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(54) **Title:** RECYCLING FIBRES FROM POLYMER COMPOSITES

(57) **Abstract:** A method of obtaining fibres from a polymer composite comprising a polymer matrix and fibres, the fibres having a length $L(m)$ of less than $0.04m$, the method comprising the steps of: introducing the polymer composite into a fluidised bed at a feed rate $F(kgm^{-3}s^{-1})$; heating the polymer composite in the fluidised bed so that the polymer matrix substantially releases the fibres from the polymer composite; and elutriating the released fibre from the fluidised bed at a fluidising velocity $V(m/s)$ of less than $2 m/s$; the feed rate F being selected from the range: $F_1 < F < F_2$ wherein F_1 is $0.0118 - 0.36L$; and F_2 is $0.0228 - 0.56L$.



RECYCLING FIBRES FROM POLYMER COMPOSITES

This invention relates to recycling reinforcing fibres from polymer composites using a fluidised bed.

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Polymer composites, such as thermoset composites, are the combination of a polymer matrix and reinforcement fibres (for instance, glass and carbon fibres). Such composites are widely used in automobile, aeronautical, chemical and building industries due to their high strength, light weight and chemical resistance. The world market for thermoset composites has been growing in volume by 3% since 1994 and it was predicted that the output of thermoset composites would be around 7 million tonnes in 2006.

15 Recycling is a high priority and various recycling methods have been proposed for waste composites. However, composites are difficult to recycle because problems arise when trying to efficiently recycle both the polymer matrix and the reinforcement fibres. Furthermore, thermoset composites are commonly regarded as the most difficult to recycle since the polymer matrix cannot be remoulded due to its cross-linked nature.

25 Recently, a high temperature fluidised bed method was developed to decompose the polymer matrix and allow the extraction of the reinforcement fibres (Jiang *et al.*: Study of a fluidised bed process for recycling carbon fibre from polymer composites. 7th World Congress of Chemical Engineering, 2005).

30 However in this method, the throughput of recycled fibre (i.e. rate at which polymer composite can be fed into a fluidised bed) is affected by a number of variables, including temperature, input fibre length, fibre diameter, and velocity of the fluidising gas. Thus, there is a need to

select the correct values for these variables in order to operate a plant at maximum throughput to avoid unnecessary waste expense during the recycling process.

5 Accordingly, in a first aspect of the invention, there is provided a method of obtaining fibres from a polymer composite comprising a polymer matrix and fibres, the fibres having a length L (m) of less than 0.04m, the method comprising the steps of:

introducing the polymer composite into a fluidised bed at a feed
10 rate F ($\text{kgm}^{-3}\text{s}^{-1}$);

heating the polymer composite in the fluidised bed so that the polymer matrix substantially releases the fibres from the polymer composite; and

elutriating the released fibre from the fluidised bed at a fluidising
15 velocity V (m/s) of less than 2 m/s;
the feed rate F being selected from the range:

$$F_1 < F < F_2$$

wherein F_1 is $0.0118 - 0.36L$; and

F_2 is $0.0228 - 0.56L$.

20

It is within the range between F_1 and F_2 that the optimum throughput of recycled fibres may be obtained. Above feed rate F_2 , fibres tend to agglomerate within the fluidising bed rather than being elutriated out of the bed, and below feed rate F_1 , the polymer composites will not be
25 recycled efficiently. Thus within these feed rates, a fluidised bed can be operated efficiently without fibre agglomeration occurring.

This range is unexpected because previous evidence suggested that at such fluidising velocities, the maximum feed rate, i.e. F_2 , would have to be
30 much lower to prevent agglomeration.

In one embodiment, F_1 may be defined by the relationship:

$$F_1 = C_1 - 0.36L$$

wherein C_1 may be between 0.0118 and 0.0128, such as 0.0120, 0.0122, 0.0124, or 0.0126.

5

In another embodiment, F_2 may be defined by the relationship:

$$F_2 = C_2 - 0.56L$$

wherein C_2 may be between 0.0218 and 0.0228, such as 0.022, 0.0222, 0.0224 or 0.0226.

10

In a yet further embodiment, the upper range (F_2) may be defined by the relationship:

$$F_2 = C_2 - 0.6L$$

wherein C_2 may be between 0.022 and 0.023, such as 0.0222, 0.0224, 15 0.0226 or 0.0228.

In a second aspect of the invention, there is provided a method of obtaining fibres from a polymer composite comprising a polymer matrix and fibres, the fibres having a length L (m) of less than 0.04m, the 20 method comprising the steps of:

introducing the polymer composite into a fluidised bed at or below a feed rate F ($\text{kgm}^{-3}\text{s}^{-1}$);

heating the polymer composite in the fluidised bed so that the polymer matrix substantially releases the fibres from the polymer 25 composite; and

elutriating the released fibre from the fluidised bed at a fluidising velocity V (m/s) of less than 2 m/s,

wherein the feed rate F is selected in accordance with:

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$$F = \frac{0.01421V}{\phi \left(1 + 9.368 \times 10^{-8} \left(\frac{L}{d} \right)^2 + 0.0927V^4 - 4.666 \times 10^{-5} V \left(\frac{L}{d} \right) \right)^2} \pm C_3$$

10 where

d is the approximate diameter of the fibre (m), and

ϕ is the mass fraction of fibre in the composite.

and wherein C_3 is 0.003.

