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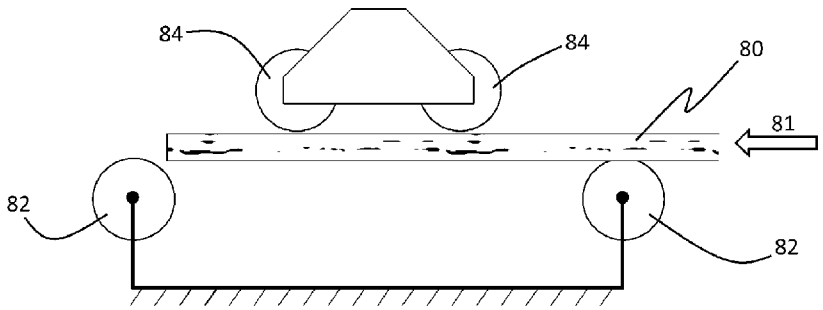


Figure 1

(57) **Abstract:** A method of manufacturing a structural panel for building construction, comprising: subjecting timber feedstock to machine stress grading wherein individual timber sticks that satisfy the grading criteria are allocated a stress grade for structural use; selecting from the timber sticks that fail to satisfy the machine stress grading standard criteria, laminas for forming a panel; arranging the selected timber laminas, without regard to visual defects, in side-by-side parallel formation; and fabricating a structural panel wherein the selected timber laminas are arranged side-by-side parallel to one another with adhesive applied between each adjacent stick incorporated into the panel.

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ENGINEERED TIMBER PANEL FOR STRUCTURAL USE AND METHOD OF FORMATION THEREOF

TECHNICAL FIELD

[001] This invention relates to engineered timber panels for use in building structures, methods for manufacturing such timber panels and buildings constructed therefrom.

BACKGROUND OF THE INVENTION

[002] There are a number of different construction systems commonly used for house construction in Australia, such as timber framing, steel framing, masonry and concrete panel. Timber and steel framed structures are typically finished with surfaces of relatively lightweight, non-structural cladding panels, whereas masonry and concrete walls are forms of solid mass construction.

[003] From an environmental impact point of view, timber structures have a number of advantages. For example, in terms of carbon emissions and storage:

Carbon released and stored in the manufacture of building materials

Material	Carbon released (kg/t)	Carbon released (kg/m^3)	Carbon stored (kg/m^3)
Sawn timber	30	15	250
Steel	700	5,300	0
Concrete	50	120	0
Aluminium	8,700	22,000	0

[004] Embodied energy is another important point of differentiation between construction systems:

Embodied energy (EE) per unit area of assembly over life span

Material	Initial EE of walls (MJ/m^2)	Maintenance EE - 40 yr. (MJ/m^2)	Total EE - 40 yr. life cycle (MJ/m^2)
Timber frame, timber clad, painted	31,020	24,750	55,770

Embodied energy (EE) per unit area of assembly over life span			
Material	**Initial EE of walls (MJ/m²)**	**Maintenance EE - 40 yr. (MJ/m²)**	**Total EE - 40 yr. life cycle (MJ/m²)**
Timber frame, brick veneer, unpainted	92,565	nil	92,565
Double brick, unpainted	141,900	nil	141,900
Autoclaved aerated concrete, painted	76,560	24,750	101,310
Steel frame, fibre cement clad, painted	75,900	24,750	100,650

[005] Embodiments of the present invention exploit modern-day timber milling practices to provide a cost effective system for building construction that combines the advantages of a solid mass construction with the environmental benefits of timber materials.

SUMMARY OF THE INVENTION

[006] In accordance with the present invention there is provided a method of manufacturing a structural panel for building construction, comprising: subjecting timber feedstock to machine stress grading wherein individual timber sticks that satisfy the grading criteria are allocated a stress grade for structural use; selecting from the timber sticks that fail to satisfy the machine stress grading standard criteria, laminas for forming a panel; arranging the selected timber laminas, without regard to visual defects, in side-by-side parallel formation; and fabricating a structural panel wherein the selected timber laminas are arranged side-by-side parallel to one another with adhesive applied between each adjacent stick incorporated into the panel.

[007] Surprisingly, it has been found that panels manufactured according to embodiments of the invention, although made from timber machine graded as not suitable for structural application, exceed measurable criteria for structural use, and expectations, when tested. In contrast to prior art systems, visual inspection of the laminas and/or specific arrangement thereof according to visual defects has been found to be unnecessary. Moreover, unlike prior art systems re-sawing is not required.

[008] The present invention also provides a timber panel for structural use in buildings, manufactured according to the method of the invention.

[009] The present invention further provides a building comprising one or more structural walls formed from at least one timber panel manufactured according to the method of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Further aspects, features and advantages of the present invention may be better understood from the following description of embodiments thereof, presented by way of example only, and with reference to the accompanying drawings, wherein:

Figures 1, 2 and 3 diagrammatically illustrate timber machine grading employed in embodiments of the invention;

Figure 4 is a flow-chart diagram of a process for manufacturing panels according to an embodiment of the invention;

Figure 5 is a diagrammatic illustration of timber feedstock for forming panels according to embodiments of the invention;

Figure 6 is a diagrammatic illustration of a timber panel for structural building according to a first embodiment of the invention;

Figure 7 is a diagrammatic illustration of a timber panel for structural building according to a second embodiment of the invention;

Figure 8 is a diagrammatic illustration of a timber panel for structural building according to a third embodiment of the invention;

Figure 9 is a diagrammatic illustration of a building structure formed from timber panels according to embodiments of the invention;

Figures 10 to 12 are diagrams showing results from testing embodiments of the invention; and

Figure 13 is a table indicating structural design properties for F-grade timbers.

