Industrial Crops & Products 213 (2024) 118448

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Granulometric characterization of Arctic driftwood sawdust from frame sawing process

Daniel Chuchala[a,*,1], Tomasz Rogoziński[b,2], Kazimierz A. Orlowski[a,3], Marta Pędzik[b,c,4], Luďka Hanincová[d,5], Olafur Eggertsson[e,f,6]

[a] Institute of Manufacturing and Materials Technology, Faculty of Mechanical Engineering and Ship Technology and EkoTech Center, Gdańsk University of Technology, Gdańsk, Poland
[b] Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland
[c] Łukasiewicz Research Network, Poznań Institute of Technology, Poznań 61-755, Poland
[d] Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, Czech Republic
[e] Icelandic Forest Research, Mógilsá, Reykjavik, Iceland
[f] Agricultural University of Iceland, Hvanneyri, Borgarnes, Iceland

ARTICLE INFO

Keywords:
Arctic driftwood
Granulometry
Sawdust
Larch wood
Pine wood
Sawing process

ABSTRACT

Arctic driftwood can be used as an alternative source of wood as construction timber and furniture material, especially in Iceland and Greenland. The use of Arctic driftwood can help in the fight against climate change, by developing land reforestation processes and reducing the volume harvested wood from forests and sustainability of harvesting processes. In this paper the results of an analysis of the effect of long-term residence of pine (*Pinus sylvestris* L.) and larch wood (*Larix sibirica* L.) stay in Arctic ice and seawater on the granulation of wood sawdust and the distribution of fine wood dust particles during the frame sawing process are presented. The distribution of wood chips and dust was analysed using sieve and laser diffraction methods. The results confirmed that Arctic driftwood, compared to normal wood for both analysed species, generate slightly more fine wood dust particles during the frame sawing process, which can be harmful to human health. However, these differences are not significant, indicating that the same dust extraction systems can be used for both sawing processes.

1. Introduction

Arctic driftwood has been reaching the coasts of Iceland and Greenland for centuries. The inhabitants of these regions used this material in different ways depending on current need, mainly: building houses, churches, boats or bridges (Mooney 2016a, 2016b, 2018; Guðmundsdóttir, 2022). Driftwood reaches the coast of Iceland and Greenland mainly from the boreal forests of northern Europe and the Russian part of Asia (Hellmann et al., 2013, 2015, 2017), and sometimes also from Alaska or northern Canada (Hellmann et al., 2017). This wood, as a result of the natural riverbank erosion and industrial wood logging, massive wood deposits enter to Arctic Ocean through the large boreal river systems (Kolář et al. 2022). Then, driftwood is carried down the sea ice by surface sea currents (Eggertsson, 1993). Today, this wood is not used widely as it was before. The availability of timber from other provenances of the world, has meant that driftwood in Iceland and Greenland is today mainly used for fuel, fence posts and wood carving. However, the climate change that is occurring, and the need to fight to reduce and/or slow it down, suggests that the use of driftwood would allow for a reduction in forest harvesting. Driftwood is a valuable construction and firewood source, and a sustainable timber management process indicated the need to use such a natural resource, which would

* Correspondence to: Institute of Manufacturing and Materials Technology, Faculty of Mechanical Engineering and Ship Technology, Gdańsk University of Technology, Gdańsk, Poland.
E-mail address: daniel.chuchala@pg.edu.pl (D. Chuchala).
[1] orcid.org/0000-0001-6368-6810
[2] orcid.org/0000-0003-4957-1042
[3] orcid.org/0000-0003-1998-521X
[4] orcid.org/0000-0003-3607-8128
[5] orcid.org/0000-0002-3319-2032
[6] orcid.org/0000-0002-7807-3539

https://doi.org/10.1016/j.indcrop.2024.118448
Received 4 October 2023; Received in revised form 3 March 2024; Accepted 23 March 2024
Available online 29 March 2024

a)

b)

Fig. 1. The investigated driftwood: (**a**) the Arctic driftwood on the coast of North Iceland; (**b**) derived experimental samples: WOOD 1 – samples Siberian larch, WOOD 2 and 3 – samples Scots pine.

Table 1
Selected properties of examined wood samples (average values with standard deviations in parentheses).

Sample name	Sample code	Raw density ρ kg m^{-3}	Oven-dry density ρ_{od} kg m^{-3}	Moisture content MC %
Driftwood Larch	DL	562.2 (15.1)	506.3 (14.1)	11.05 (0.13)
Larch	L	694.9 (31.5)	625.08 (24.3)	11.17 (0.23)
Driftwood Pine	DP	414.5 (7.0)	372.5 (6.3)	11.26 (0.02)
Pine	P	460.25 (8.9)	416.1 (8.2)	10.6 (0.3)

Table 2
Technical parameters of sash-gang saw and its saw blade used in the experimental cuttings.

Parameter		Symbol	Value	Unit
machine parameters				
number of strokes of saw frame per min		n_F	685	spm
saw frame stroke		H_F	162	mm
number of saws in the gang		m	5	–
average cutting speed		v_c	3.69	m·s^{-1}
feed speed	slow	v_{f1}	0.99	m·min^{-1}
	fast	v_{f2}	1.45	m·min^{-1}
feed per tooth	slow	f_{z1}	0.116	mm
	fast	f_{z2}	0.171	mm
tool parameters				
the sharp saw blades with stellite tipped teeth		–	–	–
overall set (kerf width)		S_t	2	mm
saw blade thickness		s	0.9	mm
free length of the saw blade		L_0	318	mm
blade width		b	30	mm
tooth pitch		t_p	13	mm
tool side rake angle		γ_f	9	°
tool side clearance		α_f	14	°
tension stresses of saws in the gang		σ_N	300	MPa

reduce the cost of transporting timber from other parts of the world and thus reduce pollution from the use of transport. The use of driftwood should also assist in the reforestation of land, which can be very beneficial in the fight against accelerating climate change.