15 In one embodiment, C_3 may be between 0 and 0.003, such as 0, 0.0005, 0.001, 0.0015, 0.002 or 0.0025.

In either aspect, the fluidising velocity may be less than or equal to 1.75m/s. The fluidising velocity may be selected from the range 0.75m/s
 20 to 1.5m/s inclusive. In one embodiment, various values may be chosen for fluidising velocity, for example the fluidising velocity might be substantially 0.9m/s, substantially 1.0m/s, substantially 1.1m/s, substantially 1.2m/s, substantially 1.3m/s, substantially 1.4m/s, or substantially 1.5m/s.

25

Previously, it was predicted that an increase in fluidising velocity would lead to a direct increase in throughput of the fluidised bed. As a result, it was thought that the maximum throughput could be achieved by increasing the fluidising velocity. It is therefore surprising that the
 30 optimum feed rate, i.e. the optimum throughput, may be achieved with relatively low fluidising velocities.

In either aspect, the length of the fibres in the composite may be selected from the range:

35

$$L_1 < L < L_2$$

wherein L_1 is selected from the list consisting of 0.001, 0.002, 0.003, 0.004, 0.005, 0.006, 0.007, 0.008, 0.009 and 0.01; and

L_2 is selected from the list consisting of 0.035, 0.03, 0.028, 0.026, 0.024, 0.023, 0.022, 0.021, 0.02, 0.019, 0.018, 0.017, 0.016 and 0.015.

5

In one embodiment, the fluidising velocity may be between 1.0m/s and 1.30m/s when the fibre length is less than or equal to 0.015m. In another embodiment, the fluidising velocity may be between 1.20m/s and 1.60m/s when the fibre length is greater than or equal to 0.015m.

10

The fluidised bed may be used under any of the conditions defined above in relation to the first and second aspects of the invention. In one embodiment, the reinforcing fibres are carbon fibres.

15 The invention will now be more fully described, by way of example only, with reference to the following drawings, in which:

20 **Figure 1** is a schematic diagram of a high temperature fluidised bed process for recycling polymer composite in accordance with the invention;

Figure 2 is a graph showing the variation of fibre release time with temperature;

25 **Figure 3** is a graph derived from experimental data showing the variation of the critical value of the elutriation rate constant K with fluidising velocity for 5mm, 20mm, and 30mm fibres;

30 **Figure 4** is a graph derived from experimental data showing the variation of the critical value of the elutriation rate constant K with fibre length;

Figure 5 is a graph derived from experimental data showing the variation in feeding rate with fibre length for various fluidising velocities; and

5

Figure 6 is a graph similar to Figure 5 showing the predicted variation in feeding rate with fibre length for various fluidising velocities.

10 Figure 1 shows apparatus for recycling polymer composite. The apparatus 1 comprises a fluidised bed 3, a polymer composite feed unit 5, and a cyclone 7. A fan 9 is provided which in use draws air from an air inlet 11 through the fluidised bed 3 and cyclone 7. Air exhausted from the cyclone 7 passes into afterburner 13.

15

Fluidised bed 3 consists of a substantially cylindrical housing 15 containing fluidising particles 17, such as sand. The bed 3 has a diameter of 0.3m and a height of 2.5m. Approximately 7kg of sand particles, having an average diameter of 0.8mm, are contained in the bed 3 in this example. Particles 17 rest on an air distributor plate 19. The air distributor plate 19 comprises many holes 21, which are dimensioned so as to allow fluidising air 23 to pass upwardly through the plate 19, but which prevent sand 15 from falling downwardly through the plate.

25 In use, fan 9 draws air 10 from the air inlet 11 past electric preheating elements 25. The preheating elements 25 are arranged to heat the air 10 prior to its entry into the fluidised bed.

Feed unit 5 holds scrap polymer composite 27. The polymer composite 27 consists of pieces of composite that have been cut into small pieces, by shredding, for example, and screened to substantially ensure

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that each piece is at or below a maximum size. Such composite 27 may be off-cuts produced during manufacturing, for example, or may comprise composite at the end of its useable life, or may be composite obtained from any other source, or a mixture of sources.

5

Each piece of polymer composite contains reinforcing fibres, which may be substantially parallel to each other, or which may be of random orientation, or intertwined, for example in a braid, depending on how the composite was manufactured originally. It will be appreciated that the maximum possible length of each reinforcing fibre within a piece of polymer composite corresponds roughly to a maximum dimension, such as diameter or diagonal length, of the piece of composite comprising the fibre. The term fibre length is used throughout to refer to the maximum fibre length expected to be present within a batch of polymer composite which has been screened to ensure each piece of composite is at or below a maximum size.

