tonne dry fibre instead of 21 kWh/tonne dry fibre;
- The amount of cationic retention aid was 0.20 kg/tonne dry fibre instead of 0.15 kg/tonne dry fibre; and
- The line load of soft nip calender was 130 kN/m instead of 103 kN/m.

[0055] The properties of the paper produced in trial 2 are presented in table 1 below.

Full scale trial 3

[0056] Full scale trail 3 was carried out in the same way as full scale trial 1 with the following exceptions:

- The energy consumption in the first LC refining was 80 kWh/tonne dry fibre instead of 130 kWh/tonne dry fibre;
- The energy consumption in the post LC refining was 20 kWh/tonne dry fibre instead of 21 kWh/tonne dry fibre;
- The line load of soft nip calender was 120 kN/m instead of 103 kN/m; and
- The hard roll of the soft nip calender was heated to 130 °C instead of 150 °C.

[0057] The properties of the paper produced in trial 3 are presented in table 1 below.

Table 1. Properties of the papers produced in full scale trials 1-3. PS means printing side. RS means reverse side. MD means machine direction. CD means cross direction. The formation number and the specific formation number were measured using an Ambertec Beta Formation Tester according to the standard SCAN-P 92:09.

Full scale trial #	**1**	**2**	**3**
Grammage (g/m^2)	137.7	138.4	139
Thickness (μm)	155	153	152
Density (kg/m3)	888	905	914
Gurley (s)	76	71	83
Bendtsen Roughness PS (ml/min)	217	139	213
Bendtsen Roughness RS (ml/min)	436	348	456
Cobb PS (g/m^2)	20	20	19.7
Cobb RS (g/m^2)	21	21	20.7
Formation number (g/m^2)	9.8	9.7	8.8
Specific Formation number (√g/m)	0.83	0.82	0.75
Tensile Strength MD (kN/m)	11.6	11.5	12.52
Tensile Strength CD (kN/m)	7.1	7.1	7.87

(continued)

Full scale trial #	1	2	3
Tensile Strain at break MD (%)	2.2	2.1	2.73
Tensile Strain at break CD (%)	7	6.5	7.2
Tensile Stiffness MD (kN/m)	1323	1274	1273
Tensile Stiffness CD (kN/m)	634	627	652
Wet Tensile Strength MD, 10 min (kN/m)	1.63	N/A	1.91
Wet Tensile index MD, 10 min (Nm/g)	11.84	N/A	13.74
Wet Tensile Strength CD, 10 min (kN/m)	1.12	N/A	1.21
Wet Tensile index CD, 10 min (Nm/g)	8.13	N/A	8.71
Wet Tensile Stiffness MD, 10 min (kN/m)	174	N/A	N/A
Wet Tensile Stiffness index MD, 10 min (Nm/g)	1264	N/A	N/A
Wet Tensile Stiffness CD, 10 min (kN/m)	77	N/A	N/A
Wet Tensile Stiffness index CD, 10 min (Nm/g)	559	N/A	N/A
Wet Tensile Strength MD, 15 min (kN/m)	1.55	1.46	1.72
Wet Tensile Index MD, 15 min (Nm/g)	11.26	10.55	12.37
Wet Tensile Strength CD, 15 min (kN/m)	1.0	0.94	1.1
Wet Tensile Index CD, 15 min (Nm/g)	7.26	6.79	7.91
Wet Tensile Stiffness MD, 15 min (kN/m)	164	170	136
Wet Tensile Stiffness index MD, 15 min (Nm/g)	1191	1228	978
Wet Tensile Stiffness CD, 15 min (kN/m)	62	71	50
Wet Tensile Stiffness index CD, 15 min (Nm/g)	450	513	360

[0058] Table 1 shows that recyclable papers having relatively high wet strength properties were successfully produced in trial 1-3. In addition, the produced papers exhibited satisfactory specific formation numbers, low porosity (i.e. high Gurley values) and low surface roughness (in particular on the printing side (PS)), while the density was kept at an acceptable level.

[0059] That beneficial formation numbers were obtained despite the additions of various papermaking chemicals is, at least in part, attributable to the order in which the papermaking chemicals were added as well as their concentrations and the pH and/or consistency of the pulp at their points of addition.

Full scale trial 4

[0060] A never-dried bleached softwood kraft pulp was provided. The pH of the pulp was adjusted to about 7.5 and the pulp was then subjected to high consistency (HC) refining (about 170 kWh/tonne dry fibre, consistency about 32%) followed by low consistency (LC) refining (36 kWh/tonne dry fibre, consistency = about 4%). Broke pulp was added to the refined pulp and the resulting pulp was subjected to thick stock screening. The proportion of broke pulp was about 15% (w/w). A-PAM (Fennobond 85E) was then added to the pulp in an amount of about 0.4 kg/tonne dry fibre. After the addition of A-PAM, the pulp was subjected to post LC refining (about 16 kWh/tonne dry fibre, consistency = about 3.3%).