Chuchala et al. (2021) showed stronger machinability properties of larch driftwood in relation to normal larch wood. Therefore, it can be assumed that the natural modification of wood during its long-term stay in ice and seawater may cause significant changes in wood, leading to the formation of more fine dusts during processing, which are hazardous

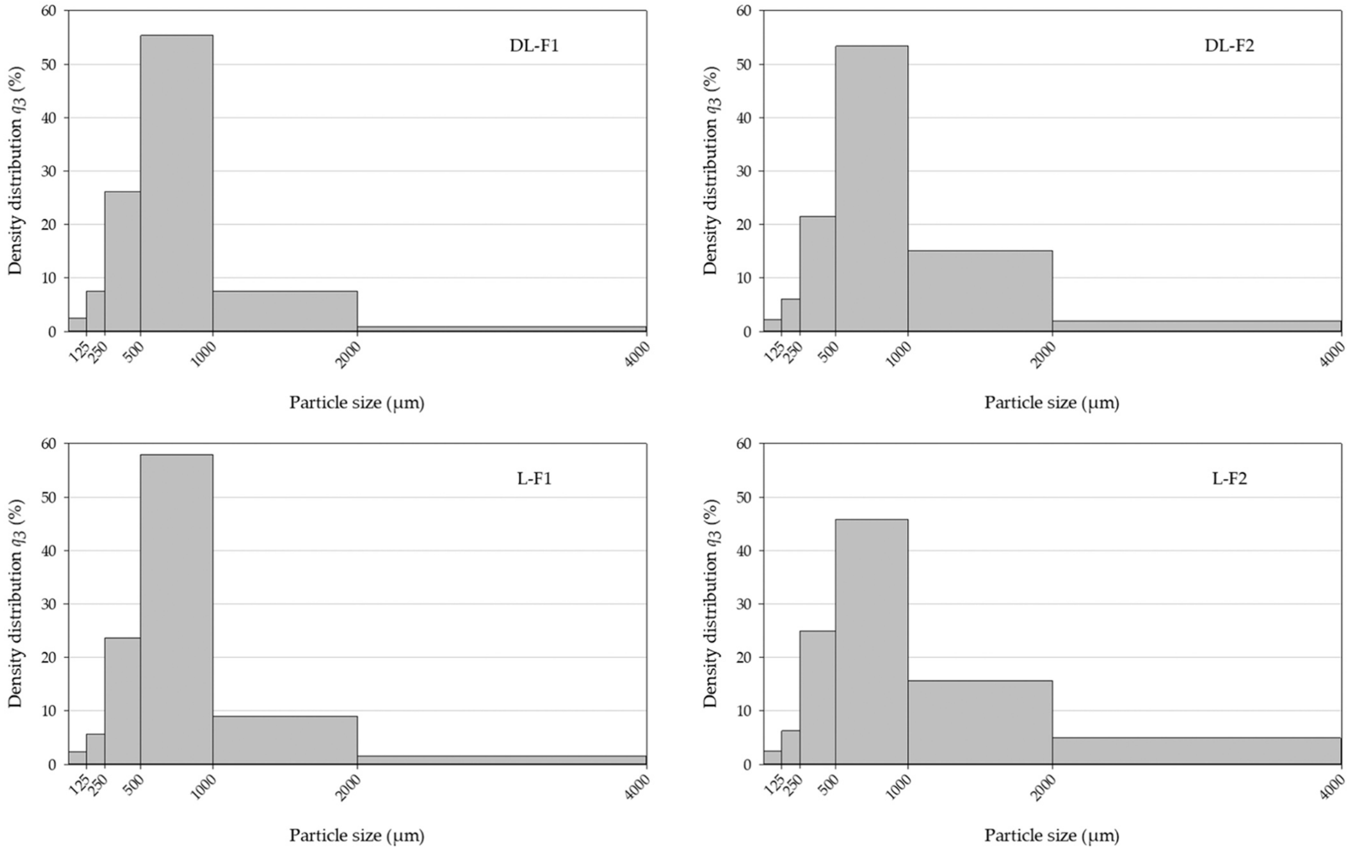

Fig. 2. Particle size distributions of larch wood dust – by sieve analysis method in a function of both drifting and normal wood and feed per tooth.

to the health of machine tool operators (Oberdörster et al., 2005; Jacobsen et al., 2010; IARC, 2012). Previous studies have shown that different treatment processes induce changes in the machinability properties (cutting forces and cutting power), mechanical properties and the granulometric composition of dust and chips produced during wood machining operations. One of the basic wood treatments in the manufacturing process is the drying process. Chuchala et al. (2020) showed that different drying methods affect the machinability and mechanical properties. On the other hand, Orlowski et al. (2019) and Rogoziński et al. (2021) showed that different wood drying methods affect the granulations of chips and dust produced during machining. Various thermal treatment processes also significantly affect the machinability properties and granulation of dust generated during machining (Kučerka and Očkajová 2018; Aro et al., 2019; Kminiak and Dzurenda, 2019; Piernik et al., 2019; Kminiak et al., 2020; Očkajová et al. 2020). Furthermore, the chemical impregnation also significantly affect machinability properties (Licow et al., 2020; Sinn et al., 2020) and granulometry of chips and dusts produced during sawing process (Hlásková et al., 2015 Orlowski et al., 2018).

Therefore, the aim of the presented research was to verify how the natural modification of wood through a long-term exposure to the salted waters and ice of the Arctic Ocean affects the level of fine dust generated during sawing operations. The results of such an analysis could be very useful for the preparation of a suitable, health-safe process for machining driftwood in order to use it as a valuable construction or furniture material.