In use, the screened pieces of polymer composite 27 are fed into the cylinder 15 using conventional screw feed 29. As the composite is fed into the bed 3, pre-heated air 23 is drawn past the preheating elements 25 and up through the distributor plate 19 into the fluidised bed 3, causing the sand particles 15 to flow in a similar manner to a fluid, as is well known. This ensures that the composite is distributed substantially evenly throughout the bed.

25

The temperature in the bed 3 is then raised to a temperature sufficiently high to at least partially decompose the polymer matrix. This may be achieved by increasing the temperature of the fluidising air. Alternatively, the bed need not be fluidised during heating, and the bed may be heated by other means, such as direct heating elements (not shown).

30

The temperature chosen must be sufficiently high to decompose the polymer in order to release the fibre from the polymer matrix. A temperature above 450°C is presently considered sufficient, as below that temperature the polymer may not decompose. The decomposition time for the polymer matrix generally reduces as temperature increases. However, the quality of some fibres, such as glass fibre, may degrade at high temperatures. Glass fibre becomes brittle, and consequently its reinforcing properties are diminished, as the temperature to which it is heated increases. In such cases, a temperature of 550°C, which balances a relatively short decomposition time with minimal degradation of fibre may be used. A higher temperature, such as 650°C or above, could be used where degradation of the fibre to be recovered is not of concern.

At 450°C or above, the polymer matrix of the polymer composite at least partially decomposes and volatilises, leaving some char behind. After some time, when the char has been oxidised to a critical level, the reinforcing fibres are released into the bed 3 by attrition (if the bed 3 was not fluidised during heating then the bed should be re-fluidised to allow attrition and elutriation of the fibres). In addition to the fibres, any filler material present in the composite is also released. The released fibres and fillers are much lighter than the sand 15 making up the fluidised bed, and are carried out of the bed by the fluidising gas 23. The vaporised components of the polymer are also carried out of the bed with the fluidising gas 23.

The composite may be introduced into the bed 3 continuously, at a predetermined feed rate, once the fluidised bed 3 has reached the chosen operating temperature. Alternatively, the fluidised bed may be operated as a batch process.

The fluidising gas 23 is drawn up out of the fluidised bed and into the cyclone 7. In the cyclone 7 fibres and fillers are separated from the fluidising air 23. Additional apparatus (not shown) may be provided to separate the fibres from the fillers if desired.

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The vaporised components of the polymer are carried out of the cyclone as part of exhaust gas 31, which is drawn into afterburner 13 by secondary fan 33. Exhaust gases 31 are heated in afterburner 13 to a temperature sufficient to fully oxidise the organic components of gas 31.

10 A temperature in excess of 1000°C is presently considered sufficient. The flue gas 35 exiting afterburner 13 is substantially clean, although if desired it may be subjected to further cleaning before release into the atmosphere, for example, to remove any traces of particulates. In addition, energy may be recovered from the hot flue gas, for example by
15 using it to heat or partially heat cold air 10 drawn into the apparatus by fan 9.

Model of Recycling Process:

There is now described a model of the recycling process, which can be
20 used to predict the throughput of recycled fibre for various conditions without the need for experimentation. In addition, the maximum likely throughput can be estimated.

It is well known that the maximum fibre feed rate can be determined
25 using the equation:

$$F = x_{cw} K \quad (1)$$

Where

F is the feed rate of the reinforcing fibres;

x_{cw} is the maximum fibre concentration in the bed by weight that
30 can be allowed

K is the elutriation rate constant.

However, the prior art suggested that Wen and Hassinger's method was best for the calculation of elutriation rate constant (K). (C.Y. Wen, R.F. Hashinger, AIChE Journal 6 (1960) 220). This suggested a linear
5 relationship between the elutriation rate constant (K) and the fluidising air velocity, i.e. higher the velocity of the fluidising gas, the higher the value of K. However, experimental investigations have now shown that this is incorrect.

10 Figures 3 and 4 show values of K at the critical (maximum) fibre concentration in the fluidised bed, above which the value of K decreases and agglomeration forms.

Figure 3 shows the critical values for K at different fibre lengths and
15 different fluidising velocities, and Figure 4 shows how the critical value of K varies with fibre length at a velocity of 0.94m/s.

It can be seen from Figure 3 that K peaks at a certain fluidising air velocity for each length, and then begins to decrease as fluidising velocity
20 is increased beyond that air velocity. This is in contrast to the linear relationship suggested by the Wen and Hassinger correlation.

For example, there is a distinct peak in the critical value of K when the fibre length is 20mm and the fluidising velocity is in the region of
25 1.175m/s. There is also a distinct peak in the critical value of K for a fibre length of 30mm when the fluidising velocity is in the region of 1.4 m/s. A less pronounced peak is seen in the critical values of K for a fibre length of 5mm, but it can still be seen that a fluidising velocity of between 0.75m/s and 1.5m/s is preferable.

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Figure 5 shows a graph drawn from the equation (1) using the new experimentally determined values of K . It can be seen that the feed rate varies depending on the fibre length and the fluidising velocity, as will be discussed in more detail below.