DETAILED DESCRIPTION

[0011] Structural timber is generally sold as a stress graded product. A stress grade

is the classification of a timber when used in structural applications, according to the requirements of Australian Standard AS 1720.1 for example. Stress grades are derived from either visual- or machine-grading, which specify the stress limits that apply to timbers used for structural applications. Stress grades are known by either:

- 'F' grades -- F4 to F34. For example F14 indicates that the basic working stress (in bending) for that timber is around 14 MPa.
- Machine-graded pine MGP -- MGP10 to MGP15. For example MGP10 indicates a minimum threshold for stiffness properties of 10,000 MPa. Currently, nearly all exotic plantation softwoods (*Pinus* species) are graded using this system.

[0012] Structural grading is based on correlation between strength and a grading parameter. In the case of machine stress grading, that relates to stiffness on the flat side of the timber stick, i.e. minor axis modulus of elasticity. Timber that is unable to meet the grading criteria required for structural use is sold as utility grade or merchant grade timber. Understandably, this grade of timber is substantially less expensive to purchase, since its scope for application is limited.

[0013] Timber machine grading is diagrammatically illustrated in Figures 1, 2 and 3. A timber stick 80 is longitudinally fed between two sets of rollers 82, 84, the flat sides of the timber facing the rollers (Figure 1). As the timber stick 80 passes between the rollers a force (indicated by arrow 86) is applied through the rollers 84 to place a load on the section of the timber supported between the rollers 82 (Figure 2). The load force and the resulting amount of deflection of the timber (minor axis bending) is used to estimate the modulus of elasticity (MoE) E as a continuous measurement along the length of the timber stick (apart from end portions where the timber does not extend the full length between rollers 82). The result is represented in a graph 90 shown in Figure 3 illustrating the measurement indicative of modulus of elasticity (MoE) along the length (d) of the timber stick. The minimum 91 determines the stress grade allocated to that particular piece of timber, in this example MGP12.

[0014] Modern machine stress grading of timber is efficient for the timber mill insofar as timber can be graded quickly and without human expertise, as is required for visual grading. Nevertheless, a single flaw such as a knot or split on a particular timber stick can

result in machine grading effectively discarding that timber as far as structural use is concerned. However, the present inventor has recognised that such timber can be put to structural use in a very efficient manner, as described herein.

[0015] Advanced engineered timber solutions use gluing, laminating and jointing techniques to increase the compressive and tensile strength of lower structural grade timbers and overcome natural weaknesses such as knots, warping, splitting and bowing. Materials include plywood, particleboard and fibreboard as well as engineered products such as glue laminated timber, laminated veneer lumber (LVL) and finger-jointed cladding or fascia.

[0016] Glulam, short for glued laminated timber, is an engineered timber product. In terms of structural use, engineered timber products such as glulam are typically employed as beams and other members in a frame construction. The manufacturing process produces large and long length glulam members from smaller pieces of stress graded seasoned timber. The high strength and stiffness of glulam enables large, unsupported spans to be constructed.

[0017] Embodiments of the present invention utilise glulam techniques in a different manner, to produce structural wall panels and the like from timber laminas that have not been able to be graded as MGP that would otherwise be suitable for structural use.

[0018] Details of the construction method (10) for producing such timberwork panels are set out below, with reference to the flow chart diagram presented in Figure 4 of the accompanying drawings.

[0019] As outlined above, timber feedstock (12) is stress graded before being sold for use. The applications for which the timber is rated is determined by the stress grade allocated to it. For softwood timber species, the stress grade is typically allocated by a machine grading process (MGP) in accordance with Australian Standard AS 1748 (Timber – Solid – Stress-graded for structural purposes). Individual timber laminas that meet the objective requirements of the MGP grading process (14) are passed for use in structural applications (16). Timber laminas (18) that do not meet those requirements is sold as utility grade or merchant grade timber. It is kiln dried and has passed the full timber manufacturing process except that it has not been able to be graded as MGP suitable product.

[0020] Timber (24) from the non-structurally graded feedstock (18) are selected (20) for use in manufacturing panels according to embodiments of the invention. Certain timber (22) may be rejected for obvious flaws such as splitting, unsuitably warped or the like.

[0021] Full length timber or finger jointed timber laminas (sticks) are to be used to produce the panels. A finger joining process (26) is applied in accordance with GLTAA qualified glulam manufacturing processes, using Jowapur 686.20 polyurethane glue. Lamina are then machined (28) to a maximum of 42mm thickness, to make up varying width of panels. Lamina (30) which have been split, or with excessive wain or machining want (allowable minimum 2/3 surface clean-up by width over maximum 1/3 of the laminate by length) are not to be used to produce panels.

[0022] To form the panels, the selected timber laminas are arranged in side-by-side parallel formation, without regard to any visual defects contained in the sticks. Jowapur 686.20 or 686.70 polyurethane glue is applied to laminates (32) prior to loading laminates into a press. Optionally, the individual lamina may also be nailed to adjacent layers. Pressure is applied to the laminates within the press (34) in accordance with GLTAA qualified glulam manufacturing processes. Once removed from presses, the panel surfaces may be dressed (36) and the panels are cut to required size (38). In some cases, a surface layer, such as plywood, may be applied (40) to one of both faces of the panel.

