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Gilvari, Hamid; Karaca, Kadir; de Jong, Wiebren; Schott, Dingena

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Influential Properties on Mechanical Degradation of Densified Torrefied Biomass in Large Scale Transportation and Storage

Hamid Gilvari *[a], Kadir Karaca [a], Wiebren de Jong [b], Dingena L. Schott [a]

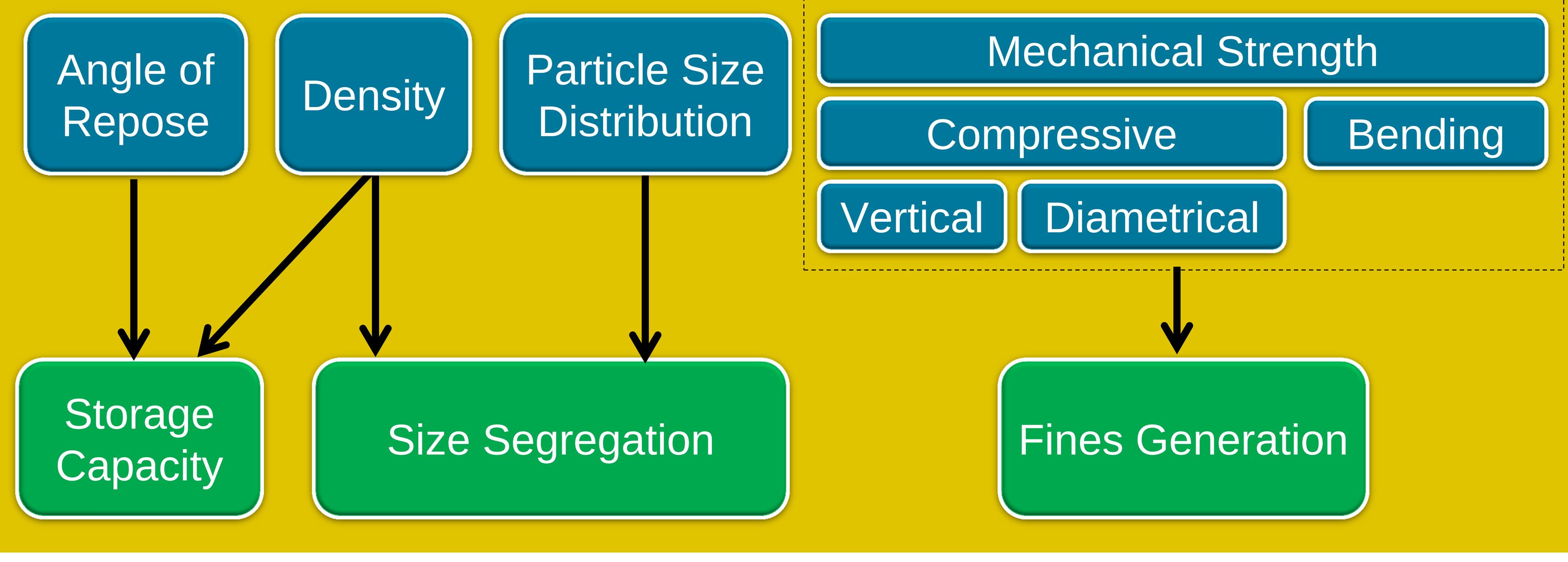
[a] Section of Transport Engineering & Logistics, Department of Maritime & Transport Technology, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology

[b] Section of Large Scale Energy Storage, Department of Process & Energy, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology

1. Introduction

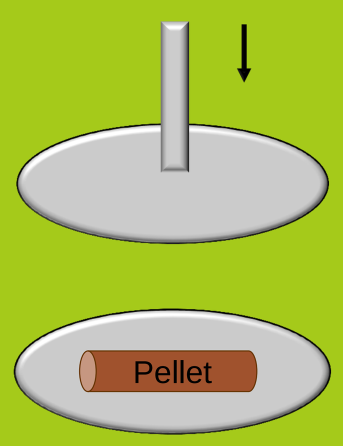
Torrefied and non-torrefied biomass pellets, due to their structure and components, are fragile and may break during large scale transportation and storage. This can produce fines and dust, which is unwanted for health and safety reasons. Dust is known to be health threatening (dust inhalation), and it causes a risk to dust explosions. Furthermore, creation of dust and fines is simply a loss of material. So far, the mechanical degradation of densified biomass has not been comprehensively studied, especially the identification of influential properties were far less considered. Understanding these properties and the mechanical behaviour of particles during transportation and storage could help to reduce the amount of created fines and dust.