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The feed rate of scrap composite material (F) that can be fed into a fluidised bed before fibre agglomeration takes place, can also be determined using the following equation:

10

$$F = \frac{0.01421V}{\phi \left(1 + 9.368 \times 10^{-8} \left(\frac{L}{d} \right)^2 + 0.0927V^4 - 4.666 \times 10^{-5} V \left(\frac{L}{d} \right) \right)^2} \quad (2)$$

Where

F is the carbon fibre composite feed rate per unit volume of fluidised bed when static [kg/m³s]

15

V is the fluidising velocity [m/s]

L is the maximum length of the carbon fibre in the feed [m]

D is the diameter of the carbon fibre [m]

ϕ is the mass fraction of carbon fibre in the composite.

20 This equation was derived from the experimental data, by a complex process comprising curve fitting to the experimentally measured values for K and x_{cw} and expressing the measured values in terms of material properties and fluidised bed process variables . It is based on the use of a fluidised bed using sand with a bulk density of 1600 kg/m³ fluidised with
25 air.

Figure 6 shows a graph drawn from the equation (2) using a range of fluidising velocities and fibre lengths.

Previously, it was thought that maximum feed rate increased as fluidising velocity increased, and decreased as fibre length increased. However, it can be seen from both Figures 5 and 6 clearly demonstrate that the highest fluidising velocities do not give the highest feed rates as was previously stated in the prior art.

Figure 5 shows a velocity in the region of 1.41m/s consistently gives a higher feed rate than the higher velocity of 1.76m/s, for any fibre length. This is also the case for a velocity of 1.5m/s, as shown in Figure 6. A velocity in the region of 1.4m/s $\pm$ 0.05m/s is preferred.

The optimum fluidising velocity also varies depending on the fibre length. For shorter fibre lengths, of 15mm and below, it can be seen that a relatively low fluidising velocity, such as 1m/s or 0.94m/s, gives feed rates that are above 0.010 kg/m³s for fibre lengths shorter than 15mm. This is much higher than previously predicted.

A fluidising velocity between 1.0m/s and 1.5m/s for shorter fibres, allows feed rates in the region of 0.018kg/m³s to be achieved for very short fibre lengths of 5mm, and feed rates in the region of 0.012 kg/m³s to be achieved for 15mm fibres. Lower fluidising velocities require less energy, and so it can be advantageous to run a bed at the lowest fluidising velocity possible that still gives a good throughput, here 1.0m/s or 1.25m/s.

For longer fibre lengths, of approximately 20mm and above, such as, 25mm and 30mm fibres, surprisingly high feeding rates of between 0.008kg/m³s and 0.004kg/m³s can be achieved with moderate fluidising velocities in the region of 1.4m/s $\pm$ 0.05m/s. For instance, a fluidising velocity of between 1.20m/s and 1.5m/s, such as 1.41m/s allows a

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maximum feed rate of approximately 0.008kg/m³s for 20mm fibres, and 0.004kg/m³s for 30mm fibres.

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CLAIMS

1. A method of obtaining fibres from a polymer composite comprising a polymer matrix and fibres, the fibres having a length L (m) of less than
5 0.04m, the method comprising the steps of:
introducing the polymer composite into a fluidised bed at a feed rate F ($\text{kgm}^{-3}\text{s}^{-1}$);
heating the polymer composite in the fluidised bed so that the polymer matrix substantially releases the fibres from the polymer
10 composite; and
elutriating the released fibre from the fluidised bed at a fluidising velocity V (m/s) of less than 2 m/s;
the feed rate F being selected from the range:
$$F_1 < F < F_2$$

15 wherein F_1 is $0.0118 - 0.36L$; and
 F_2 is $0.0228 - 0.56L$.
2. A method according to claim 1 wherein $F_1 = 0.0123 - 0.36L$.
- 20 3. A method according to claim 1 wherein $F_1 = 0.028 - 0.36L$.
4. A method according to any preceding claim wherein $F_2 = 0.223 - 0.56L$.
- 25 5. A method according to any of claims 1 to 3 wherein $F_2 = 0.218 - 0.56L$.
6. A method according to any of claims 1 to 3 wherein $F_2 = 0.22 - 0.6L$.

7. A method of obtaining fibres from a polymer composite comprising a polymer matrix and fibres, the fibres having a length L (m) of less than 0.04m, the method comprising the steps of:

introducing the polymer composite into a fluidised bed at or below
5 a feed rate F ($\text{kgm}^{-3}\text{s}^{-1}$);

heating the polymer composite in the fluidised bed so that the polymer matrix substantially releases the fibres from the polymer composite; and

elutriating the released fibre from the fluidised bed at a fluidising
10 velocity V (m/s) of less than 2 m/s,

wherein the feed rate F is selected in accordance with:

$$F = \frac{0.01421V}{\phi \left(1 + 9.368 \times 10^{-8} \left(\frac{L}{d} \right)^2 + 0.0927 V^4 - 4.666 \times 10^{-5} V \left(\frac{L}{d} \right)^2 \right)} \pm C_3$$

where

d is the approximate diameter of the fibre (m), and

ϕ is the mass fraction of fibre in the composite; and

25 wherein C_3 is 0.003.

