

BREAKAGE MATRIX METHOD TO PREDICT DEGRADATION OF WOOD PELLETS IN HANDLING

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What is Breakage Matrix (BM) ?

- It is a mathematical approach
- It links bench scale experiment to the real scale applications
- Can use to predict degradation
- It requires an input for particle size distribution (PSD)
- Breakage fraction are calculated as percentage mass fraction with respect to the input PSD.
- Input vector and BM is multiplied and output vector is taken.

Wood pellets and pelletiser



Theoretical approach

- PSD of input is taken and weight fraction percentage value of input PSD is shown as a column vector

$$F = \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ \vdots \\ f_n \end{bmatrix}$$

- If the same sieves set is used in analysing the output, breakage matrix becomes a square/orthogonal matrix

$$\text{BM} = \begin{bmatrix}
 \frac{m_1}{m_1} & 0 & 0 & 0 & 0 & 0 & 0 \\
 \left(\frac{m_1 - m_2}{m_1}\right) & \left(\frac{m_2 - m_3}{m_2}\right) & 0 & 0 & 0 & 0 & 0 \\
 \left(\frac{m_2 - m_3}{m_1}\right) & \left(\frac{m_3 - m_4}{m_2}\right) & \left(\frac{m_3 - m_4}{m_3}\right) & 0 & 0 & 0 & 0 \\
 \left(\frac{m_3 - m_4}{m_1}\right) & \left(\frac{m_4 - m_5}{m_2}\right) & \left(\frac{m_4 - m_5}{m_3}\right) & \left(\frac{m_4 - m_5}{m_4}\right) & 0 & 0 & 0 \\
 \left(\frac{m_4 - m_5}{m_1}\right) & \dots & \dots & \dots & 0 & 0 & 0 \\
 \dots & \dots & \dots & \dots & \left(\frac{m_{n-1} - m_n}{m_{n-1}}\right) & 0 & 0 \\
 \left(\frac{m_{n-1} - m_n}{m_1}\right) & \dots & \dots & \dots & \left(\frac{m_{n-1} - m_n}{m_{n-2}}\right) & \left(\frac{m_{n-1} - m_n}{m_n}\right) & 0
 \end{bmatrix}$$

- Input vector (F) to the breakage matrix relationship can be given as

$$\begin{bmatrix} b_{11} & b_{12} & \dots & b_{1,n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \vdots & b_{mn} \end{bmatrix} * \begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{bmatrix} = \begin{bmatrix} o_1 \\ o_2 \\ \vdots \\ o_m \end{bmatrix}$$

Breakage extraction(BEX)

- Breakage extraction is the sum of all percentage weight fractions with respect to the first sieve