2. Materials and methods

2.1. Materials

The study was carried out on Arctic driftwood samples collected from the North Coast of Iceland (latitude: 66.167418° N, longitude: −16.647679° W). The driftwood samples were collected by courtesy of a local farmer, who was the owner of that land (Fig. 1a). Collected driftwood logs were cut into boards and in this shape were stored in outdoor conditions for a period of two years. Randomly selected two boards were used for preparation of the four rectangular blocks from each board (Fig. 1b) of dimensions 50 mm × 50 mm × 600 mm (width (W) × height (H) × length (L), respectively). Rectangular blocks were prepared in the carpentry workshop Trésmiðja H Ben ehf in Akureyri (Iceland). All experimental samples after transportation to Poland were conditioned in laboratory conditions for 12 months, assuring constant air temperature (T_a) of 20 °C and relative humidity (RH) of 65%.

Experimental samples were subjected to the biological species verification process. The samples were verified as Siberian larch (*Larix sibirica* L.) and Scots pine (*Pinus sylvestris* L.). The wood anatomical analysis process was carried out by microscopic observation on Leica DM2500 light microscope (Leica Microsystems, Wetzlar, Germany) with magnification of 1000×. Ultrathin (10–20 µm) samples of transverse, tangential and radial sections were cut-out with the microtome and mounted on the microscope slide. The tree species of the driftwood where analysed using standard wood anatomical methods based on e.g. the anatomical descriptions in Eggertsson (1993) and Hellmann et al. (2013), (2015), (2017). The provenance of analysed drifted logs was estimated by combining microscopic observations and literature references as the Central or Eastern Siberia (Hellmann et al., 2015, 2017).

The second group of samples for comparative analysis, as a reference material, were prepared from a log of Siberian larch imported by the sawmill from Eastern Siberia. Unfortunately, it has not been possible to obtain Scots pine from Eastern Siberia. Therefore, for this species as reference material were used Scots pine harvested from Pomeranian Region of Poland. The reference samples were prepared with similar dimensions to driftwood samples and matching (as much as possible)

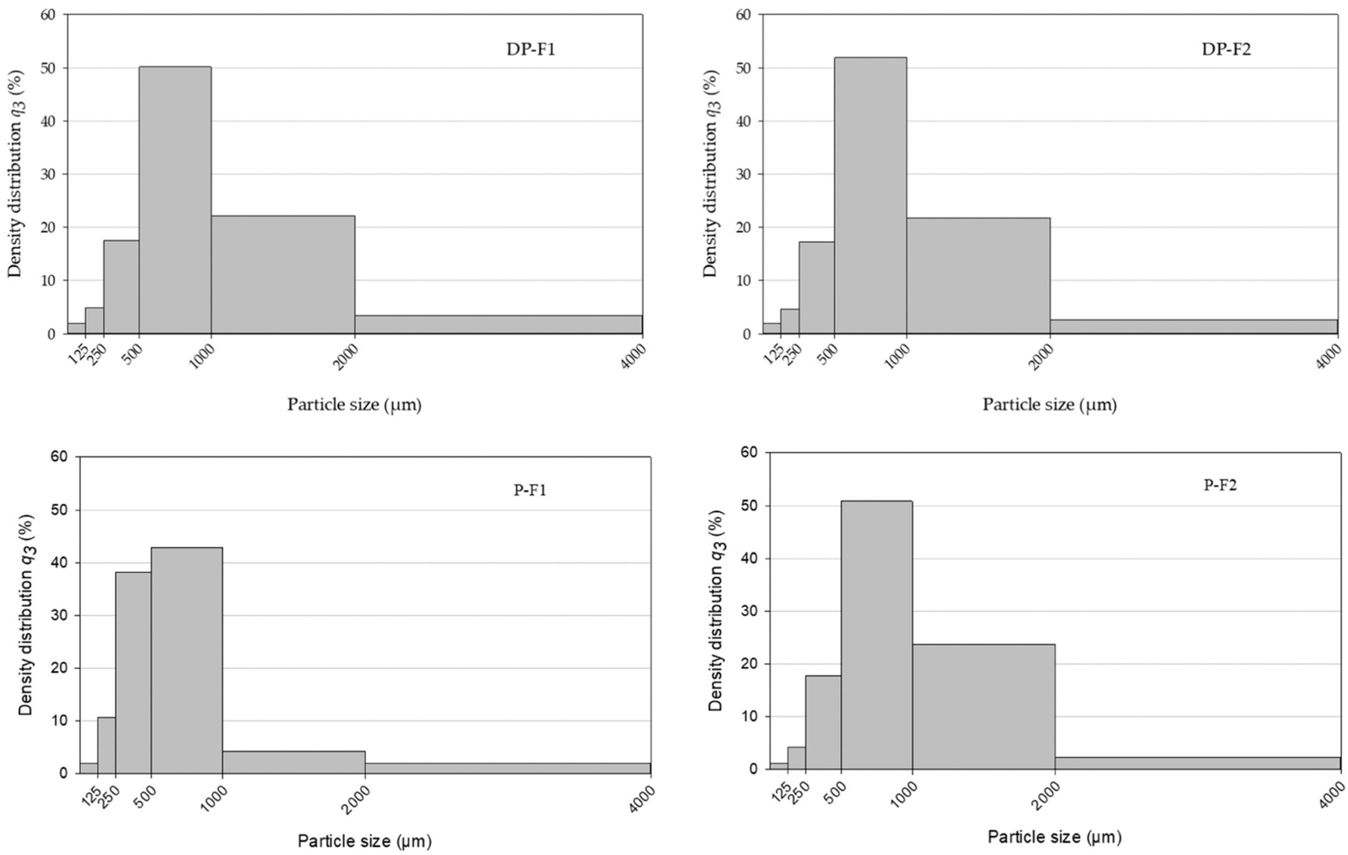

Fig. 3. Particle size distributions of pine wood dust – by sieve analysis method in a function of both drifting and normal wood and feed per tooth.

Table 3
Mean particle-size distribution of dust for drifting and normal wood for both analysed species and standard deviations (SD).