8. A method according to claim 7 wherein $C_3 = 0.001$.

9. A method according to claim 7 wherein $C_3 = 0$

30

10. A method according to any preceding claim wherein the fluidising velocity is less than or equal to 1.75m/s.

11. A method according to any preceding claim wherein the fluidising
35 velocity is selected from the range 0.75m/s to 1.5m/s.

12. A method as claimed in any preceding claim wherein the fluidising velocity is substantially 1.0m/s.

5 13. A method as claimed in any of claims 1 to 11 wherein the fluidising velocity is substantially 1.25m/s.

14. A method as claimed in any of claims 1 to 11 wherein the fluidising velocity is substantially 1.5m/s.

10

15. A method as claimed in any preceding claim wherein the length of the fibres in the composite are selected from the range:

$$L_1 < L < L_2$$

wherein L_1 is 0.001m

15 L_2 is 0.03m

16. A method as claimed in any of claims 1 to 11 wherein the fibre length is less than or equal to 15mm and the fluidising velocity is substantially between 1.0m/s and 1.30m/s.

20

17. A method as claimed in any of claims 1 to 10 wherein the fibre length is greater than or equal to 15mm and the fluidising velocity is substantially between 1.20m/s and 1.60m/s.

25 18. A method as claimed in any preceding claim wherein the reinforcing fibres are carbon fibres.

