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Calibration of handheld moisture meter for forest fuels

A handheld moisture meter has been calibrated to see the possibilities of using it for forest fuel supplies with higher moisture content than 45 %, which is a common forest fuel in Sweden. The results shows that it enables fast measurements of the moisture content and it meets the requirements for production management of forest fuels. This info-sheet is based on a conference proceeding submitted to FORMEC conference, Madrid 2018.

HEATING VALUES AND MOISTURE CONTENT

Heating values are highly correlated to the moisture content (MC) of the fuel which may change throughout the supply chain and therefore needs to be estimated/measured at different points in the biomass supply chain. For example, a freshly cut tree can hold up to 60% water and stored uncommuted energy wood can have as low MC as 20%.

Thus, the challenge of managing forest fuel supply chains is to maintain, or improve, the quality throughout the supply chain, and in order to achieve that MC needs to be determined frequently over time.

The method used today to determine MC is the thermo-gravimetric method using oven drying. Traditional sample preparation for MC analysis is labor intensive and thus is the number of samples that can be analyzed limited, mainly due to cost.

To be able to predict the material fuel properties, representative samples of the material has to be taken. Measurement for trade require high precision and accuracy and measurement for production management less. In general, higher precision requires that a larger amount of samples has to be taken.

Here precision is defined as: the ability to measure with consistency and that the instrument doesn't have large deviations between each measurement. Here accuracy is defined as: to be able to measure with little deviation from the reference value.

HANDHELD MOISURE METER

In forest fuel production management there is a demand for fast, portable, and cost-effective moisture content (MC) determination technology. The handheld Wile Bio Moisture Meter (WBMM) (Fig. 1), has a potential to be used in such management but has however not been calibrated for forest fuels with high MC (> 45%), which is a common MCs of forest fuels. The WBMM allows direct measurement in the chip pile and gives a MC value within 5-10 sec. It is fast and require no sample preparation.

Figure 1. The hand held Wile Bio Moisture Meter (WBMM) (Farmcomp 2018).

The WBMM is relatively cheap, around 1 000 Euro, and thus cost-effective. The biggest disadvantage of this capacitance technique is that it does not work on frozen material.

The WBMM is based on capacitance technology, which measures the ability of the sampled material to store electrical charge. The top of the measuring body acts like a plus pole and the plate acts like a negative pole (Fig. 1).

The instrument is provided with five settings which the user can shift between:

1. stem wood chips
2. fine logging residues chip
3. medium logging residues chip
4. course logging residue chips
5. program 0 which gives the capacitance value and is used for calibration of the equipment.

Figure 2. Demonstration of the handheld Wile Bio Moisture Meter (WBMM) in a pile of stem wood.

PREVIOUS TESTS

Previous tests of the WBMM on hog fuel with a MC of 10-70% (coarse chips; 254 samples) and logging residues chips with a MC of 8-50% (61 samples), show that on average 56% of the hog fuel samples was overestimated with 5.3%-units, and 44% of the samples was underestimated with 6.7%-units. The corresponding values for logging residues was: 46% of samples was overestimated with 2.3%-units and 54% was underestimated with

1.9%-units. Previous tests also show that on average, for MC classes between ca 20-50% using the default calibra- tion settings in the instrument, the WBMM underes- timated the MC with 6.0%-units with a deviation of ± 3.8%-units (95% confidence interval (CI)). The WBMM was then calibrated for MC classes up to 50% MC and the overall accuracy improved and gave an underestimation of 2.4 %-units.

TRIALS

The study was designed to create calibration curves for five well defined types of forest fuels (Table 1) and then validate the calibrations on new (independent) sets of samples. Both calibration and validation measurement was carried out in a laboratory environment.

The material used in the study (Table 1) was collected at the fuel terminal of Umeå Energy heat and power plant at Dåvamyran (north of Sweden). The samples were collected in 20 liter buckets and sealed with a lid (Fig. 3). The aim was to create two different MC classes for each fuel type. Sampling were done on evenly distributed points across the chip pile to capture variations within the biomass. All samples had MC between 40 and 59.9%. The samples were either dried or added with water in order to create variations in MC.

The stem wood chips constitutes of low grade logs which had been chipped on site and stored on the fuel yard with- out coverage for a few days before sampling. The stem wood consisted of a mixture of hard woods, betula pubes- cence and alnus incana. The logging residues consisted of tops and branches from clear cuttings mainly of conifers, pinus sylvestris and picea abies and had been chipped at the fuel yard in June-July 2017. Sampling were performed between 2017-12-01 and 2018-02-28.

Figure 3. Sampling of logging residues before calibration.