[0061] The post LC-refined pulp was routed to the machine chest, in which alum was dosed in an amount of 3-4 kg/tonne dry fibre such that the pH of the pulp was adjusted to about 5.2. Dyes (violet and blue) and cationic starch (Raisamyl 50021, about 3.5 kg/tonne dry fibre) were also added to the pulp in the machine chest. Rosin size (about 2 kg/tonne dry fibre), AKD (0.5 kg/tonne dry fibre) and cationic G-PAM (Fennobond 3150E, 2.5 kg/tonne dry fibre) were

added to the pulp in the piping leading from the machine chest to the wire pit. The consistency of the pulp in this position was 2.2%. After the additions of rosin size, AKD and cationic G-PAM, but before the wire pit, the pulp was subjected to pumping.

[0062] Between the wire pit and the headbox pump, "heavier" particles (like sand and metal) were separated from the pulp by means of a hydrocyclones system. Air was removed from the pulp by a Perivac deaerator. Downstream the headbox pump, but upstream the headbox, cationic retention aid (Fennopol K 7526P, 0.15 kg/tonne dry fibre) and anionic retention aid/silica (FennoSil 5000, 0.3 kg/tonne dry fibre) were added. The cationic retention aid was added before machine screens and the silica was added after the machine screens.

[0063] In the headbox, the pH of the pulp was still about 5.2. The SR number of the pulp was 23. The headbox consistency of the pulp was about 0.2%. A paper web was formed in a forming section comprising a one-ply fourdrinier wire and a wire shaker. At the downstream end of the forming section, the web was steamed by means of a steam box to obtain an even moisture profile in the cross direction before the press section.

[0064] The press section had three nips; first a single-felted nip operated at a line load of 60 kN/, then another single-felted nip operated at a line load of 70 kN/m and finally a shoe press nip operated at a line load of 850 kN/m.

[0065] The web from the press section was dried in a drying section having seven dryer groups and a Clupak unit (used to compact/microcrêpe the web) arranged in series. The Clupak unit was arranged between dryer groups four and three, which means that the paper web was dried in the drying section both before and after the Clupak unit. No calendering was carried out.

[0066] The resulting paper was tested according to PTS-method PTS-RH:021/97 (Draft Oct 2019) 'Identification of the recyclability of paper and board packages and of graphic print products' - Category II: Paper and board for Recycling (PfR) that are predominantly used in the manufacture of packaging papers. The paper passed all the tests of the method and was thus found to be "Recyclable" (despite the wet strength properties). Other properties of the paper are presented in table 2 below.

Full scale trial 5

[0067] A never-dried unbleached softwood kraft pulp was provided. The pH of the pulp was adjusted to about 8 and the pulp was then subjected to high consistency (HC) refining (about 160 kWh/tonne dry fibre, consistency about 32%) followed by low consistency (LC) refining (85 kWh/tonne dry fibre, consistency = about 4%). Broke pulp was added to the refined pulp and the resulting pulp was subjected to thick stock screening. The proportion of broke pulp was about 15% (w/w). A-PAM (Fennobond 85E) was then added to the pulp in an amount of about 0.4 kg/tonne dry fibre. After the addition of A-PAM, the pulp was subjected to post LC refining (about 27 kWh/tonne dry fibre, consistency = about 3.3%).

[0068] The post LC-refined pulp was routed to the machine chest, in which alum was dosed in an amount of 7 kg/tonne dry fibre such that the pH of the pulp was adjusted to about 5.3. Cationic starch (Raisamyl 50021, 5 kg/tonne dry fibre) was also added to the pulp in the machine chest. Rosin size (about 1.5 kg/tonne dry fibre), AKD (0.4 kg/tonne dry fibre) and cationic G-PAM (Fennobond 3150E, 2.8 kg/tonne dry fibre) were added to the pulp in the piping leading from the machine chest to the wire pit. The consistency of the pulp in this position was 2.2%. After the additions of rosin size, AKD and cationic G-PAM, but before the wire pit, the pulp was subjected to pumping.

[0069] Between the wire pit and the headbox pump, larger pieces were separated from the pulp by means of a hydrocyclones system. Air was removed from the pulp by a Perivac deaerator. Downstream the headbox pump, but upstream the headbox, cationic retention aid (Fennopol K 7526P, 0.2 kg/tonne dry fibre) and anionic retention aid/silica (FennoSil 5000, 0.2 kg/tonne dry fibre) were added. The cationic retention aid was added before machine screens and the silica was added after the machine screens.

[0070] In the headbox, the pH of the pulp was still about 5.3. The SR number of the pulp was 20. The headbox consistency of the pulp was about 0.2%. A paper web was formed in a forming section comprising a one-ply fourdrinier wire and a wire shaker. At the downstream end of the forming section, the web was steamed by means of a steam box to obtain an even moisture profile in the cross direction before the press section.

[0071] The press section had three nips; first a single-felted nip operated at a line load of 60 kN/, then another single-felted nip operated at a line load of 70 kN/m and finally a shoe press nip operated at a line load of 850 kN/m.