$$\text{BEX}_k = \sum_{i=1}^m O_i^k, \quad 1 \leq k \leq p,$$

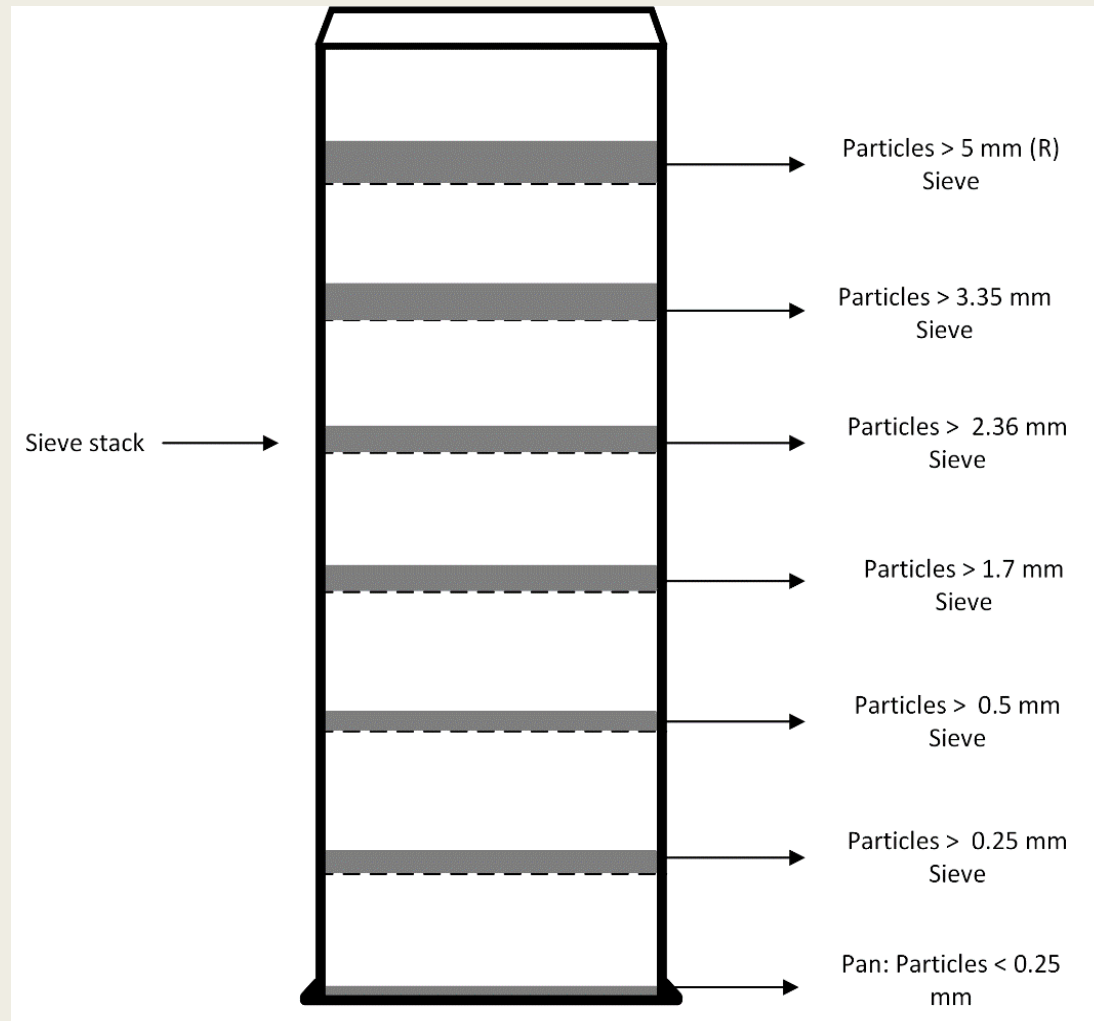
Back calculation

- reverse calculation is used in order to check whether it is possible to find input PSD which gives desired output PSDs

$$f_1 \in \frac{BE_1 - 1 + b_{12}^1}{b_{12}^1 - b_{11}^1}, \frac{BE_1 - 1 + b_{13}^1}{b_{13}^1 - b_{11}^1}$$

$$f_2 \in \frac{b_{11}^1 - 1 + b_{13}^1}{b_{13}^1 - b_{12}^1} \cdot f_1 + \frac{BE_1 - 1 + b_{12}^1}{b_{12}^1 - b_{11}^1}$$