Table 1. Description of measured fuel types and calibration functions for the different products with corresponding R2 values and average difference between the predicted and reference values (Diff.) and corresponding 95%-level confidence intervals (CI). The response value is given as MC (%) and the x represents the capacitance value given by WBMM with program 0. n=number of samples.

Material	MC (%)	Calibr. (n)	Valid. (n)	Calibration function	R^2	Diff. (%-units)	CI (%-units)
Stem wood	40-49.9	3	2	-0.078x+199.33	0.729	1.71	0.45
Stem wood	50-59.9	5	4	-0.078x+199.33	0.729	0.43	3.2
Stem wood	40-49.9	12	5	-0.119x+281.71	0.706	-0.45	1.87
Stem wood	50-59.9	4	2	-0.119x+281.71	0.706	3.03	0.88
Stem wood	40-49.9	5	5	-0.090x+225.67	0.728	0.70	0.81
Stem wood	50-59.9	5	3	-0.090x+225.67	0.728	1.03	5.06
Logging residues	50-59.9	7	5	-0.006x+69.48	0.720	-0.04	0.61
Logging residues	40-49.9	17	5	-0.143x+334.46	0.876	0.27	0.78
Logging residues	50-59.9	9	5	-0.143x+334.46	0.876	-1.50	1.07

In this study, the WBMM program 0 was used to determine the capacitance and relate it to the reference MC value. Measurements were done on a 10 L subsample taken from the 20 L sample. For each sample measured with the WBMM a reference method were used to predict the "true value" to create the calibration curve.
Subsequently, The validation was done using an independent set of data and the created calibration models for each products. The capacitance value received on the validation material set were then used in the calibration model to predict a MC (MC_pred). This value was then compared with the reference value (MC_ref) received from the corresponding oven drying method. The deviation of the predicted value were calculated as: MC_diff = MC_ref – MC_pred [%-points]. The precision of the prediction model was calculated with a 95% confidence interval (CI) in each MC class.

CONCLUSIONS OF CALIBRATION

On average, the deviation (precision) of all validation measurements from the "true" value was 1 %-units (Table 1) The overall accuracy was overestimated with 0.3%-units; in general MC of stem wood and medium course logging residues was over estimated and course logging residues was underestimated. The created calibration functions have R2 values above 0.7. The functions are valid for measurements in an environment that holds 20 °C.

PRACTICAL IMPLEMENTATION

At the Dåva combined heat and power plant a measurement inaccuracy of 5%-units is accepted when determine MC on comminuted forest fuels at the fuel yard. Our results show that a calibrated WBMM meets such requirements as it on average only overestimated the MC with 0.3%-units. The Swedish Forest Board has stated that a measuring method must have less than 1% systematic error on annual basis regarding accuracy. As the studied technology is sensitive to particle sizes previous studies concludes that at least 10 samples should be taken for course materials and 3 for more homogeneous material in order to fulfill a maximum of 1%-unit deviation.

As the WBMM is cost-effective (when it has been calibrated!) relative the oven drying method it is possible to take numerous samples and thus render possibilities to reach the same overall accuracy as with a reference method. The calibration functions created in present study are only valid for use in room temperature and if to be used in other temperatures, functions needs to be complemented with weights for temperature. If creating calibration curves for production management, were less accuracy is needed, dividing fuel types in many different classes might be overkill. For example, all types of stem wood chips in present study and all types of logging residues was treated as single products calculations indicates that it is not of vital importance to classify the material into very specific product categories.

COMPARE WITH TODAY'S MEASUREMENT OF THE MOISTURE CONTENT

At Dåva CHP plant log yard, for determining the chipped fuels the common procedure is to take seven small samples (approx. 3 deciliter each) and merge them to a general sample, put the sample immediately in a freezer until scaled and oven dried for MC determination. This routine gives however no information about the vari- ation in the samples, i.e. calculation of accuracy is not possible. As the cost of MC determination using the oven drying method is highly correlated to how many samples you take and the number of samples handled in practice is kept to "as few as possible". However, with the WBMM there is insignificantly extra costs between taking seven or fourteen samples, and still you can calculate the accuracy.

Technologies as the WBMM is suitable for production management were the requirements of accuracy and precision is lower than for trade measurements. They could render possibilities to increase precision in fuel logistics management. They could also be used for inventory and production management at a fuel yard. However, local conditions must be considered meaning that calibration for different assortments and temperature must be done before operational use.

CONCLUSIONS

Our study show that the WBMM can be calibrated for various assortments/fuel products with high MC content and give accuracy's significantly below industry demands (e.g. a 5%-unit limit) for fuel yard management and give complementary knowledge to previous work. Our study also indicate that more general prediction functions for operational use should be made.

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