Dust	Arithmetic mean diameter µm	SD µm
DL-F1	642.9	173.0
DL-F2	720.9	220.8
L-F1	670.0	194.8
L-F2	686.4	289.1
DP-F1	785.8	259.9
DP-F2	791.0	242.4
P-F1	550.3	201.7
P-F2	812.0	238.0

DL-F1 – driftwood larch sawed with feed per tooth f_{z1}; DL-F2 – driftwood larch sawed with feed per tooth f_{z2}; L-F1 – larch sawed with feed per tooth f_{z1}; L-F2 – larch sawed with feed per tooth f_{z2}; DP-F1 – driftwood pine sawed with feed per tooth f_{z1}; DP-F2 – driftwood pine sawed with feed per tooth f_{z2}; P-F1 – pine sawed with feed per tooth f_{z1}; P-F2 – pine sawed with feed per tooth f_{z2};

similar structure properties, e.g.: annual ring orientation as well as late/early wood ratio. The reference wood samples were not exposed to any production treatment. The wood density ρ as a ratio of the wood mass to its volume at the air-dry state (moisture content MC = 12%), was measured separately on each block of both driftwood and reference sample groups (Table 1).

2.2. Sash gang saw and saw blade

Experimental cutting tests were conducted on the PRW15M sash-gang saw with a hybrid dynamically balanced driving system and elliptical teeth trajectory movement (Wasielewski and Orlowski 2002). Detailed technical parameters of the sash-gang saw and saw blades used in experimental cutting tests are presented in Table 2. The sawing process was conducted with two levels of feed speed: $v_{f1} = 0.99\ \mathrm{m\ min^{-1}}$ and $v_{f2} = 1.45\ \mathrm{m\ min^{-1}}$. This corresponds to a feed per tooth f_{z1} 0.116 mm and 0.171 mm, respectively. The mean value of feed per tooth f_z for a sash-gang saw was calculated as in Eqs. 1 and 2 (Chuchala et al., 2020; Sinn et al., 2020; Chuchala et al., 2021).

$$f_z = \frac{1000 \cdot v_f \cdot t_p}{n_F \cdot H_F} \tag{1}$$

$$v_f = \frac{L}{t_c} \tag{2}$$

where: v_f – feed speed ($\mathrm{m \cdot min^{-1}}$), t_p – tooth pitch (mm), L – length of the sample (m), H_F – saw frame stroke (mm), n_F – number of strokes of saw frame per min (spm) and t_c – cutting time (min) necessary to process sample of the length L.

2.3. Wood dust particle size analysis

Dust and wood chips generated during the frame sawing process were collected into the box located under the sawing frame inside of the machine tool. The frame of the sawing machine had a top-down air blowing system. Air blowing system and gravitation directed the dust and chips into the box. The box was emptied after each set of cut wood (species, type, feed per tooth) and the collected portion was taken for granulometric analysis. An extensive granulometric analysis was performed with two complementary methods. The first covered the general particle size distribution without any information considering the finest fractions of dust and was determined by sieving method. A set of standardized wire sieves with mesh sizes of 2, 1, 0.5, 0.25, 0.125 mm was used for this purpose. The set of sieves was placed on the top sieve of the vibratory sieve shaker Retsch AS 200 (Retsch GmbH, Haan, Germany).

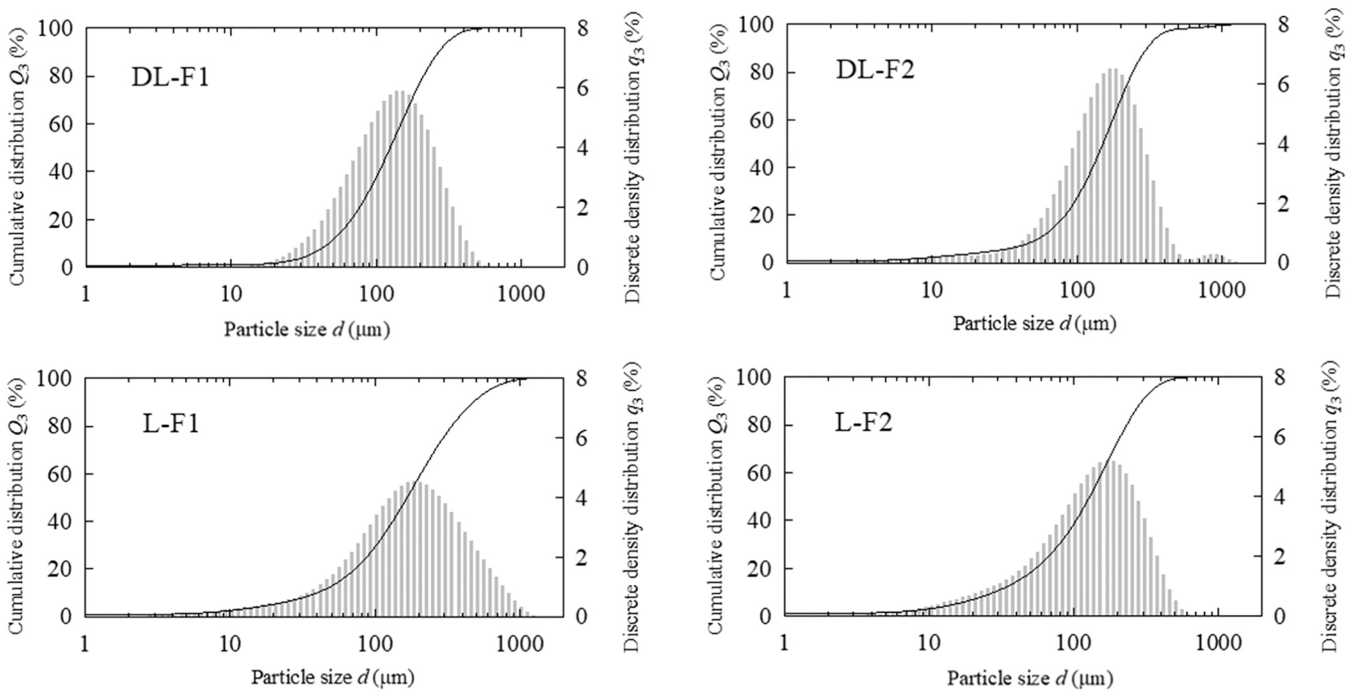

Fig. 4. Particle size distributions of larch wood dust fraction < 125 μm as a function of both wood types (normal and drifted) and feed per tooth.