[0072] The web from the press section was dried in a drying section having seven dryer groups and a Clupak unit (used to compact/microcrêpe the web) arranged in series. The Clupak unit was arranged between dryer groups four and three, which means that the paper web was dried in the drying section both before and after the Clupak unit. No calendering was carried out.

[0073] The properties of the paper produced in trial 5 are presented in table 2 below. Further, the inventors expect the paper produced in trial 5 to be recyclable according to the PTS method discussed above.

Table 2. Properties of the papers produced in full scale trials 4 and 5. PS means printing side. RS means reverse side. MD means machine direction. CD means cross direction.

Full scale trial #	**4**	**5**
Grammage (g/m^2)	75.7	72.3
Gurley (s)	17.3	19.1
Bendtsen Roughness PS (ml/min)	635	786
Bendtsen Roughness RS (ml/min)	1133	1197
Cobb (g/m^2)	21.1	23.3
Brightness (%)	83.5	N/A
Tensile Strength MD (kN/m)	6.1	7.48
Tensile Strength CD (kN/m)	4.6	4.56
Tensile index MD (Nm/g)	80.8	103.4
Tensile index CD (Nm/g)	60.3	63.3
Tensile Strain at break MD (%)	6.5	6.8
Tensile Strain at break CD (%)	8.7	8.4
Tear strength MD (mN)	1039	884
Tear strength CD (mN)	1125	1081
Tear index MD (mNm^2/g)	13.7	12.1
Tear index CD (mNm^2/g)	14.8	14.8
Wet Tensile Strength MD, 10 min (kN/m)	0.81	1.05
Wet Tensile index MD, 10 min (Nm/g)	10.7	14.5
Burst strength (kPa)	517	579
Burst index (kPam^2/g)	6.8	8.1

Claims

1. A method of producing a paper on a paper machine, comprising the steps of:

a) providing a pulp, such as a mixture of hardwood pulp and softwood pulp;
b) adding cationic glyoxylated polyacrylamide (G-PAM) to the pulp;
c) forming a web from the pulp in a forming section comprising a head box;
d) pressing the web in a press section;
e) drying the web in a drying section; and
f) optionally calendering the web in a calender.

2. The method of claim 1, wherein the pulp is refined, e.g. such that the Schopper-Riegler number measured according to ISO 5267-1:1999 of the pulp in the head box is 20-30, preferably 22-30, such as 23-28.

3. The method of claim 1 or 2, wherein the pH of the pulp is in the range of 4.8-5.5 when the cationic G-PAM is added.

4. The method of any one of the preceding claims, wherein the consistency of the pulp is in the range of 1.5-3.0 % when the cationic G-PAM is added.

5. The method of any one of the preceding claims, wherein cationic G-PAM is added in a total amount of 1.5-3.0 kg/tonne dry fibre, preferably 2.0-3.0 kg/tonne dry fibre, more preferably 2.5-3.0 kg/tonne dry fibre.

6. The method of any one of the preceding claims, wherein the pulp is not subjected to refining after the cationic G-PAM addition.

7. The method of any one of the preceding claims, further comprising adding an anionic polymer, such as anionic polyacrylamide (A-PAM), to the pulp before the cationic G-PAM is added.

8. The method of claim 7, wherein the pH of the pulp is in the range of 6.5-8.0 when the anionic polymer is added.

9. The method of any one of the preceding claims, further comprising adding at least one hydrophobic size, such as rosin size and/or AKD, to the pulp.

10. The method of claim 9, wherein the pH of the pulp is in the range of 4.8-5.5 and the consistency of the pulp is in the range of 1.5-3.0 % when the at least one hydrophobic size is added.

11. The method of any one of the preceding claims, further comprising adding clay to the pulp in such an amount that the ash content of the paper is in the range of 2.0-5.5 %, such as 3.0-5.0 %.

12. The method of any one of the preceding claims, wherein consistency of the pulp in the head box is 0.20-0.60 %, preferably 0.30-0.55 %, more preferably 0.35-0.50 %.

13. The method of any one of the preceding claims, wherein the calender is a soft nip calender operated at a line load of 60-170 kN/m, such as 80-140 kN/m, such as 100-140 kN/m, and/or a temperature of 100-200 °C, such as 100-150 °C or 120-180 °C.

14. The method of any one of the preceding claims, wherein the grammage measured according to ISO 536:2019 of the paper is at least 100 g/m^2 and/or the density measured according to ISO 534:2011 of the paper is at least 600 kg/m^3.

15. The method of any one of the preceding claims, wherein the specific formation number measured according to SCAN-P 92:09 of the paper is below 1.00 $\sqrt{g/m}$, such as below 0.90 $\sqrt{g/m}$, such as below 0.85 $\sqrt{g/m}$.

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Application Number
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Place of search	Date of completion of the search	Examiner
Munich	13 July 2021	Karlsson, Lennart

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