[0023] Figure 5 illustrates timber feedstock 100 for use in forming panels according to embodiments of the invention, showing full length timber 101 and an example of a timber lamina 102 that has a finger joint at 105. According to one exemplary embodiment of the invention, the timber feedstock 100 comprises 90mm × 45mm seasoned timber of 2950mm lengths. It is of course possible to use other sizes/dimensions of timber feedstock (another example is 140mm × 45mm) to form panels of various thicknesses, widths and lengths according to embodiments of the invention.

[0024] Figure 6 illustrates an example of a completed panel 120 in which a plurality of timber laminas 100 have been laminated together. The panel 120 comprises twenty-two timber laminas 100 bonded together according to the process as described herein, with Jowapur one component polyurethane prepolymer adhesive as per AS/NZL 4364 to produce panels, in this instance, approximately 2950mm high × 950mm wide.

[0025] Figure 7 illustrates another example of a completed panel 140 in which a plurality of timber sticks 100 have been laminated together. The panel 140 comprises twenty-two timber sticks 100 glued and nail laminated together according to the process as described herein. The lamina are bonded using Bostik Ultraset adhesive in accordance with manufacturer's recommendation, with individual lamina additionally fixed to one another using power driven 75mm bullet head nails at 300mm spacing. The panel 140 further comprises 9mm thick structural plywood applied to both faces (grain direction may be vertical or horizontal) using adhesive and 40-45mm power driven flat-head nails.

[0026] Figure 8 illustrates a panel 160, similar in construction to panel 140 but having a door opening formed therein. Other pre-formed wall panel structures can of course also be manufactured, for example with window apertures and the like.

[0027] An example of a portion of a building structure 200 constructed from panels fabricated in accordance with embodiments of the invention is illustrated in Figure 9. As can be seen, the individual laminas of the panels (120, 160) forming the walls of the structure 200 are oriented vertically. The individual panels may be interconnected to one another in a variety of different ways, in this case using plates 130, 135 that are each nailed or screwed to the two adjacent timber panels.

[0028] The structural characteristics of panels 120 have been tested for compression loading and in-plane shear/racking loading by a university to determine ultimate strength and serviceability limits in accordance with AS 1170.1 loading code. The testing results are outlined below, with reference to Figures 10, 11 and 12.

[0029] Timberwork panel samples were tested under static axial compression loading. The nominal length, width and thickness of the specimens tested were 2910mm, 950mm and 90mm, respectively. The measured average moisture content of the specimens varied from 7.5% to 10.2%. Specimens were tested in a 1MN MTS Universal Testing Machine (UTM) as shown in Figure 3. The panels were tested under compression with simply supported boundary condition. Therefore, no rotational restraints existed at the top and bottom connections to the MTS machine. The test specimen was placed within a 125 PFC steel section with the specimen sandwiched between the flanges. The cavity within the flanges was 110 mm which provided a 20mm tolerance fit to the specimens that were 90 mm

thick. The UTM provided the force resistance and axial shortening. In addition, two optoNCDT 1302-200mm laser extensometers were used to measure the out-of-plane deformation of the specimen at mid-height.

[0030] One result of axial compression force-deformation response is shown in Figure 10(a). No sign of damage was observed as the specimen was pushed to a maximum of 90% of the testing machine capacity. The maximum axial compression force recorded was 906.8kN that corresponded to 8.1mm axial displacement. The out-of-plane movement recorded using the two lasers is shown in Figure 10(b).

[0031] One specimen was tested under axial squash test, wherein a portion of the panel with dimensions 400×300×85mm was subjected to compression by means of a 5MN Instron Static Testing Machine. The force-displacement response of the specimen is shown in Figure 11. The maximum axial compression force recorded was 1113.7kN that corresponded to 3.1mm axial displacement. The maximum stress under squash load is therefore:

$$\sigma = \frac{P_{max}}{A} = \frac{1113.7 \times 10^3}{300 \times 85} = 43.7\ MPa$$

[0032] Three timberwork panel samples of the same dimensions specified above were tested under 4-point bending test. The average moisture content of the specimen was approximately 7.5%. The panels were tested as simply-supported beam elements subjected to the four-point bending tests. The symmetrical two-point loads on the top of the specimen were 900mm apart, while the symmetrical two-point supports at the bottom were 2840mm apart. The load was applied to the specimen by means of a 5MN Instron Static Loading Machine, with one laser extensometer used to measure deformation of the specimen at the mid-length. The force versus mid-span deformation responses of the panels serving as simply-supported beam elements is shown in Figure 12. The results of the bending tests were used to calculate the maximum flexural stress developed by the panels, with the results from the three test being:

$$\sigma_1 = 46.23\,MPa$$
$$\sigma_2 = 44.72\,MPa \qquad \sigma_{average} = 45.00\,MPa$$
$$\sigma_3 = 44.15\,MPa$$

[0033] For comparison, Figure 13 indicates structural design properties for F-grade structural timbers. Based on the results of the testing, it can be seen that the panels constructed according to embodiments of the invention exhibit properties comparable with stress graded timbers in the region of F-14 to F-27.

[0034] The invention has been described by way of non-limiting example only and many modifications and variations may be made thereto without departing from the spirit and scope of the invention.

[0035] Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms part of the prior art base or common general knowledge in the relevant art in Australia or elsewhere on or before the priority date of the disclosure and claims herein.