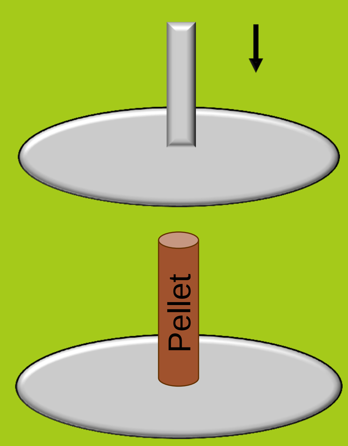
The objective is to experimentally identify the particle and bulk characteristic properties affecting material degradation and investigate their relationships for different kinds of black and white wood (torrefied and non-torrefied) pellets.

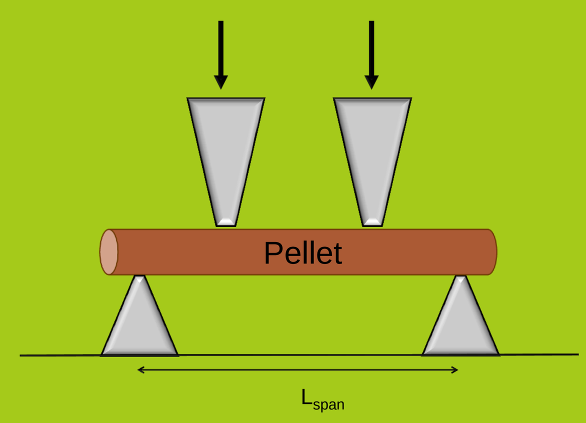


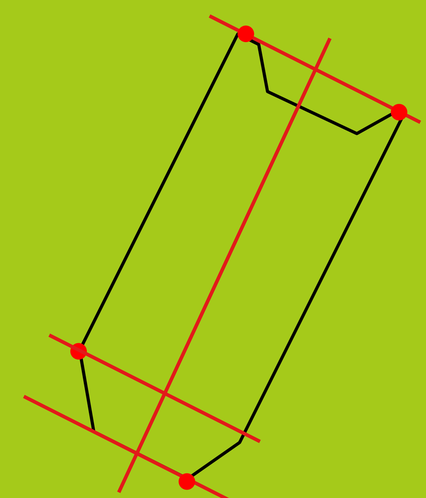
2. Materials and Methods

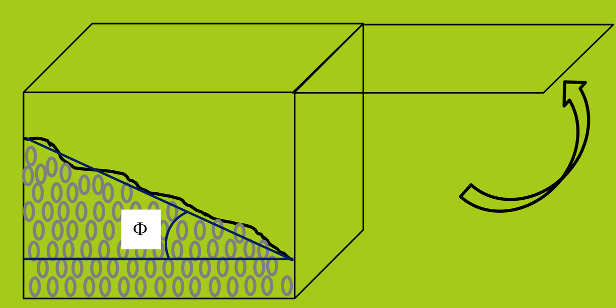
6 different torrefied biomass pellets and 5 different non-torrefied biomass pellets were used for the experiments. All pellets are cylindrical in shape and are 6 mm in diameter. They were tested in a series of 5 experiments described below, furthermore particle and bulk densities are determined for all samples. All the material were tested in 'as received' condition. Detailed characteristics of the torrefaction and densification processes are unknown. However, Ash and Spruce materials have been torrefied under the same conditions and densified in the same manner.











2.1 Diametrical Compression

The diametrical compression (also called as tensile test) is calculated based on the maximum force a pellet could withstand before failure. The tensile strength is calculated by:

$$\sigma = \frac{2F}{\pi D L}$$

Where F is the maximum force (N), D is the diameter (mm) and L (mm) is the length of the pellets.

2.2 Vertical Compression

Pellets are normally broken at both ends, creating a non-uniform surface. In order to measure the vertical strength and to ensure that broken ends do not effect on the results, both ends were subjected to sandpaper for smoothing and polishing. Then the maximum force a pellet could tolerate before failure is reported.

2.3 Bending Strength

The bending test resembles the particle breakage in bending during transportation. The maximum stress for a cylinder in 4-point bending is calculated by:

$$\sigma_b = \frac{4FL}{\pi D^3}$$

Where F is the maximum force at failure (N), L_{span} is the span length (mm), and D is the pellet diameter (mm). For all the experiments here, the span length is kept constant at 20 mm.

2.4 PSD

A novel quick and easy computer aided method for determination of the PSD of cylindrical densified biomass based on image processing is presented. In this method, first the extreme points of each pellet are determined. Then an orientation line along the major axis of the pellet is drawn. The next step is to draw a line from each extreme point orthogonal to the orientation line. Finally, the maximum distance between the extreme lines determines the particle length.