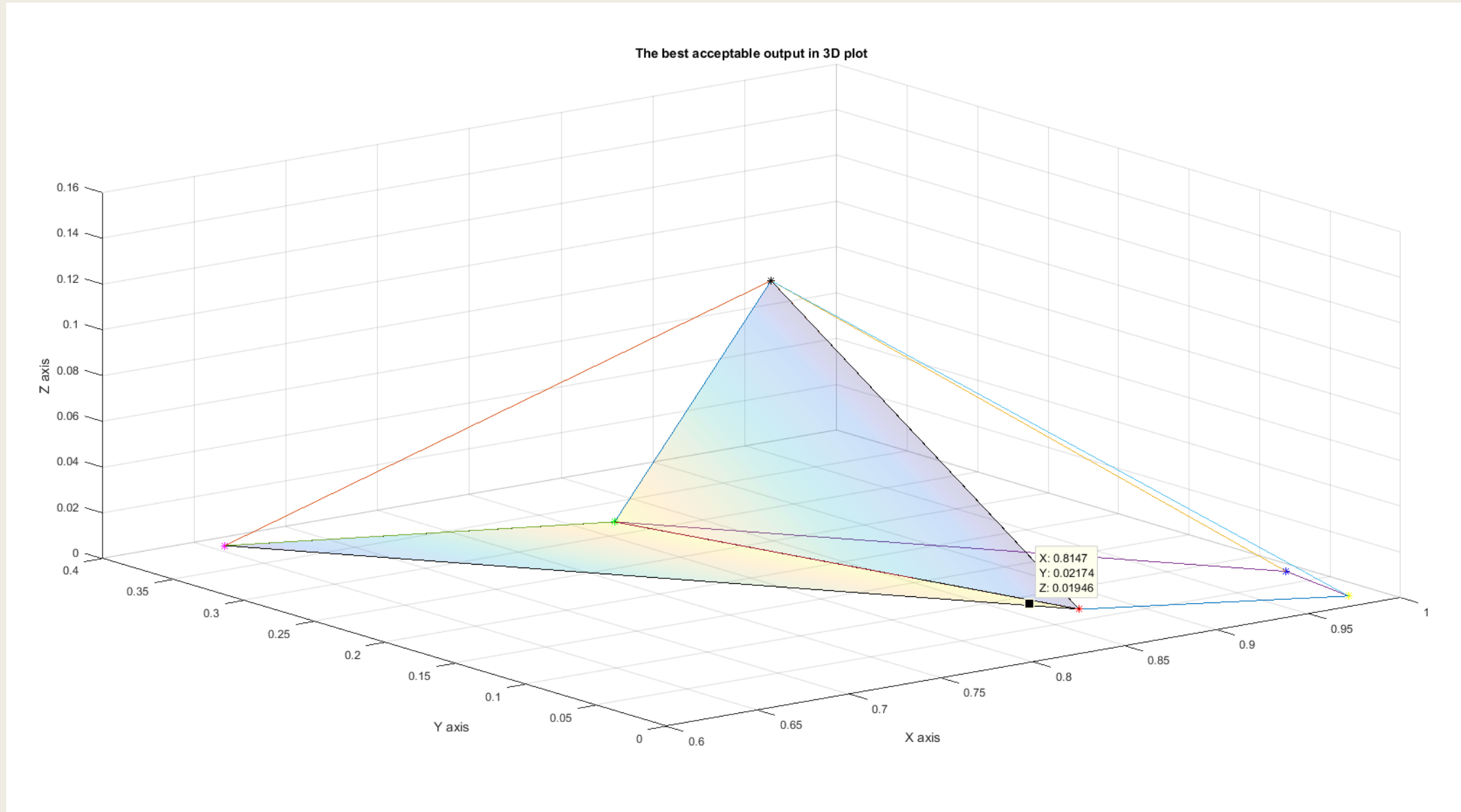
Sieve analysis and attrition Impact Tester