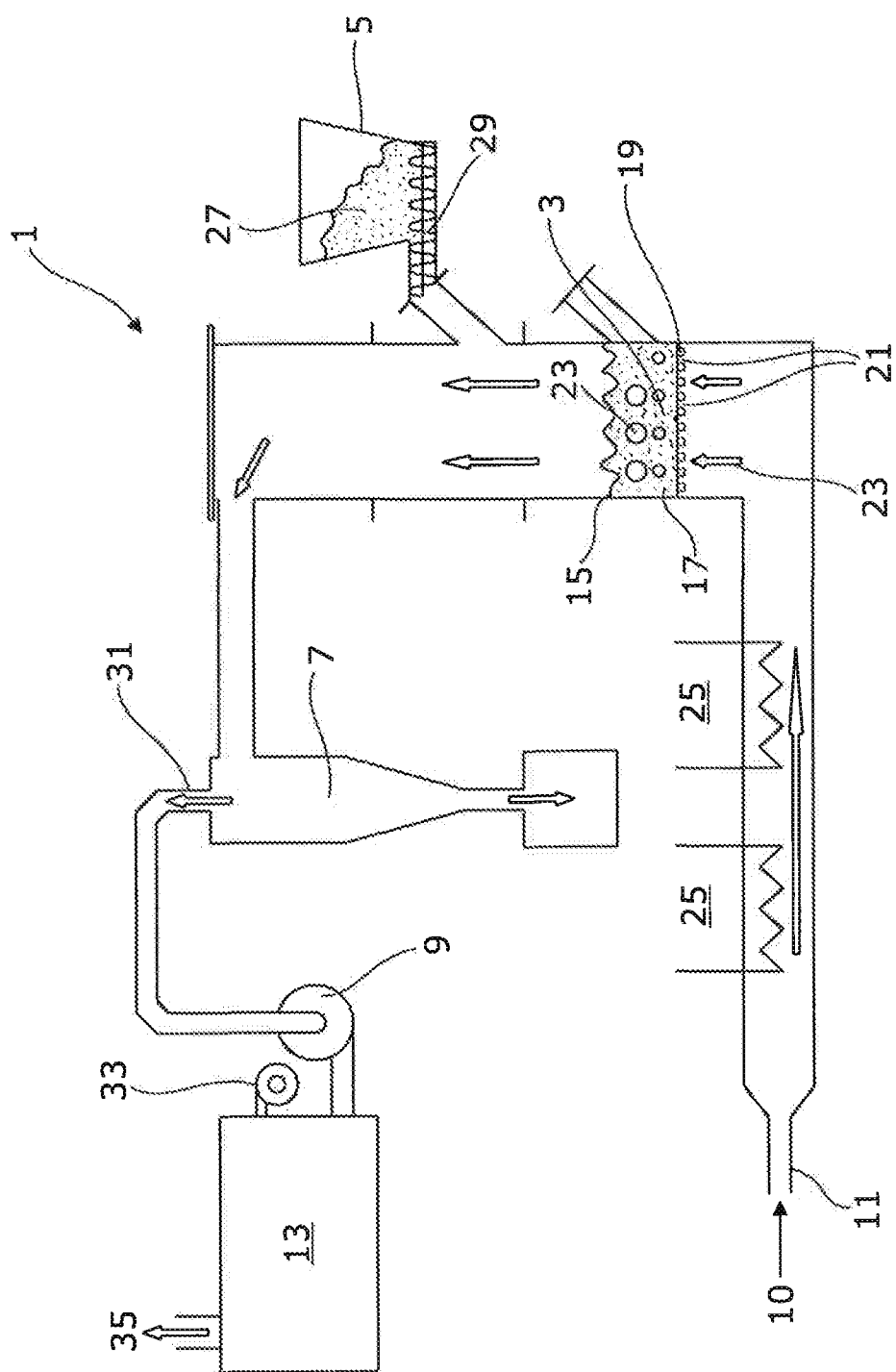


Figure 1

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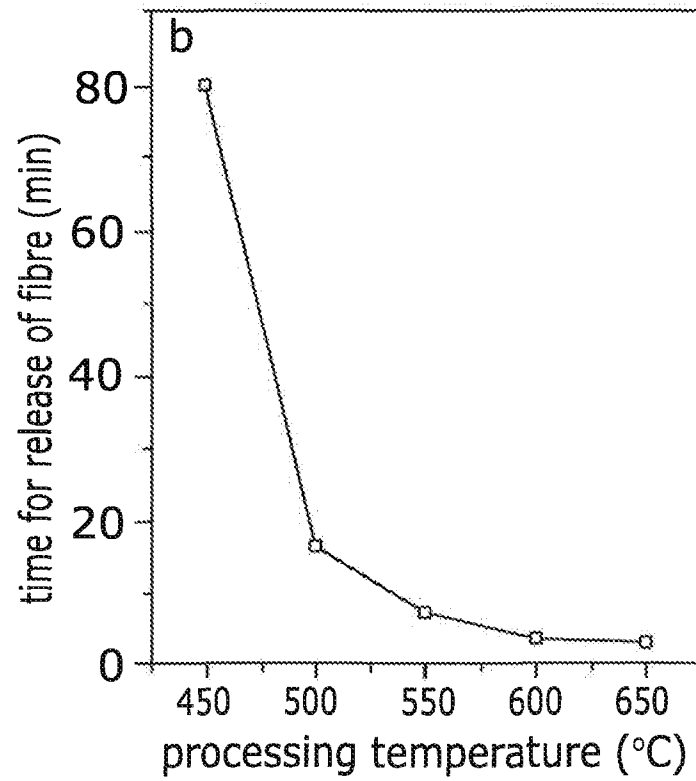


