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# The effect of particle size distribution on the bulk thermal conductivity of biomass pellets

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## Introduction

The large-scale storage of biomass pellets is challenging due to health issues, material loss, and the risk of fire and explosions. The thermal conductivity is a material property which plays a key role in determining the self-heating properties of biomass. Meanwhile, understanding the thermal conductivity and the affecting factors help to better understand and reduce the risk of self-heating and fire explosions.

## Objective

The objectives are (1) to characterise the thermal conductivity of batches of bulk biomass pellets with different particle size distributions and (2), to determine the correlations between the bulk thermal conductivity and the mean particle length of the pellets.

## Material and Methods

Biomass pellets with 6 mm diameter made of sawdust were used in this study. Ten batches of pellets with different particle size distributions were selected for the experiments as shown in figure 1.

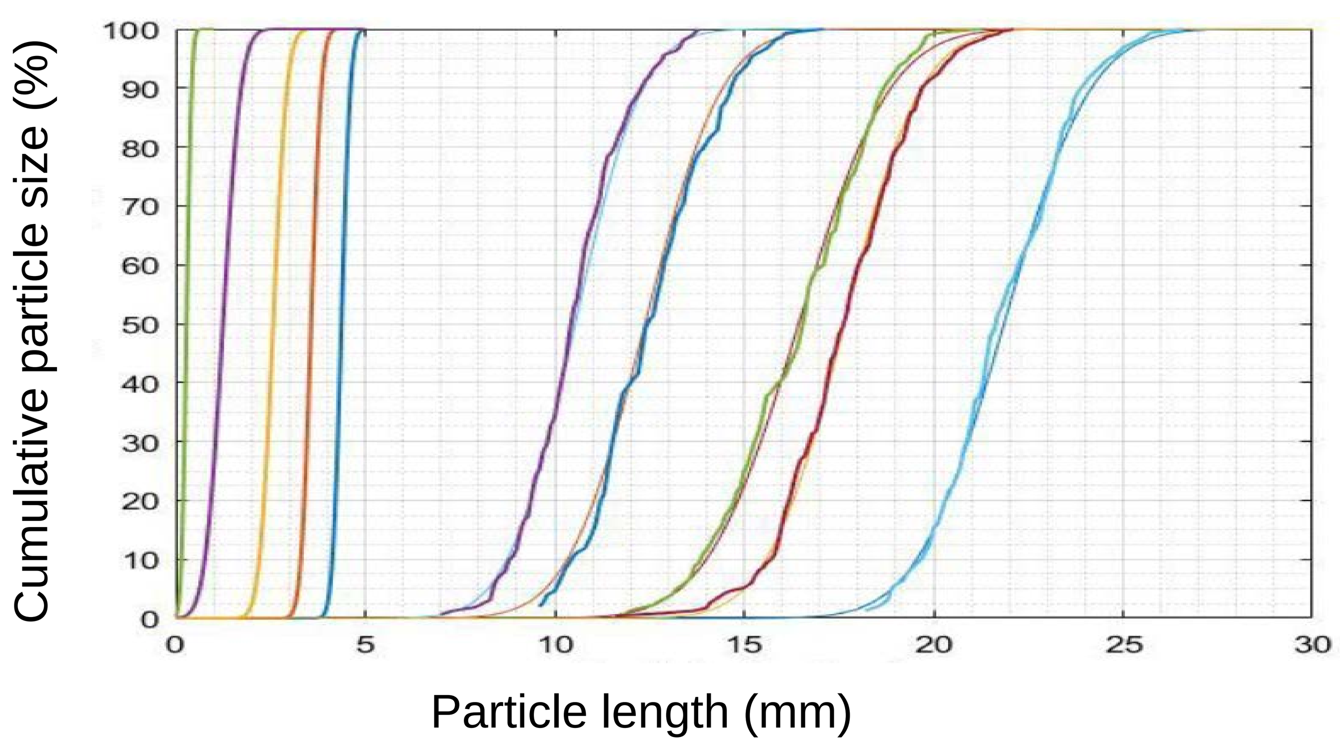



Figure 1. Particle size distribution of different batches of the pellets

The measurements were conducted based on the steady state split-bar method (SSM) according to the standard method of measuring the thermal conductivity of polymers (figure 2). To verify the measurement of the custom-build apparatus, the thermal conductivity of 6 batches of the sample were also measured using the transient plane source method (TPS)