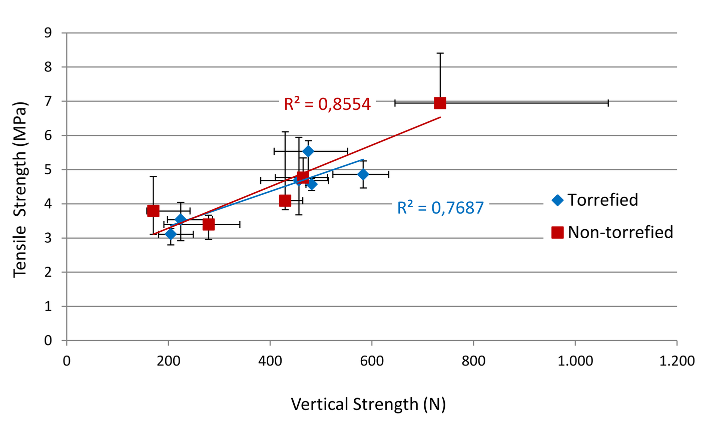
2.5 Angle of Repose

The angle of repose of the materials was measured by the ledge test. Around 1 kg of each sample was used for the experiments. Each test was repeated 5 times and the reported angle of repose is the average value of all the tests.

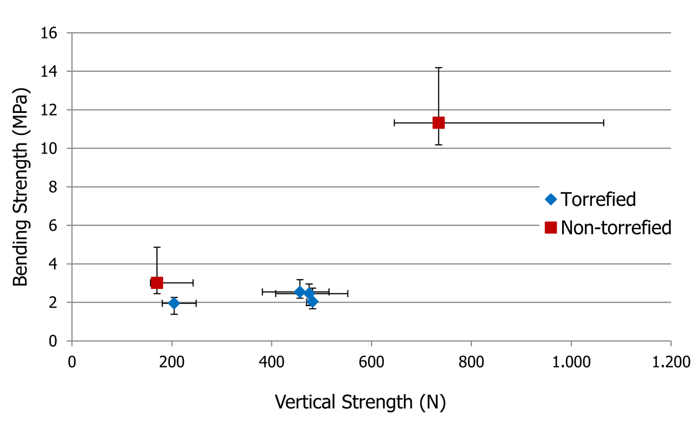
3. Results

3.1 The relationship between different mechanical strengths

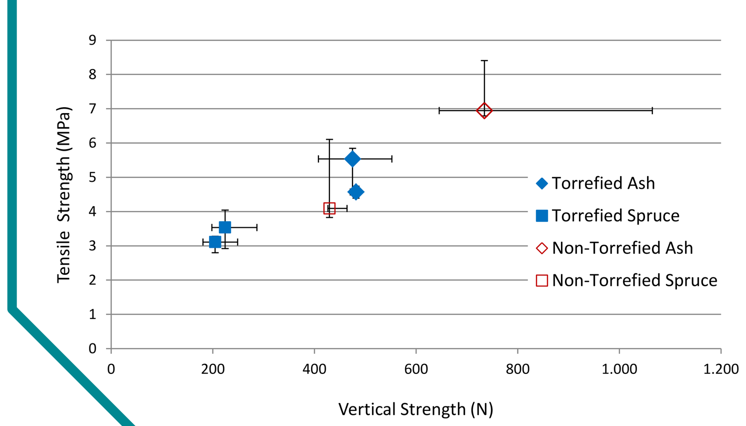
Tensile Strength vs Vertical Strength



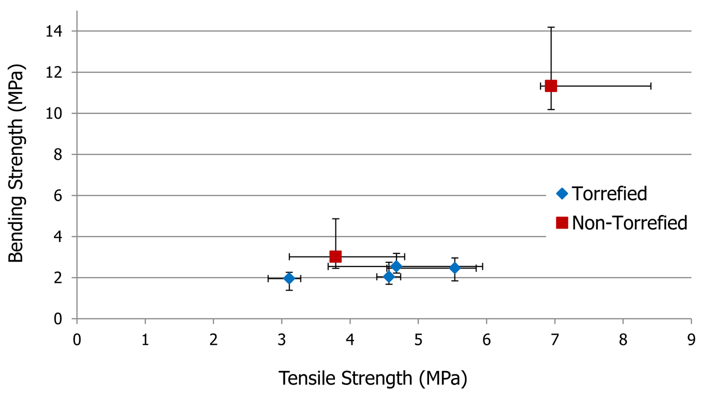
Bending Strength vs Vertical Strength



Strength of Hardwood vs Softwood

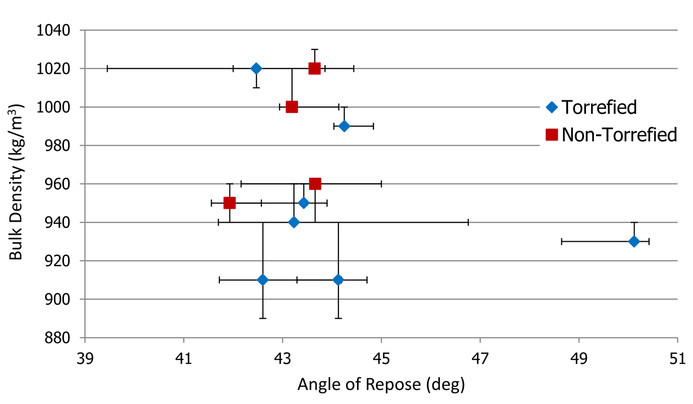


Bending Strength vs Tensile Strength

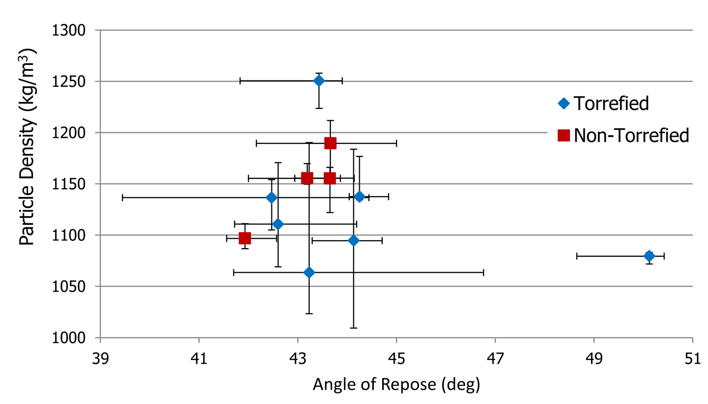


3.2 Angle of repose

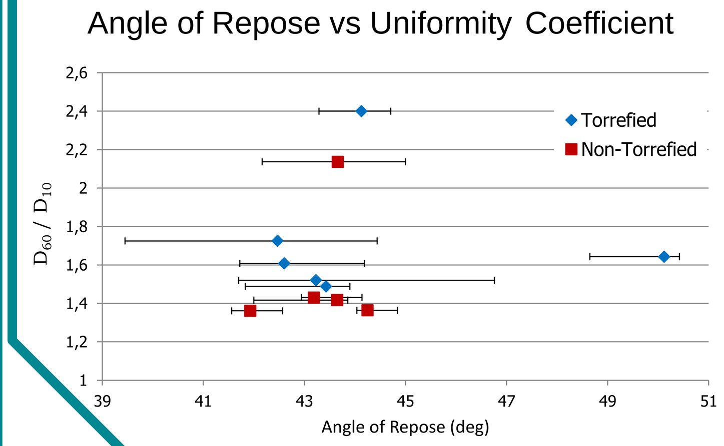
Angle of Repose vs Bulk Density



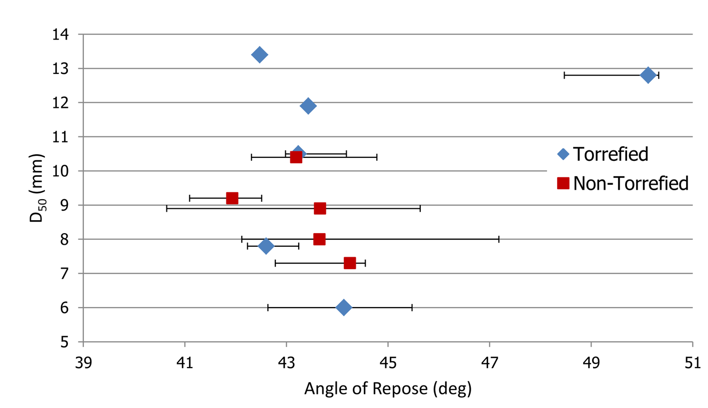
Angle of Repose vs Particle Density



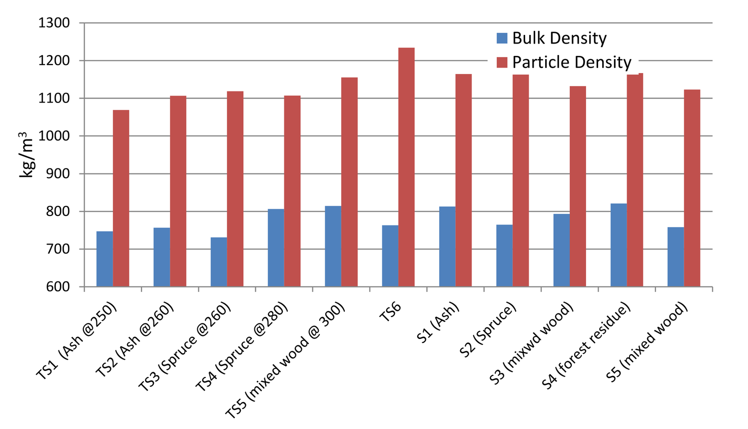
