**NYU-ViscoMOD Software Manual**

**Extraction of Elastic Modulus from Dynamic Mechanical Analysis for Solid Materials**

**Software Introduction**

In Dynamic Mechanical Analysis (DMA), the master curve is a fundamental concept used to predict the viscoelastic behavior of a material over a broad range of frequencies or time scales by employing the time-temperature superposition principle (TTS). Since direct experimental measurements at very high or low frequencies are often impractical, master curves are constructed by shifting isothermal frequency-dependent storage modulus along the logarithmic frequency axis. This process aligns data obtained at different temperatures to form a single, continuous curve representing the material’s response over an extended frequency range. The shift factors used in this process are typically modeled using the Williams-Landel-Ferry (WLF) equation:

where *T* is the temperature, is a reference temperature chosen to construct the compliance master curve and , are material-specific constants adjusted to fit the values of the shift factor . However, for composite material, the constants are often unknown. In this software, free shifting method is utilized, which provides a more general approach to acquire . With master curve composed, sigmoidal function is implemented

where is storage modulus, is frequency, *A*, *B*, *C*, and *D* are fitting coefficients. Once these coefficients are acquired, the equation 2 is used to represent the master curve throughout entire frequency range for the material. Using only , the time domain relaxation modulus can be determined by

where is the angular frequency and *t* is time. Equation 3 is integrated numerically to obtain the relaxation function to acquire the stress response in the time-domain. To use a time-domain relaxation function to determine the stress history in a material based on its strain history

Here, , , and represent stress, strain and the time variable used in the integration process, respectively. For situations involving constant strain rate deformation with a strain rate of starting from time *t* = 0, the convolution integral simplifies to

where is strain rate. For Quasi-static mechanical property, is often selected between to .

**User Manual**

The user needs to upload a comma-separated values (CSV) file with a format shown as **Table 1,** where frequency is in Hz and storage modulus is in MPa, and temperature in degree Celsius.

Screenshot of first page

## **Table 1. CSV dataset formation for software**

|  |  |  |
| --- | --- | --- |
| Temperature | Frequency | Storage Modulus |
| 30 | 0.1 | 34.09 |
| 30 | 0.127 | 34.178 |
| 30 | 0.162 | 34.285 |

…

|  |  |  |
| --- | --- | --- |
| 150 | 6.17 | 19.946 |
| 150 | 7.87 | 19.791 |
| 150 | 10 | 19.29 |

The dataset will be plotted on a Cartesian coordinate system with frequency in X-axis and storage modulus in Y-axis for visualization. Free shifting method is applied to automatically compose the master curve and shift factors are provided.

Equation 2 is then used to fit the master curve to determine the coefficient of *A*, *B*, *C* and *D*. Here, coefficient A and D can be tuned to increase accuracy and a real-time fitting curve will be plotted for user to make the adjustment.

Then, master curves for all reference temperatures with fitting lines will be presented for checking the fitting status at each temperatures. If the fitting line is incorrect, that means the coefficient A and D need to be adjusted.

Once all the fitting lines are correct, the transformation can be proceeded to estimate the elastic modulus at strain rate from to .

At each graph, the user can download the graph and the calculated data as .jpg and .csv file respectively.

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Patent number [US Patent #10,345,210](https://patents.google.com/patent/US10345210B2/en?q=(Method+to+estimate+strain+rate+dependent+elastic+modulus+of+materials+dynamic+mechanical+analysis+data.+nikhil)&oq=Method+to+estimate+strain+rate+dependent+elastic+modulus+of+materials+using+dynamic+mechanical+analysis+data.+nikhil+)

The software is freely available for use and publication, provided that appropriate acknowledgement is given.

\*Disclaimer: The developer takes no responsibility of the calculation.