Sieve analysis critical for non-spherical, in particular elongated or fibrous wood particles. The sieving parameters were set in accordance with the standard ISO 3310–1: amplitude 2 mm, sieving time t = 15 min, sawdust sample mass 50 g. The particle size distributions were obtained by weighing the fractions remaining on the sieves after sieving. A laboratory balance Radwag 510/C/2 (Radwag, Radom, Poland) with weighing accuracy 0.001 g was used for weighing the sawdust fractions. Basing on the results of determination of particle-size distribution the arithmetic mean diameter and the standard deviation of each distribution were calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i \bullet q_{3_i}}{N} \tag{1}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x}) \bullet q_{3i}}{n-1}} \tag{2}$$

where:

$\bar{x}$ – arithmetic mean value of distribution; q_3 – density distribution by mass; x – average value of particle size class; n – number of particle size classes; N – the sum of the distribution by mass; σ – standard deviation of distribution.

However, the sieve analysis provides only a general particle-size distribution without any information on the mass content of potentially respirable dust fraction. Therefore, laser particle size analysis as second method was used. The Analysette 22 Microtec Plus laser particle sizer (Fritsch, Germany) was used to specify details regarding the size of the respirable dust particles smaller than 125 μm (collected in the bottom collector). The laser particle sizer automatically measures a particle size according to a predetermined Standard Operating Procedure which uses Fraunhofer calculation model and assuming that the density is constant. Therefore, the volume distribution is a mass distribution. The obtained results were processed with the MaScontrol software. It gives two types of quantities; the sum of the distribution Q(x) and the density of the distribution q(x). According to dQr(x) = qr(X) dx, qr(x) is a component of dQr(X), which is contained in the interval dx for particles from x and x + dx. The result is a random variable r (when r = 3, means volume distribution), where:

$$q_r(x) = \frac{x^r \bullet q_0(x)}{\sum_{i=1}^{n} x_i^r \bullet q_{0i}(x_i)} = \frac{dQ_r(x)}{dx} \tag{3}$$

The most important particle size ranges (<2.5 μm, 2.5–4 μm, 4–10 μm) were used to calculate the content of fine particles in the total mass of sawdust.

3. Results and discussion

The results of the sieve analysis of the obtained sawdust are presented in Fig. 2 for larch and Fig. 3 for pine. In Table 3 are presented the values of arithmetic means of the particle diameter and standard deviations for all analysed types of samples. Analysing the data in Figs. 2 and 3, it can be observed that as the feed per tooth increases during the sawing process, bigger sawdust sizes are obtained. This phenomenon was observed for both analysed wood species, as well as for natural wood and driftwood. In additional similar observation was obtained by Rogoziński et al. (2021) for pine and beech wood dried by two different methods. Overall, there were no noticeable differences in dust size proportions depending on whether the wood was drifted or normal. Only in the case of pine wood sawed with a lower feed per edge was the proportion of normal wood dust in the 125 – 500 μm size significantly higher compared to driftwood. Driftwood had, in this case, a higher proportion of dust in sizes above 1000 μm (Fig. 3). This phenomenon is also reflected in the value of the arithmetic mean of the dust particle diameters, which for normal pine wood is significantly smaller for sawing with a lower feed per tooth f_{z1} than the corresponding value obtained for driftwood (Table 3). The sieve method showed no noticeable differences between the dust sizes obtained for normal and driftwood. For both wood species analysed, the proportions of dust sizes particularly hazardous to human health (IARC, 2012), i.e. smaller than 125 μm, were similar for normal and driftwood (Figs. 2 and 3).

However, the sieve method does not allow the analysis of fine wood dust particles, and it is the fine particles that are most dangerous to the health of woodworking machinery operators. Therefore, an additional dust analysis was carried out using the laser method. The results of fine particles of wood dusts are presented in Fig. 4 and Fig. 5. Both Figs. (4 and 5) show that the dust batch that passed through the sieve with the