Angle of Repose vs Uniformity Coefficient



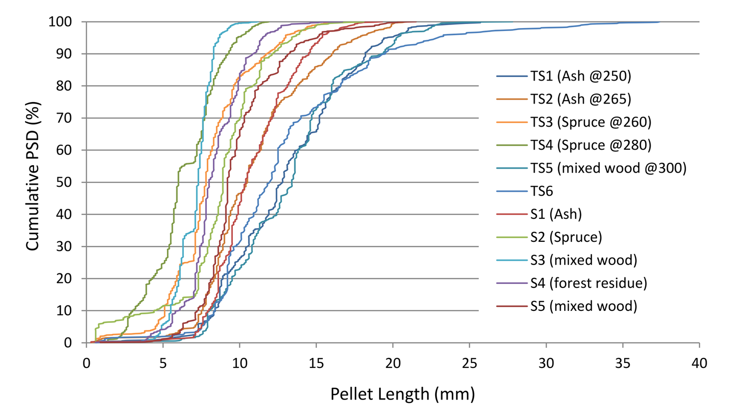
Angle of Repose vs Median Particle Size



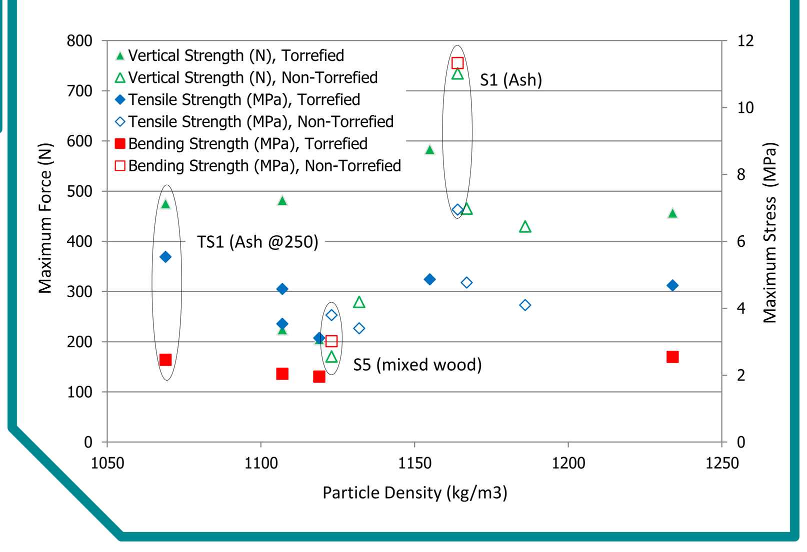
3.3 Particle and Bulk Densities



3.4 PSD



3.5 Particle Density vs Mechanical Strength



4. Conclusions

- ✓ Torrefaction notably decreases the mechanical strength of the tested hardwood (Ash) and likely also for softwood (Spruce)
- ✓ There is no relationship found between particle density and mechanical strength, as such, higher particle densities do not necessarily lead to higher mechanical strength
- ✓ We observed a strong relationship between vertical and diametrical compression results, however, relationship between compression and bending strength was not observed
- ✓ We observed no correlation between the angle of repose and densities, nor the angle of repose and PSD
- ✓ The angle of repose for all the pellets was in the range of 40 to 50°

Further work

- ✓ More test with other pellets preferably produced by the same torrefaction and densification processes are required to fully understand the effect of biomass type (i.e. hardwood and softwood) on the mechanical strength
- ✓ As the presence of cracks on the pellet surface could possibly affects the results of the bending test, it requires further investigation
- ✓ This research points out the characteristics of a range of torrefied and non-torrefied biomass pellets and paves the way for further research on the breakage behaviour of them. Furthermore, the results are useful for the pellet producers to identify the most influential properties of biomass relevant for handling and storage and supports them to improve the pellet quality in terms of fines generation

Acknowledgment

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*Corresponding author: Hamid Gilvari
Email: H.Gilvari@tudelft.nl

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