[0036] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

CLAIMS

1. A method of manufacturing a structural panel for building construction, comprising: subjecting timber feedstock to machine stress grading wherein individual timber sticks that satisfy the grading criteria are allocated a stress grade for structural use; selecting from the timber sticks that fail to satisfy the machine stress grading standard criteria, laminas for forming a panel; arranging the selected timber laminas, without regard to visual defects, in side-by-side parallel formation; and fabricating a structural panel wherein the selected timber laminas are arranged side-by-side parallel to one another with adhesive applied between each adjacent stick incorporated into the panel.

2. The method of claim 1, further comprising nailing adjacent laminas to one another in addition to applying adhesive.

3. The method of claim 1 or claim 2, further comprising affixing a sheet material, such as plywood, to one or both faces of the panel.

4. A timber panel for structural use in buildings, manufactured according to the method of claim 1, 2 or 3.

5. A structural timber panel for building construction, wherein the structural timber panel is fabricated by: subjecting timber feedstock to machine stress grading wherein individual timber sticks that satisfy the grading criteria are allocated a stress grade for structural use; selecting from the timber sticks that fail to satisfy the machine stress grading standard criteria, laminas for forming a panel; arranging the selected timber laminas, without regard to visual defects, in side-by-side parallel formation; and fabricating a structural panel wherein the selected timber laminas are arranged side-by-side parallel to one another with adhesive applied between each adjacent stick incorporated into the panel.