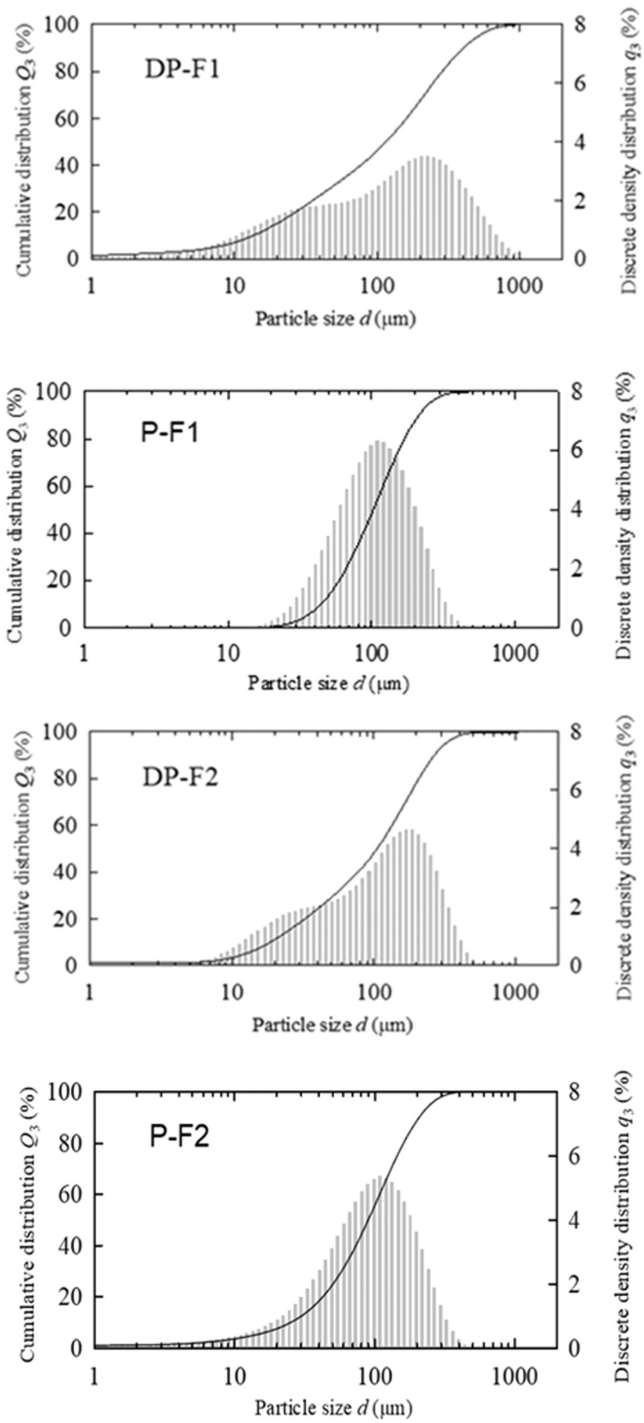

Fig. 5. Particle size distributions of pine wood dust fraction < 125 µm as a function of both wood types (normal and drifted) and feed per tooth.

Table 4
Statistical values of fine particles of the dust (<125 µm) and standard deviations (SD).

Dust	Arithmetic mean diameter µm	SD µm
DL-F1	143.32	142.56
DL-F2	173.36	173.36
L-F1	201.49	187.24
L-F2	148.02	105.83
DP-F1	167.79	217.81
DP-F2	127.40	167.80
P-F1	117.51	68.61
P-F2	106.16	74.17

smallest mesh in the sieve method, i.e. potentially only particles smaller than 125 µm in diameter, very much contains dust particles of larger sizes. This phenomenon is due to the fact that wood dust particles do not have a sphere-like shape, but more like a cylinder (Ding et al., 2020; Santamaría-Herrera et al., 2023). This shape allows a particle to pass through a sieve with a mesh diameter of less than 125 µm if the smaller particle dimension (diameter of the cylinder base) is smaller than the sieve mesh, and despite the fact that the larger particle dimension (height of the cylinder) is significantly larger than the sieve mesh.

Fig. 4 shows the distribution of fine dust particles for larch wood. There were minor differences between the distributions for samples produced during the sawing process with different feed per edge, either for normal and driftwood. As the value of feed per edge increases, the proportion of 10–20 µm particles increases slightly. Whereas larch driftwood dusts are characterised by a higher proportion of particles larger than 100 µm. On the other hand, in the Fig. 5 are shown the distribution of fine dust particles for pine wood in wide range (≤1000 µm). The distribution of fine driftwood dust particles is broader for size <20 µm, for both analysed feeds per tooth. This phenomenon is clearly different from the case of larch wood presented in Fig. 4. This phenomenon may be caused by the lower density of pine wood compared to larch wood (Table 1), and thus a higher proportion of earlywood, which potentially could have been characterised by greater absorption of seawater (Maldas and Kamdem, 1999; Javed et al., 2015) and incorporation of sodium (Bartocci et al., 2017), which resulted in greater brittleness of the material (Johnson et al., 1992, Nguyen et al., 2019). On the other hand, the average values shown in Table 4 present a somewhat different picture of this phenomenon. The average values of fine dust size for driftwood are higher than for normal wood. However, both average values have a very high standard deviation, which makes it possible to conclude that the two results (Fig. 5 and Table 4) are not mutually exclusive. Thus, it can be seen that, despite the differences in cutting forces shown by Chuchala et al. (2020), (2021), there are no noticeable differences in dust granulation between larch driftwood and normal wood. Only in the case of pine wood was an increased proportion of fine dust fractions noted for driftwood compared to normal wood. This is very visible for the smallest fractions (≤10 µm), as shown in Fig. 6. Fig. 6 also shows that, for most of the wood analysed, the proportion of the finest dust fraction increases with increasing feed per tooth. Only in the case of driftwood pine, such a relationship does not occur. These differences are not large and were not noticeable in the sieve analysis.

The current Directive (European Union) 2017/2398 of the European Parliament and of the Council specifies that occupational exposure limits are 2 mg wooden dust per m^3. This limitation applies to the inhalable fraction, which is the fraction containing the smaller fractions: thoracic and respirable.

4. Conclusions

Long-term staying of wood in Arctic Ocean waters can affect the machinability properties of wood and, as a result of this can affect the level of fine dust generated during sawing operations. Based on the carried out experimental tests and analysis of obtained results, it can be concluded that:

- Larch driftwood shows no significant differences in dust and chip granulation compared to normal larch wood.
- As the feed per tooth increases, the proportion of 10–20 µm particles increases slightly for driftwood and natural wood of both analysed species.
- In the case of pine driftwood, the distribution of fine dust particles is stronger for size <20 µm, for both analysed feeds per tooth.