Figure 2

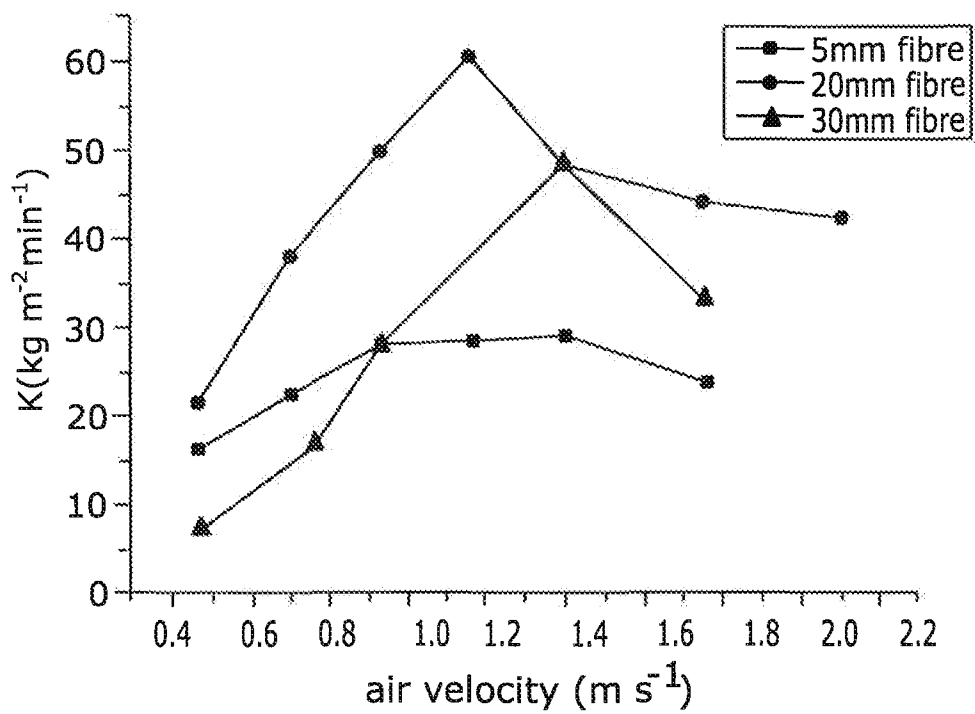


Figure 3

3/4

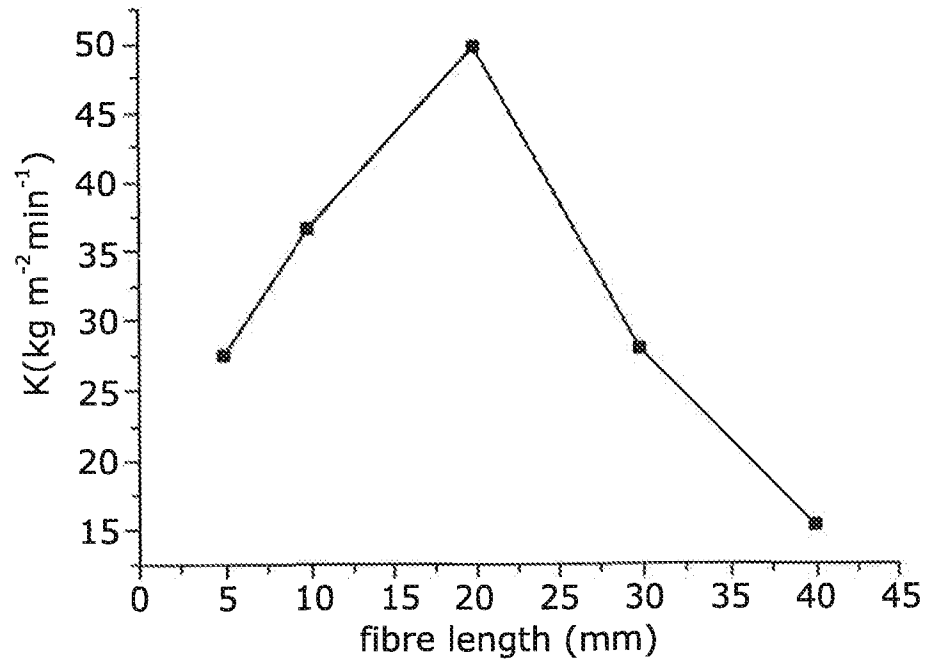


Figure 4

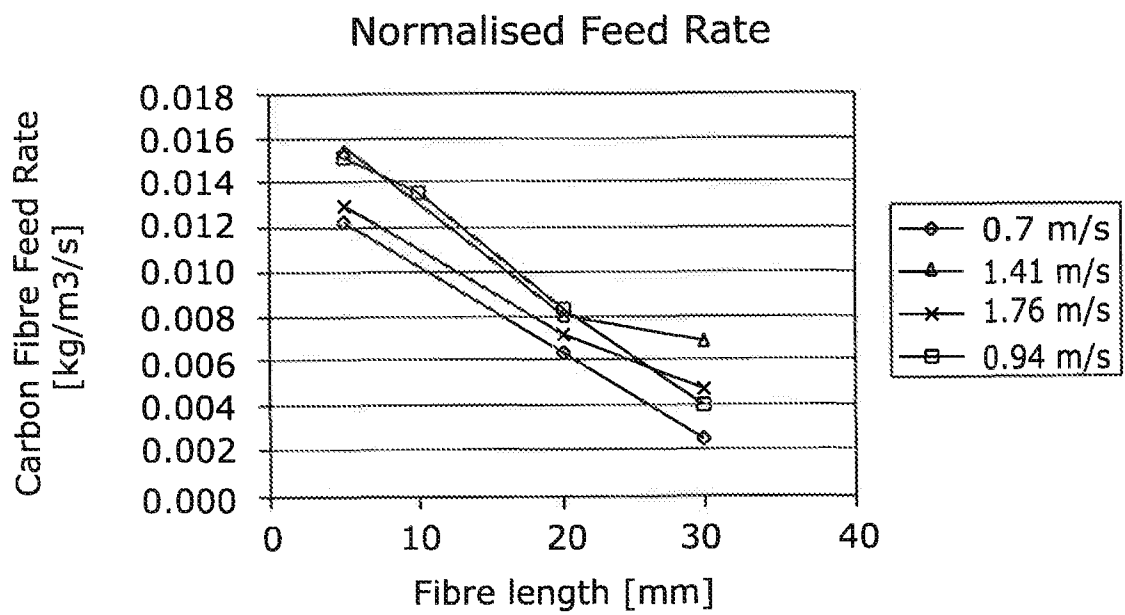


Figure 5

Maximum Carbon Fibre Composite Feed Rate

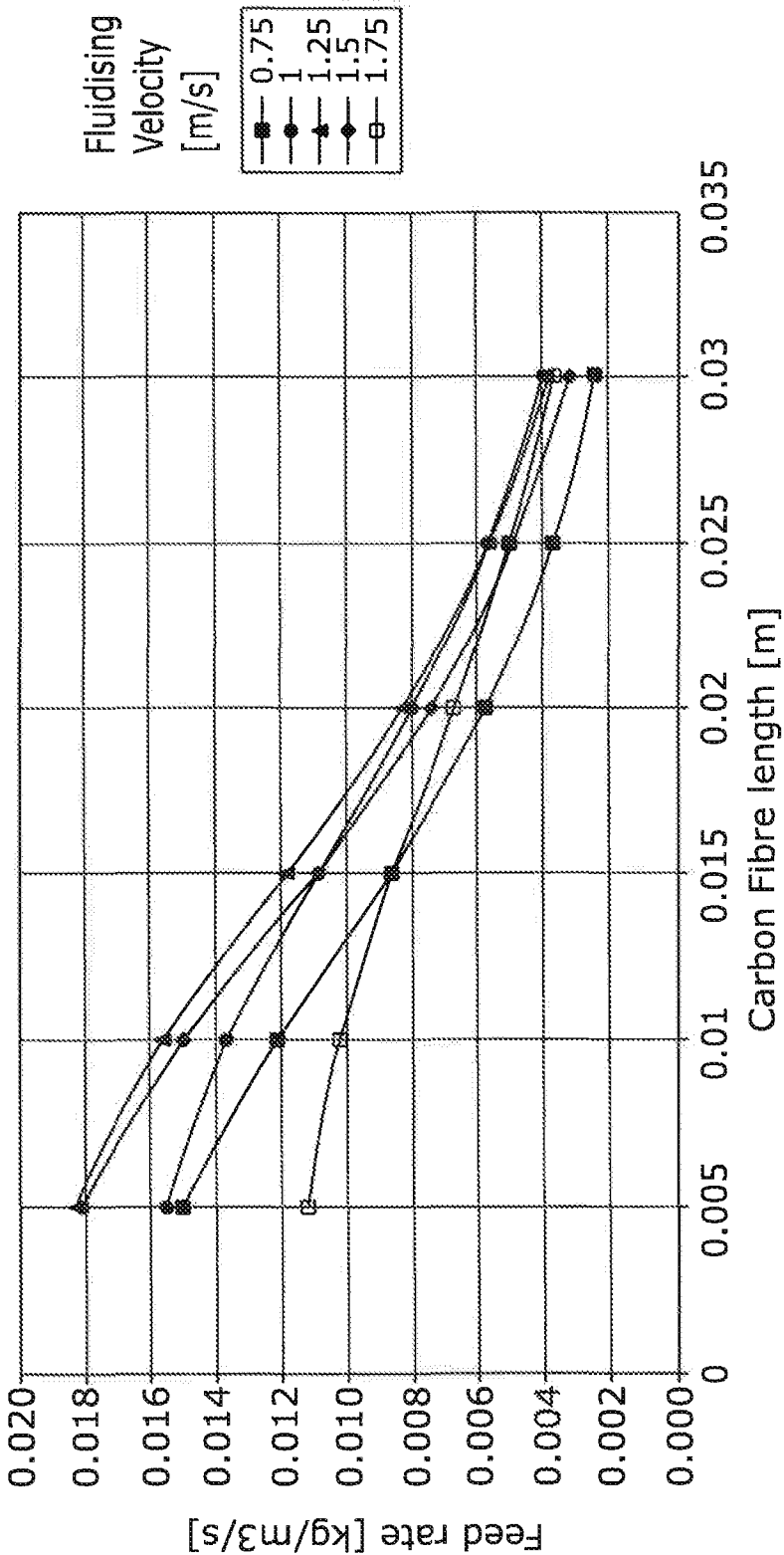


Figure 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2012/051369

A. CLASSIFICATION OF SUBJECT MATTER

INV. C08J11/04 B09B3/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C08J B09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	S.J. PICKERING ET AL: "A fluidised-bed process for the recovery of glass fibres from scrap thermoset composites", COMPOSITES SCIENCE AND TECHNOLOGY, vol. 60, no. 4, 1 March 2000 (2000-03-01), pages 509-523, XP55039913, ISSN: 0266-3538, DOI: 10.1016/S0266-3538(99)00154-2 *Section 2.3* page 512, left-hand column ----- -/--	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

3 October 2012

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2012/051369

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KENNERLEY J R ET AL: "The characterisation and reuse of glass fibres recycled from scrap composites by the action of a fluidised bed process", COMPOSITES, IPC BUSINESS PRESS LTD. HAYWARDS HEATH, GB, vol. 29, no. 7, 1 July 1998 (1998-07-01), pages 839-845, XP004131459, ISSN: 0010-4361, DOI: 10.1016/S1359-835X(98)00008-6 abstract	1-18