6. A building comprising one or more structural walls formed from at least one timber panel according to claim 5.

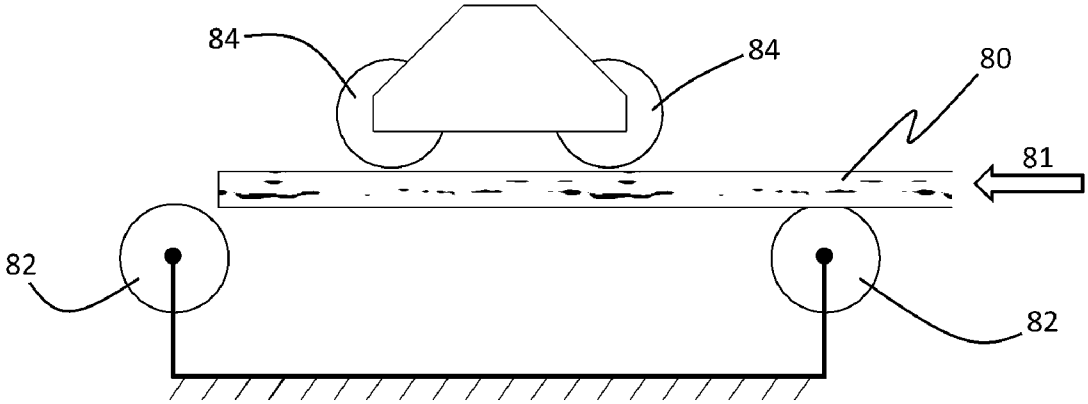


Figure 1

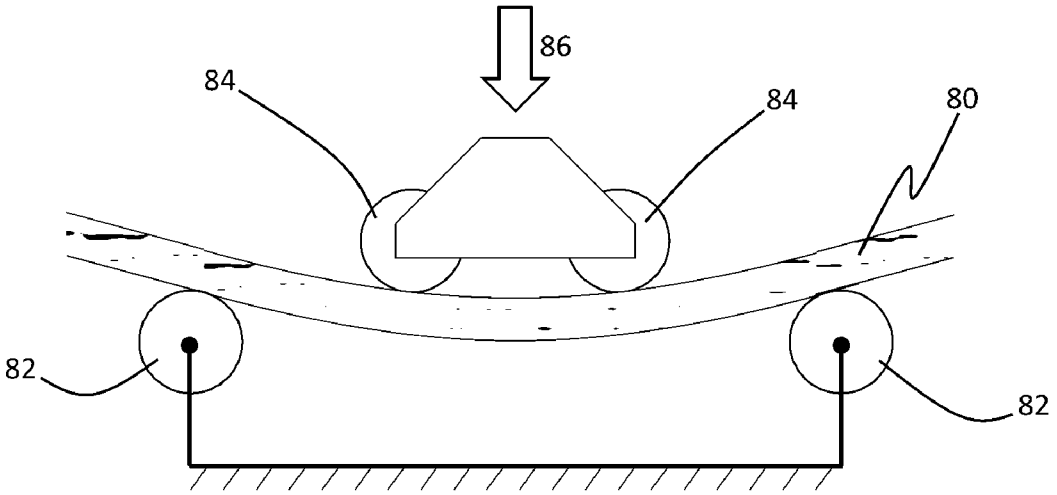


Figure 2

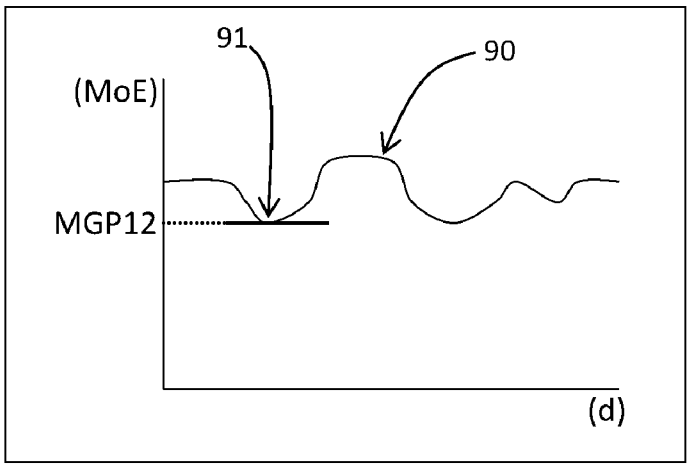


Figure 3

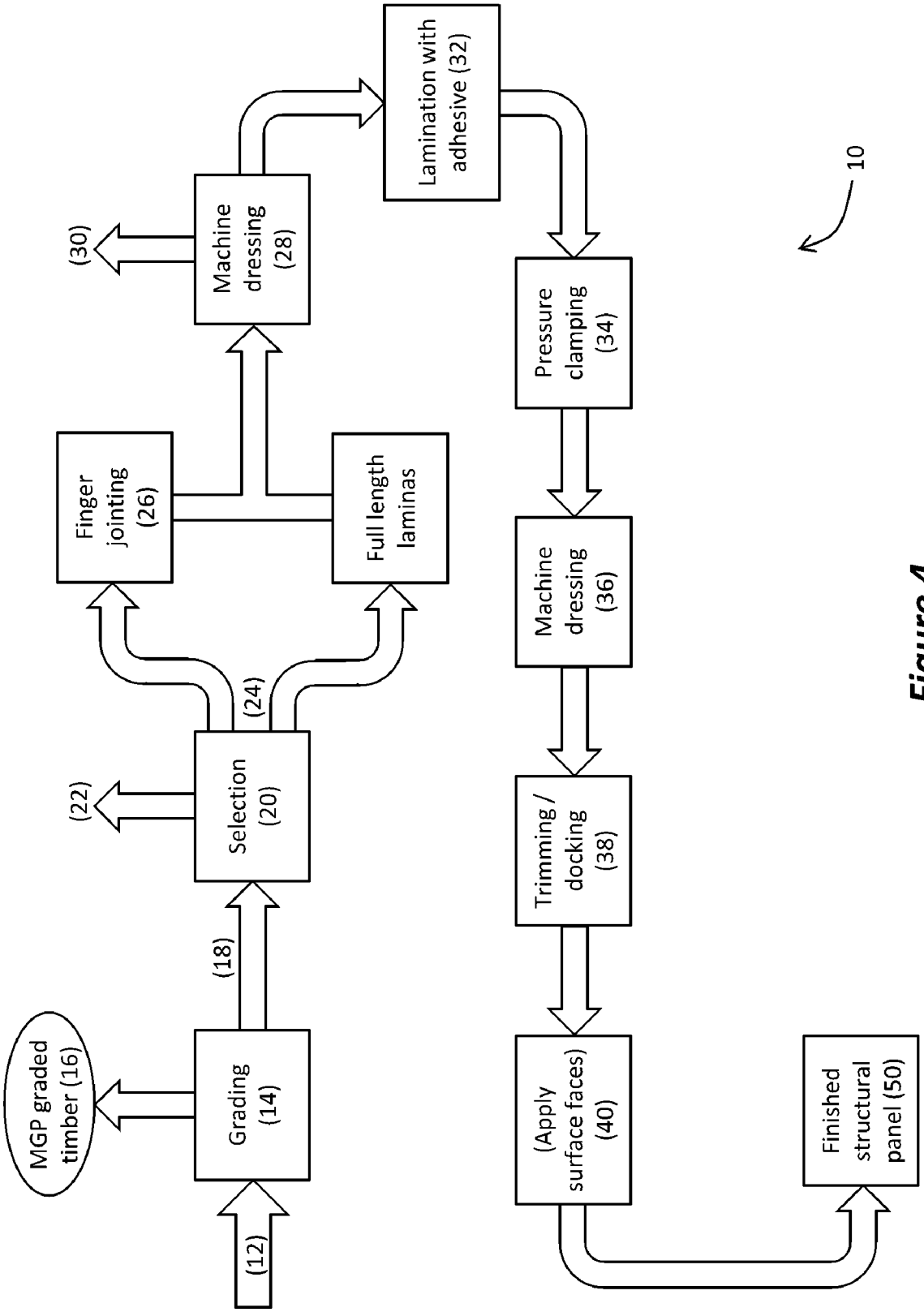

MGP graded timber (16)
Grading (14)
(12)
(18)
Selection (20)
(22)
(24)
Finger jointing (26)
Full length laminas
Machine dressing (28)
(30)
Lamination with adhesive (32)
Pressure clamping (34)
Machine dressing (36)
Trimming / docking (38)
(Apply surface faces) (40)
Finished structural panel (50)
10