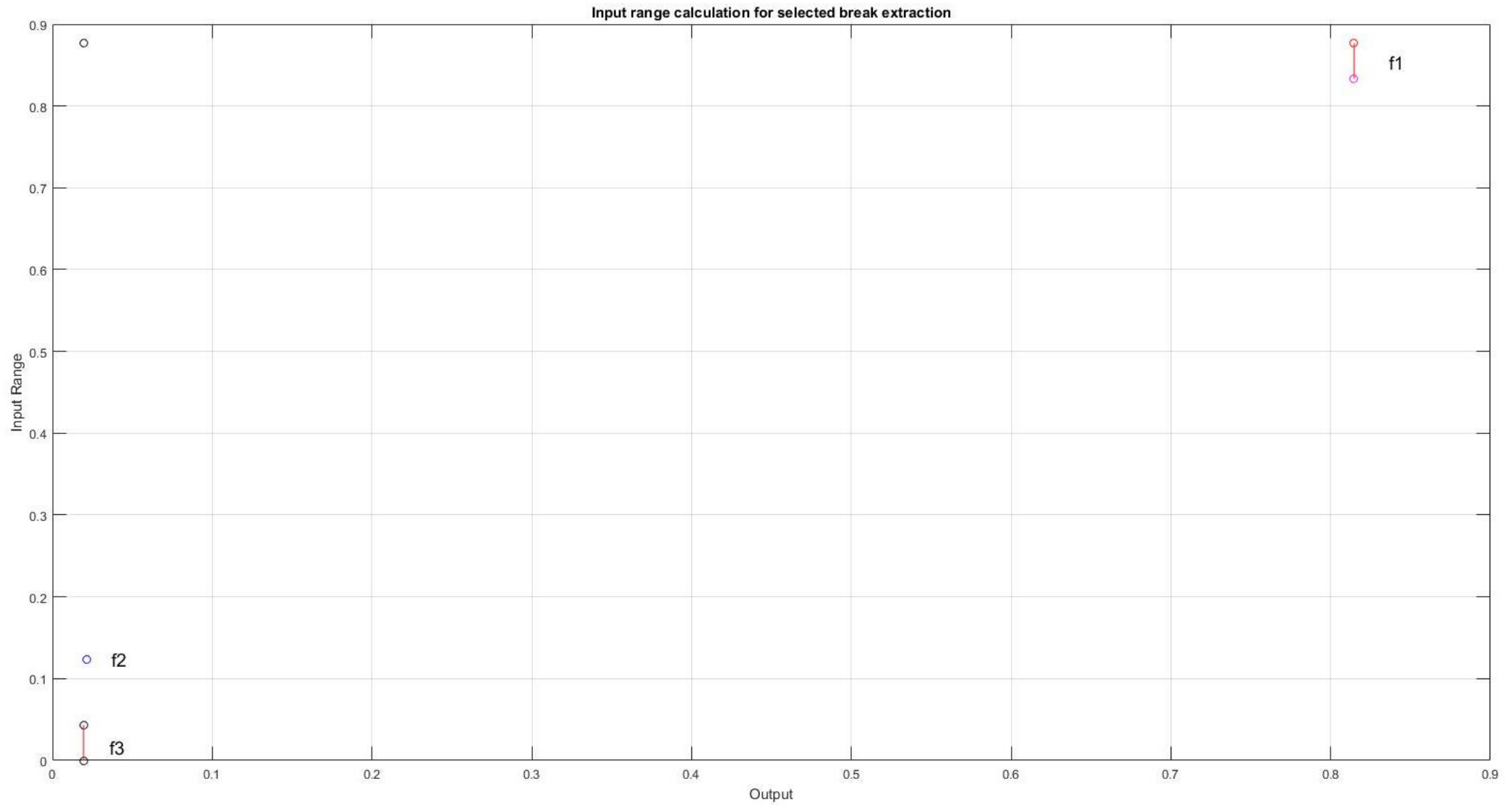
Calculation of BM

$$\begin{bmatrix} 0.9788 \\ 0.0178 \\ 0.0002 \\ 0.0006 \\ 0.0013 \\ 0.0013 \end{bmatrix} \cdot \begin{bmatrix} 0.8323 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0095 & 0.6988 & 0 & 0 & 0 & 0 & 0 \\ 0.0167 & 0.1651 & 0.7336 & 0 & 0 & 0 & 0 \\ 0.1161 & 0.0452 & 0.0996 & 0.6322 & 0 & 0 & 0 \\ 0.0022 & 0.0792 & 0.1577 & 0.3548 & 0.9595 & 0 & 0 \\ 0.0026 & 0.0083 & 0.0052 & 0.0094 & 0.0285 & 0.9840 & 0 \end{bmatrix} = \begin{bmatrix} 0.8147 \\ 0.0217 \\ 0.0195 \\ 0.1149 \\ 0.0240 \\ 0.0040 \end{bmatrix}$$

The best acceptable output



Back calculation



Conclusions

- Breakage matrix is a mathematical approach.
- Can be used to determine output PSD from a breakage event.
- This method is applied in predicting biomass pellet degradation.
- A bench scale attrition impact tester was used to gather experimental data.
- The development of breakage matrices and calculation procedures are explained through a worked example.
- The back calculation example is capable of predicting input PSD for a known case.
- Such a method can be used for checking samples in any step of handling and transport operation and estimate input or output PSD.
- Further study into the application of breakage matrices to a broader set of conditions relating to wood pellet handling systems is currently underway at The Wolfson Centre for Bulk Solids Handling Technology.

Thank you