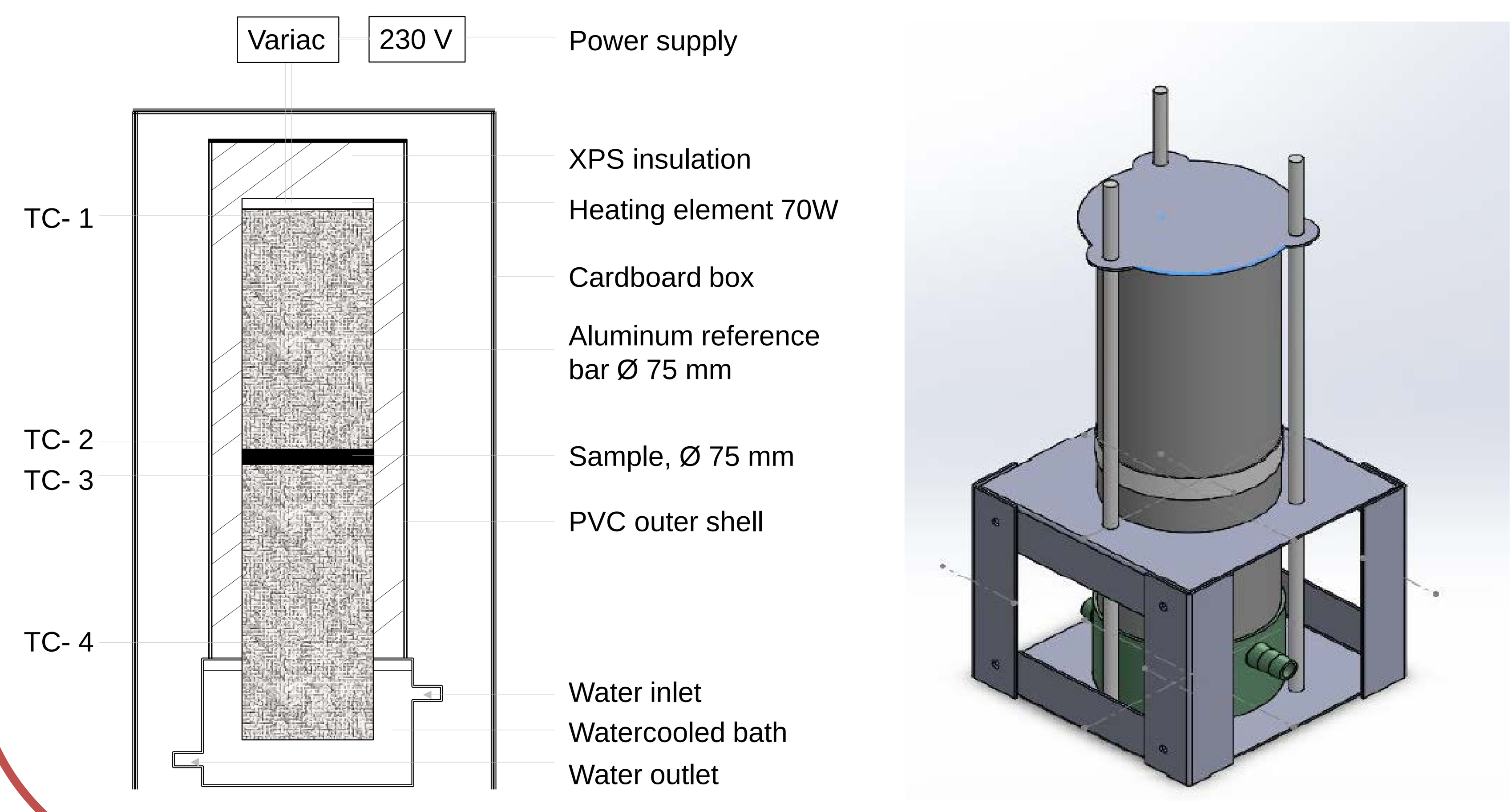



Figure 2. Setup configuration

## Calculations

The thermal conductivity was measured based on:

$$k_s = \frac{L_S Q_s}{A_{cs}\Delta T_s}$$

Where

$$\Delta T_s = \left(T_2 - \frac{L_o Q_1}{A_{cs}k_{al}}\right) - \left(T_3 + \frac{L_o Q_2}{A_{cs}k_{al}}\right), \text{ and } Q_s = \frac{Q_1+Q_2}{2}$$

$$Q_1 = \frac{k_{al}A_{cs}(T_1 - T_2)}{L_{tc}} - \frac{2\pi k_{ins}L_{tc}\left(\frac{(T_1+T_2)}{2} - T_{amb}\right)}{\ln(\frac{r_2}{r_1})}$$

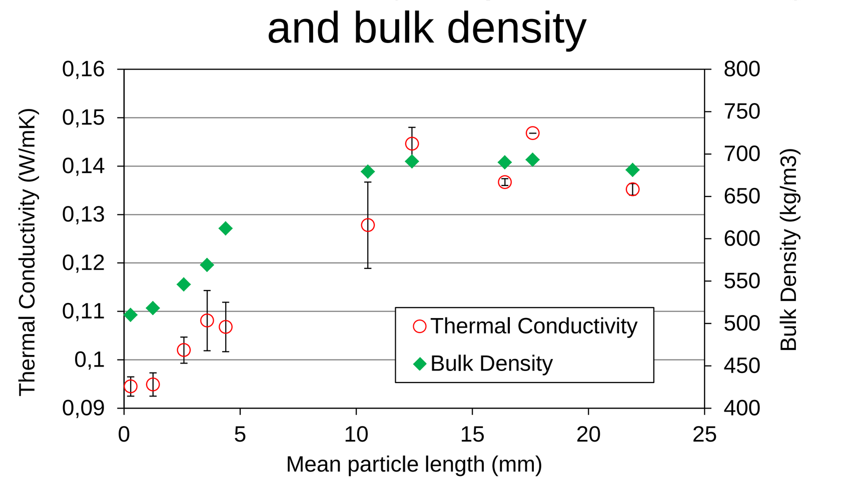
$$Q_2 = \frac{k_{al}A_{cs}(T_3 - T_4)}{L_{tc}} - \frac{2\pi k_{ins}L_{tc}\left(\frac{(T_3+T_4)}{2} - T_{amb}\right)}{\ln(\frac{r_2}{r_1})}$$