Figure 4

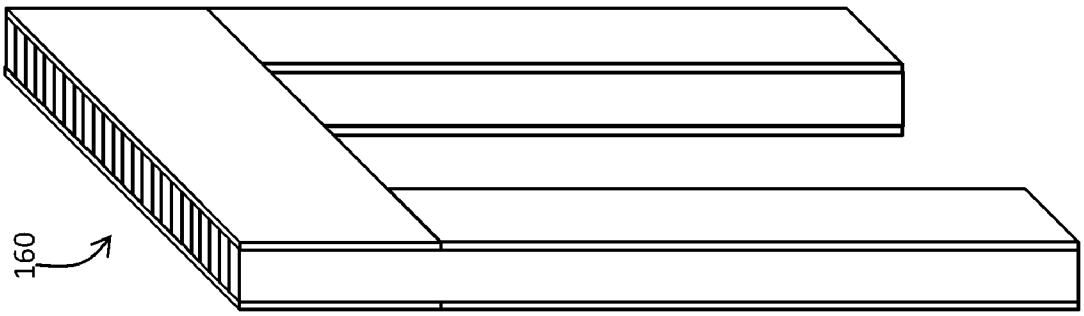


Figure 8

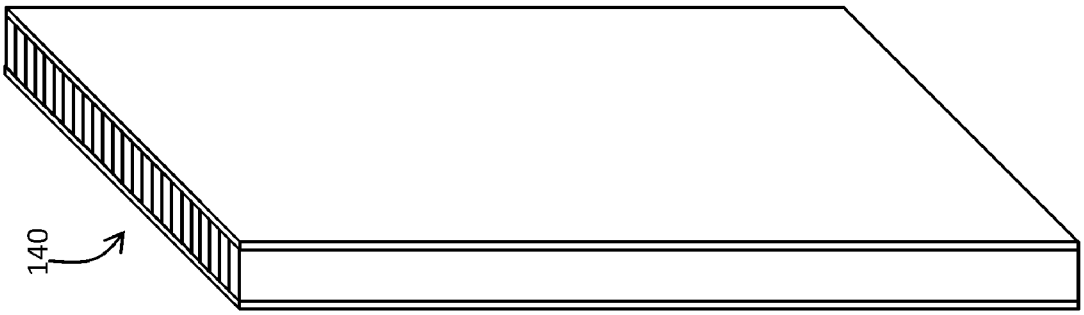


Figure 7

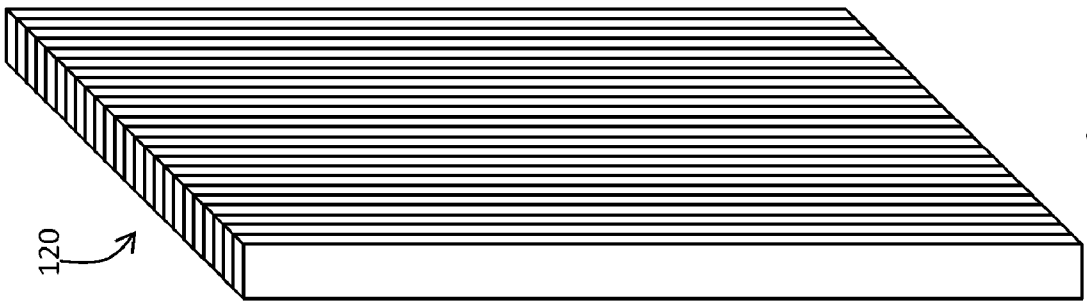