X	PICKERING ET AL: "Recycling technologies for thermoset composite materials-current status", COMPOSITES PART A: APPLIED SCIENCE AND MANUFACTURING, ELSEVIER SCIENCE PUBLISHERS B.V., AMSTERDAM, NL, vol. 37, no. 8, 1 August 2006 (2006-08-01), pages 1206-1215, XP028012910, ISSN: 1359-835X, DOI: 10.1016/J.COMPOSITESA.2005.05.030 [retrieved on 2006-08-01] abstract	1-18
X	JIANG ET AL: "Surface characterisation of carbon fibre recycled using fluidised bed", APPLIED SURFACE SCIENCE, ELSEVIER, AMSTERDAM, NL, vol. 254, no. 9, 12 October 2007 (2007-10-12), pages 2588-2593, XP022472443, ISSN: 0169-4332, DOI: 10.1016/J.APSUSC.2007.09.105 abstract	1-18
X	DATABASE WPI Week 200929 Thomson Scientific, London, GB; AN 2009-G47326 XP002683670, & CN 101 380 638 A (UNIV BEIHANG) 11 March 2009 (2009-03-11) abstract	1-18
A	JP 11 116727 A (NIPPON KOKAN KK) 27 April 1999 (1999-04-27) abstract	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2012/051369

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
CN 101380638	A	11-03-2009	NONE	

JP 11116727	A	27-04-1999	NONE	