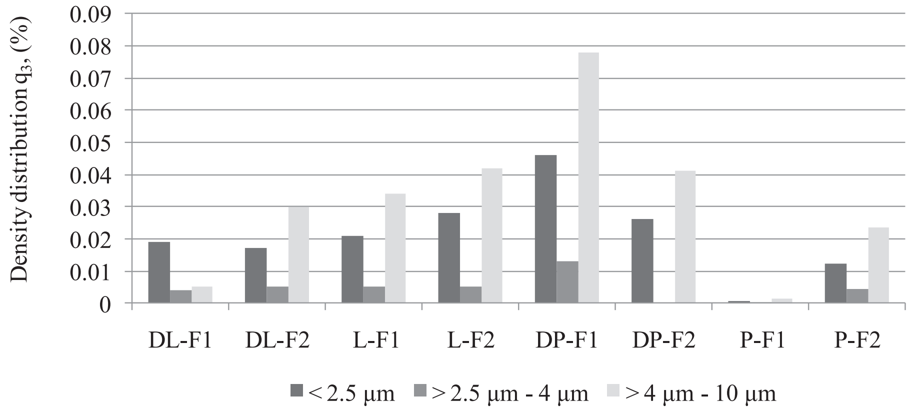

Fig. 6. Content of the finest particles (≤10 µm) in the total mass of sawdust.

- The process of sawing driftwood generates slightly more finest sawdust fractions than normal wood. However, these differences are not significant, indicating that the same dust extraction systems can be used for both sawing processes.

CRediT authorship contribution statement

Kazimierz Orlowski: Writing – original draft, Methodology, Investigation, Formal analysis. **Tomasz Rogoziński:** Writing – original draft, Methodology, Investigation, Formal analysis. **Daniel Chuchala:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Olafur Eggerstsson:** Writing – original draft, Formal analysis. **Luďka Hanincová:** Writing – original draft, Formal analysis. **Marta Pędzik:** Writing – original draft, Formal analysis.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Daniel Chuchala reports financial support was provided by Argentum Triggering Research Grants. Daniel Chuchala reports a relationship with Argentum Triggering Research Grants that includes: funding grants.

Data Availability

Data will be made available on request.

Acknowledgments

Authors would like to acknowledge the Stella Pauli and Rögnvaldur Harðarson for their help in collecting driftwood samples. The authors gratefully acknowledge the Harðar Benediktsson from Trésmiðja H Ben ehf (Akureyri, Iceland) and Piotr Taube from Sylva Sp. z o. o. (Wiele, Poland) for support in preparing samples of the wood used in the experiment. Financial support for this study from Gdansk University of Technology by the DEC-15/2021/IDUB/I.3.3 grant under the Argentum Triggering Research Grants - 'Excellence Initiative - Research University' program is gratefully acknowledged.

References

Aro, M.D., Geerts, S.M., French, S., Cai, M., 2019. Particle size analysis of airborne wood dust produced from sawing thermally modified wood. Eur. J. Wood Prod. 77 (2), 211–218. https://doi.org/10.1007/s00107-019-01385-z.

Bartocci, P., Barbanera, M., D'Amico, M., Laranci, P., Cavalaglio, G., Gelosia, M., Ingles, D., Bidini, G., Buratti, C., Cotana, F., Fantozzi, F., 2017. Thermal degradation of driftwood: Determination of the concentration of sodium, calcium, magnesium, chlorine and sulfur containing compounds. Waste Manag. 60, 151–157. https://doi.org/10.1016/j.wasman.2016.08.035.

Chuchala, D., Sandak, J., Orlowski, K.A., Muzinski, T., Lackowski, M., Ochrymiuk, T., 2020. Effect of the drying method of pine and beech wood on fracture toughness and shear yield stress. Materials 13, 4692. https://doi.org/10.3390/ma13204692.

Chuchala, D., Sandak, A., Orlowski, K., Sandak, J., Eggertsson, O., Landowski, M., 2021. Characterization of arctic driftwood as naturally modified material. Part 1: machinability. Coatings 11, 278. https://doi.org/10.3390/coatings11030278.

Ding, T., Zha, J., Zhu, N., Wang, C., 2020. A comparative study of morphological characteristics of medium-density fiberboard dust by sieve and image analyses. J. Wood Sci. 66, 55. https://doi.org/10.1186/s10086-020-01896-x.

Eggertsson, O., 1993. Origin of the driftwood on the coasts of Iceland: a dendrochronological study. J. öKull. 43, 15–32.

Guðmundsdóttir, L., 2022. Driftwood utilization and procurement in Norse Greenland. Acta Boreal. 39 (2), 138–167. https://doi.org/10.1080/08003831.2022.2131089.

Hellmann, L., Tegel, W., Eggertsson, Ó., Schweingruber, F.H., Blanchette, R., Kirdyanov, A., Gärtner, H., Büntgen, U., 2013. Tracing the origin of Arctic driftwood. J. Geophys. Res.: Biogeosci. 118, 68–76. https://doi.org/10.1002/jgrg.20022.

Hellmann, L., Tegel, W., Kirdyanov, A.V., Eggertsson, Ó., Esper, J., Agafonov, L., Nikolaev, N.A., Knorre, A.A., Myglan, V.S., Churakova, O., Schweingruber, F.H., Nievergelt, D., Verstege, A., Büntgen, U., 2015. Timber logging in Central Siberia is the main source for recent Arctic driftwood. Arct., Antarct., Alp. Res. 47 (3), 449–460. https://doi.org/10.1657/AAAR0014-063.

Hellmann, L., Tegel, W., Geyer, J., Kirdyanov, A.V., Nikolaev, A.N., Eggertsson, Ó., Altman, J., Reinig, F., Morganti, S., Wacker, L., Büntgen, U., 2017. Dendro-provenancing of Arctic driftwood. Quat. Sci. Rev. 162, 1–11. https://doi.org/10.1016/j.quascirev.2017.02.025.

Hlásková, L., Rogoziński, T., Dolny, S., Kopecký, Z., Jedinak, M., 2015. Content of respirable and inhalable fractions in dust created while sawing beech wood and its modifications. Drewno 58 (194), 135–146. https://doi.org/10.12841/wood.1644-3985.096.11.