Figure 6

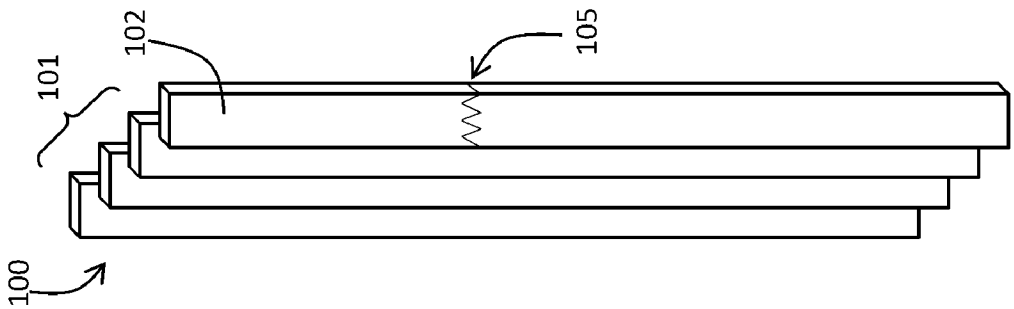


Figure 5

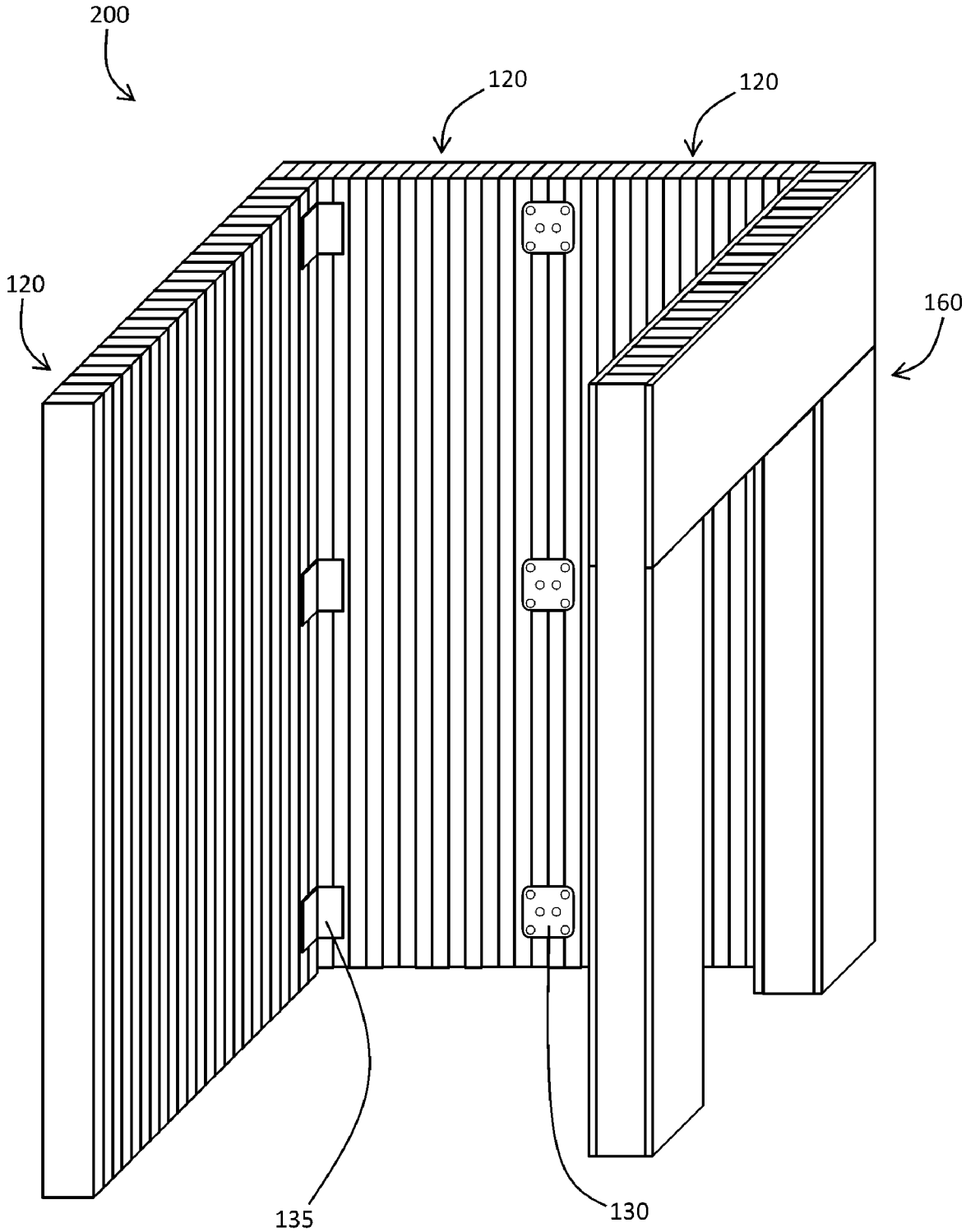
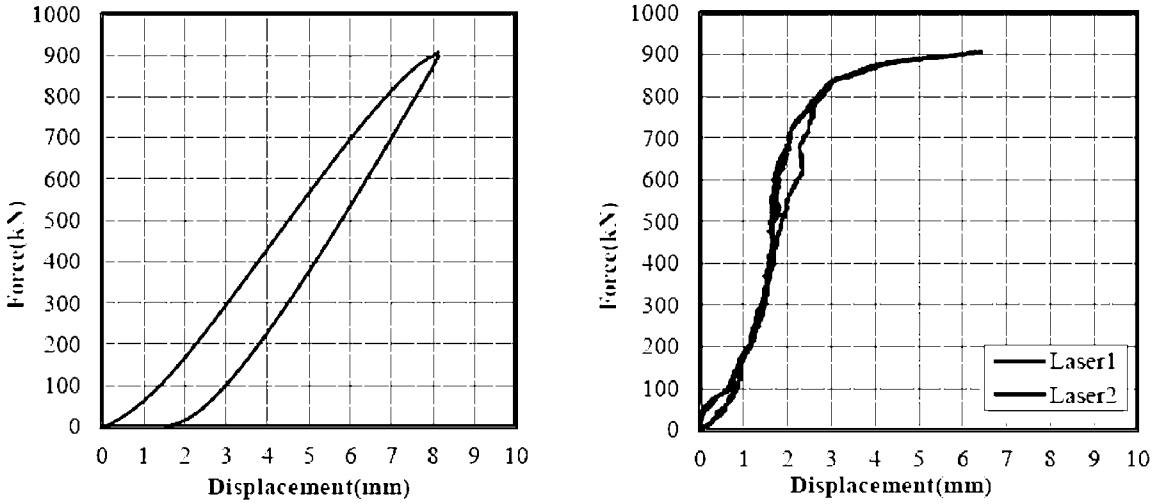