Table 1. Definition of the terms used in the calculations

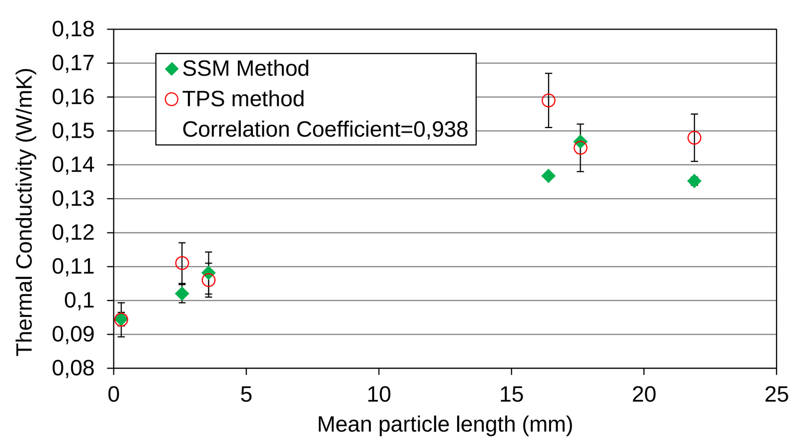
| Term | Definition |
|---|---|
| $k_s$ | Thermal conductivity of the sample |
| $L_S$ | Sample thickness (m) |
| $L_o$ | Thermocouples distance from the sample surface (0.005 m) |
| $L_{tc}$ | Distance between the thermocouples (0.135 m) |
| $A_{cs}$ | Contact area of the aluminium rod with the sample (0.0044 m$^2$) |
| $k_{al}$ | Thermal conductivity of aluminium (188 W/mK) |
| $k_{ins}$ | Thermal conductivity of the insulation (0.03 W/mK) |
| $r_1$ | Inner radius of the insulation ring (0.0375 m) |
| $r_2$ | Outer radius of the insulation ring (0.059 m) |
| $T_1, T_2, T_3, T_4$ | Recorded temperatures by thermocouples |
| $T_{amb}$ | Ambient temperature |

## Results

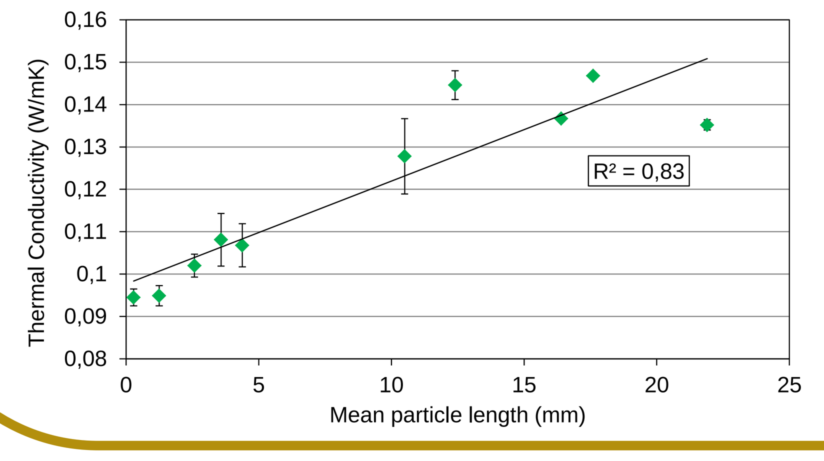
Thermal conductivity vs pellet mean length and bulk density



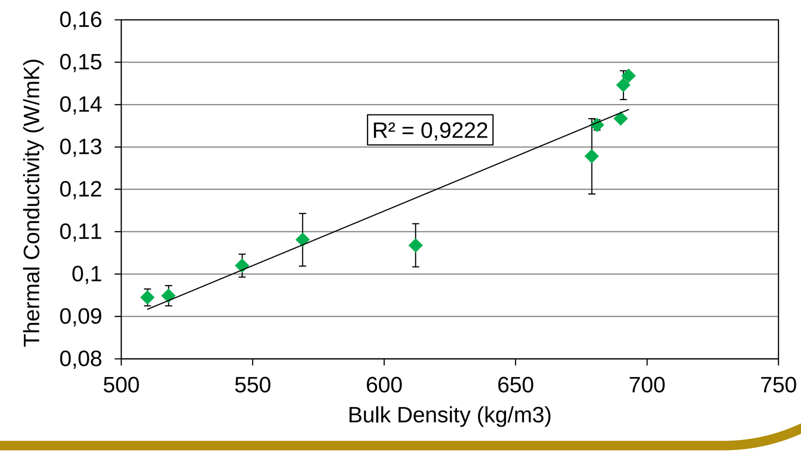

SSM method vs TPS method




Thermal conductivity vs pellet mean length




Thermal conductivity vs bulk density




## Conclusions

- ✓ The thermal conductivity highly depends on the bulk density, however, it does not show a high correlation with the mean particle length
- ✓ Increasing the particle size distribution does not necessarily lead to higher bulk densities

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