IARC, 2012. Arsenic metals fibres and dusts: IARC monographs on the evaluation of carcinogenic risks to humans. IARC, Lyon, France.

Jacobsen, G., Schaumburg, I., Sigsgaard, T., Schlünssen, V., 2010. Nonmalignant respiratory diseases and occupational exposure to wood dust. Part II. Dry wood industry. Ann. Agr. Env Med 17 (1), 29–44.

Javed, M., Kekkonen, P., Ahola, S., Telkki, V., 2015. Magnetic resonance imaging study of water absorption in thermally modified pine wood. Holzforschung 69 (7), 899–907. https://doi.org/10.1515/hf-2014-0183.

Johnson, B.R., Ibach, R.E., Baker, A.J., 1992. Effect of salt water evaporation on tracheid separation from wood surfaces. For. Prod. J. 42 (7/8), 57–59.

Kminiak, R., Dzurenda, L., 2019. Impact of sycamore maple thermal treatment on a granulometric composition of chips obtained due to processing on a CNC machining centre. Sustainability 11 (3), 718. https://doi.org/10.3390/su11030718.

Kminiak, R., Orłowski, K., Dzurenda, L., Chuchała, D., Banski, A., 2020. Effect of thermal treatment of birch wood by saturated water vapor on granulometric composition of chips from sawing and milling processes from the point of view of its processing to composites. Appl. Sci. 10, 7545. https://doi.org/10.3390/app10217545.

Kolář, T., Rybníček, M., Eggertsson, Ó., Kirdyanov, A., Čejka, T., Čermák, P., Žid, T., Vavrčík, H., Büntgen, U., 2022. Predicted sea-ice loss will terminate Iceland's driftwood supply by 2060 CE. Glob. Planet. Change 213, 103834. https://doi.org/10.1016/j.gloplacha.2022.103834.

Kučerka, M., Očkajová, A., 2018. ThermoWood and granularity of abrasive wood dust. Acta Fac. Xylologiae 60 (2), 43–51. https://doi.org/10.17423/afx.2018.60.2.04.

Licow, R., Chuchala, D., Deja, M., Orlowski, K.A., Taube, P., 2020. Effect of pine impregnation and feed speed on sound level and cutting power in wood sawing. J. Clean. Prod. 272 (2020), 122833 https://doi.org/10.1016/j.jclepro.2020.122833.

Maldas, D.C., Kamdem, D.P., 1999. Wettability of Extracted Southern Pine. For. Prod. J. 49 (11/12), 91–93.

Mooney, D.E., 2016b. A 'North Atlantic island signature' of timber exploitation: Evidence from wooden artefact assemblages from Viking Age and Medieval Iceland. J. Archaeol. Sci.: Rep. 7, 280–289. https://doi.org/10.1016/j.jasrep.2016.05.021.

Mooney, D.E., 2016a. Examining possible driftwood use in Viking Age Icelandic boats. Nor. Archaeol. Rev. 49 (2), 156–176. https://doi.org/10.1080/00293652.2016.1211734.

Mooney, D.E., 2018. Does the 'Marine Signature' of driftwood persist in the archaeological record? An experimental case study from Iceland. Environ. Archaeol. 23 (3), 217–227. https://doi.org/10.1080/14614103.2017.1377404.

Nguyen, T.T., Xiao, Z., Che, W., Trinh, H.M., Xie, Y., 2019. Effects of modification with a combination of styrene-acrylic copolymer dispersion and sodium silicate on the mechanical properties of wood. J. Wood Sci. 65, 2. https://doi.org/10.1186/s10086-019-1783-7.

Oberdörster, G., Oberdörster, E., Oberdörster, J., 2005. Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. Environ. Health Perspect. 113, 823–839.

Očkajová, A., Kučerka, M., Kminiak, R., Rogoziński, T., 2020. Granulometric composition of chips and dust produced from the process of working thermally modified wood. Acta Fac. Xylologiae 62 (1), 103–111. https://doi.org/10.17423/afx.2020.62.1.09.

Orlowski, K., Chuchala, D., Dzurenda, L., 2018. The effect of full-cell impregnation of pine wood (*Pinus sylvestris* L.) on the fine dust content during sawing on a frame sawing machine. Trieskove a Beztrieskove Obrabanie Dreva 11 (1), 131–137.

Orlowski, K., Chuchala, D., Muzinski, T., Baranski, J., Banski, A., Rogozinski, T., 2019. The effect of wood drying method on the granularity of sawdust obtained during the sawing process using the frame sawing machine. Acta Fac. Xylologiae Zvolen 61, 83–92. https://doi.org/10.17423/afx.2019.61.1.08.

Piernik, M., Rogoziński, T., Krauss, A., Pinkowski, G., 2019. The influence of the thermal modification of pine (*Pinus sylvestris L.*) wood on the creation fine dust particles in plane milling. J. Occup. Health 00, 1–8. https://doi.org/10.1002/1348-9585.12075.

Rogoziński, T., Chuchala, D., Pędzik, M., Orlowski, K., Dzurenda, L., Muzinski, T., 2021. Influence of drying mode and feed per tooth rate on the fine dust creation in pine and beech sawing on a mini sash gang saw. Eur. J. Wood Wood Prod. 79, 91–99. https://doi.org/10.1007/s00107-020-01608-8.

Santamaría-Herrera, A., Hoyuelos, F.J., Casado-Marcos, C., 2023. Characterization of the explosiveness of wood dust. Process Saf. Environ. Prot. 169, 252–259. https://doi.org/10.1016/j.psep.2022.10.087.

Sinn, G., Chuchala, D., Orlowski, K.A., Taube, P., 2020. Cutting model parameters from frame sawing of natural and impregnated Scots pine (*Pinus sylvestris* L.). Eur. J. Wood Wood Prod. 78, 777–784. https://doi.org/10.1007/s00107-020-01562-5.