Figure 9



(a) Axial compression force-deformation response

(b) Out-of-plane deformation at the center

Figure 10

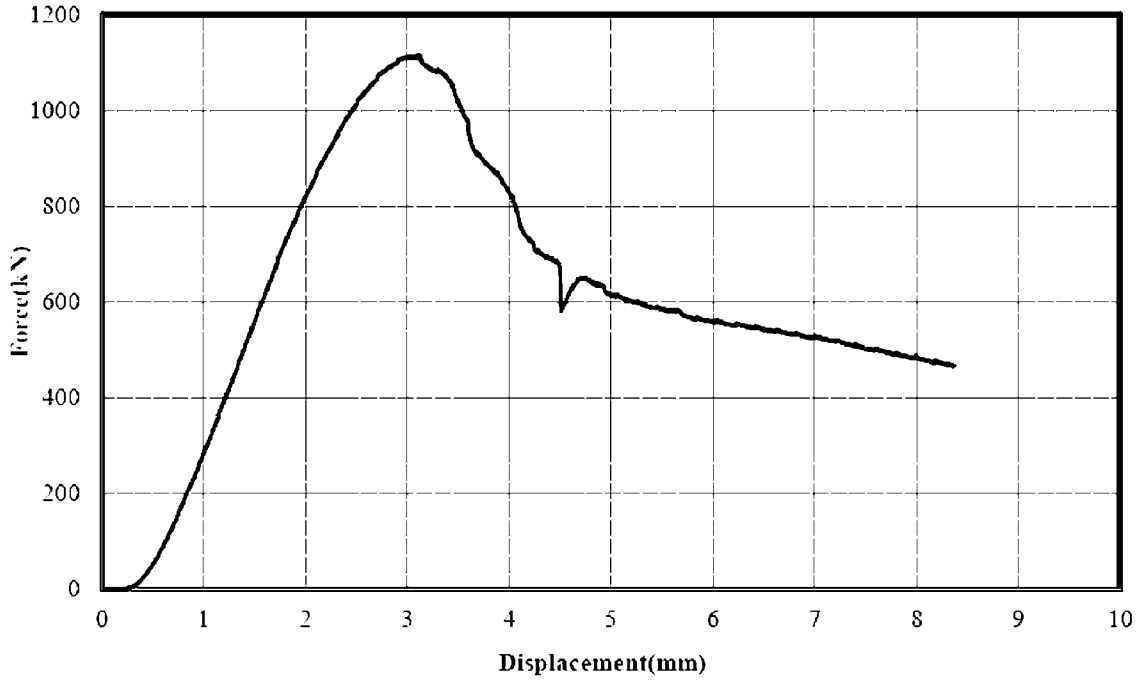


Figure 11

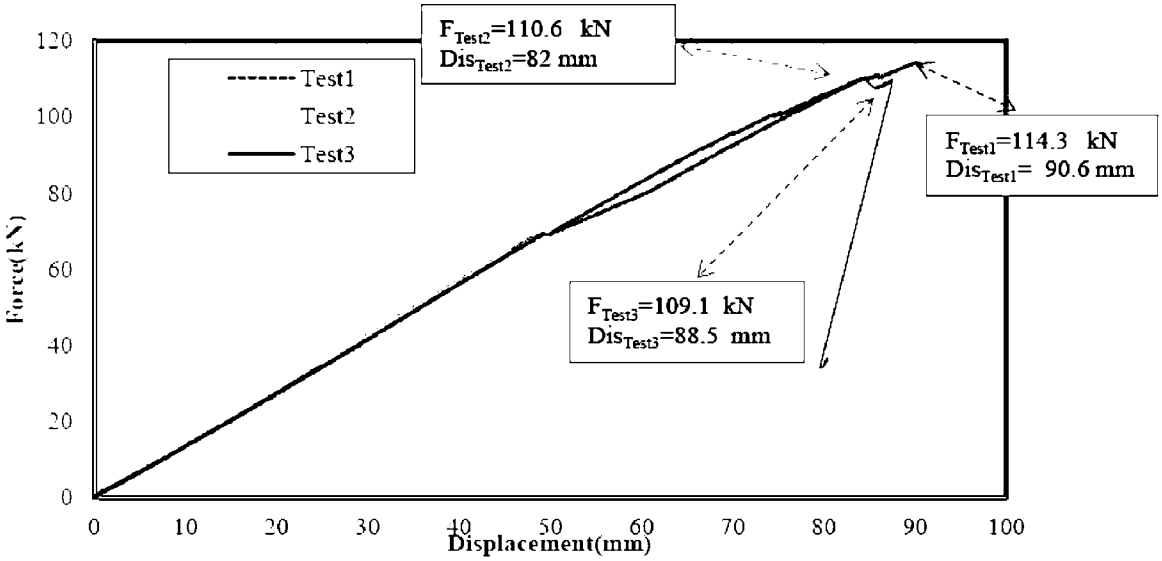


Figure 12

Stress Grade	Characteristic strength, MPa					Characteristic short duration average modulus of elasticity parallel to grain, MPa (E)
	Bending (f'_b)	Tension parallel to grain (f'_t)		Shear in beam (f'_s)	Compression parallel to grain (f'_c)	
		Hardwood	Softwood			
F34	100	60	50	7.2	75	21 500
F27	80	50	40	6.1	60	18 500
F14	40	25	21	3.7	30	12 000
F11	35	20	17	3.1	25	10 500
F8	25	15	13	2.5	20	9 100
F7	20	12	10	2.1	15	7 900
F5	16	9.7	8.2	1.8	12	6 900
F4	13	7.7	6.5	1.5	9.7	6 100

Figure 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2020/050603

A. CLASSIFICATION OF SUBJECT MATTER

B27M 1/00 (2006.01) B27M 3/00 (2006.01)

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)

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)

DATABASES: PATENW; IC/CNN/LOW: B27M1/00, B27M3/00; Keywords Method, Manner, Manufacture, Process, Laminate, Glue, Timber, Wood, Select, Choose, Stress, Machine, Grade, Standard, Recycle, Re-use and similar keywords. ESPACENET AND AUSPAT: Applicant/Inventor name searched; Viewed cited/citing of relevant documents. Google patents: Method of manufacturing laminated timber. Applicant(s)/Inventor(s) name searched in internal databases provided by IP Australia.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 July 2020	01 July 2020

Name and mailing address of the ISA/AU

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	**PCT/AU2020/050603**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 2013270595 A1 (WOOD ENGINEERING TECHNOLOGY LIMITED) 16 January 2014 Entire document	1 - 6
X	WO 2004/080713 A1 (WOOD ENGINEERING TECHNOLOGY LIMITED) 23 September 2004 Entire document	1 - 6
A	US 6358352 B1 (SCHMIDT) 19 March 2002 Entire document	1 - 6
A	CA 1265031 A (UNIVERSITY OF TORONTO INNOVATIONS FOUNDATION) 30 January 1990 Entire document	1 - 6

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2020/050603**

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