

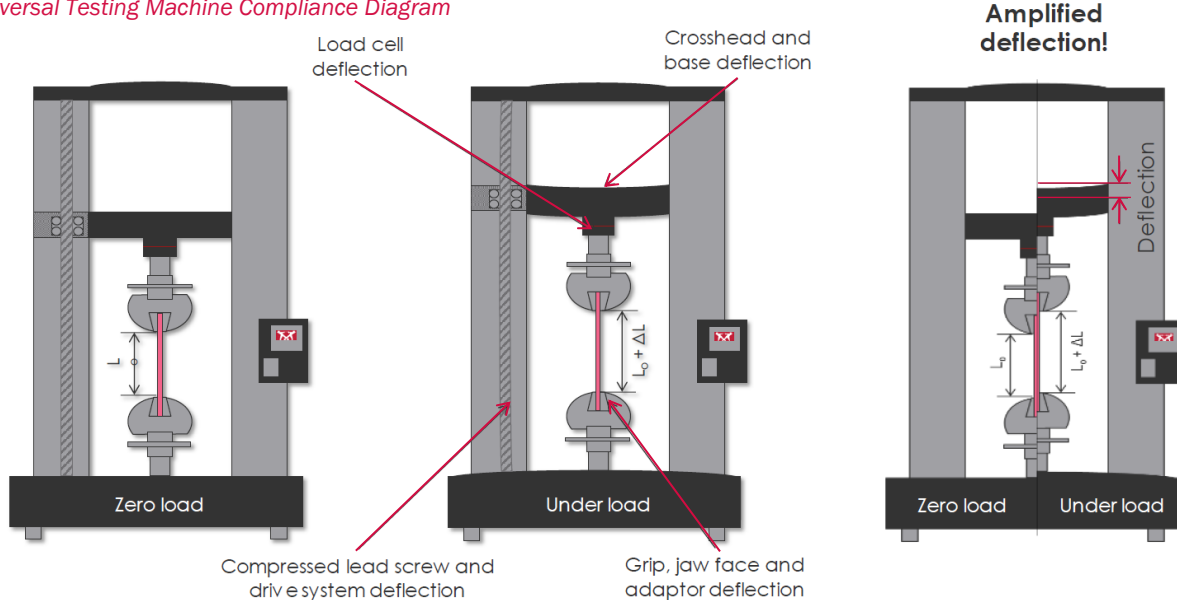
Universal Testing Machine Compliance

What is it?

Many people believe that only test specimens experience deformation during mechanical testing. This is not true: whenever a testing machine is subjected to a force, the entire system – frame, load cell, grips, couplings, and specimen – experiences some degree of deformation. When testing software measures displacement, it takes its raw displacement output from an optical encoder attached to the motor, meaning that measured displacement is actually the sum of total system deformation. To determine the displacement of the specimen only, machine compliance (deformations associated with the load frame, load cell, and grips) must be removed from this measurement. Please note that machine compliance is specific to each system and is dependent on the forces a given system is subjected to.

[Bluehill software](#) allows users to configure the virtual measurement called *Corrected Displacement* for all test types (tension, compression, flexure, etc). This creates a second set of displacement data where machine compliance has been removed. Corrected displacement can be used like any other raw data source (time, force, etc.) for graphs, calculations, and results.

Figure 1 – Universal Testing Machine Compliance Diagram



Why is it important?

Extensometers are the preferred, more accurate solution for measuring displacement as they take their measurements directly from the specimen, eliminating the need for a correction. When extensometers cannot be used, Corrected Displacement should be used to gain more accurate displacement measurements. Testing standards will specify if extensometers are required.

When a test's total displacement is small, machine compliance can be a significant portion of the output displacement given by the software. Similarly, machine compliance can affect calculations that use data captured at small displacements. For example, the region of displacement for an ISO 178 flexural modulus calculation is between 0.085 mm and 0.427 mm¹. Because of the inherent inaccuracy when not correcting for machine compliance, many ASTM and ISO testing standards, such as ISO 178, require test labs to remove any compliance from displacement data if reporting certain results². It is worth restating that configuring Corrected Displacement is recommended in cases where displacement (and consequently strain) results are sourced from crosshead position, not an extensometer. Please refer to the following pages for a guide to configuring Corrected Displacement in Bluehill Universal.

¹ §9.3 of "ISO 178:2019 – Plastics – Determination of flexural properties", when using preferred specimen dimensions

² Refer to Table 2 of "ISO 178:2019 – Plastics – Determination of flexural properties"

How do you configure Corrected Displacement in Bluehill?

Note: this example shows Corrected Displacement being used for a compression test of a plastic component

1. Create a compliance file to be imported into the test method's Corrected Displacement virtual measurement.

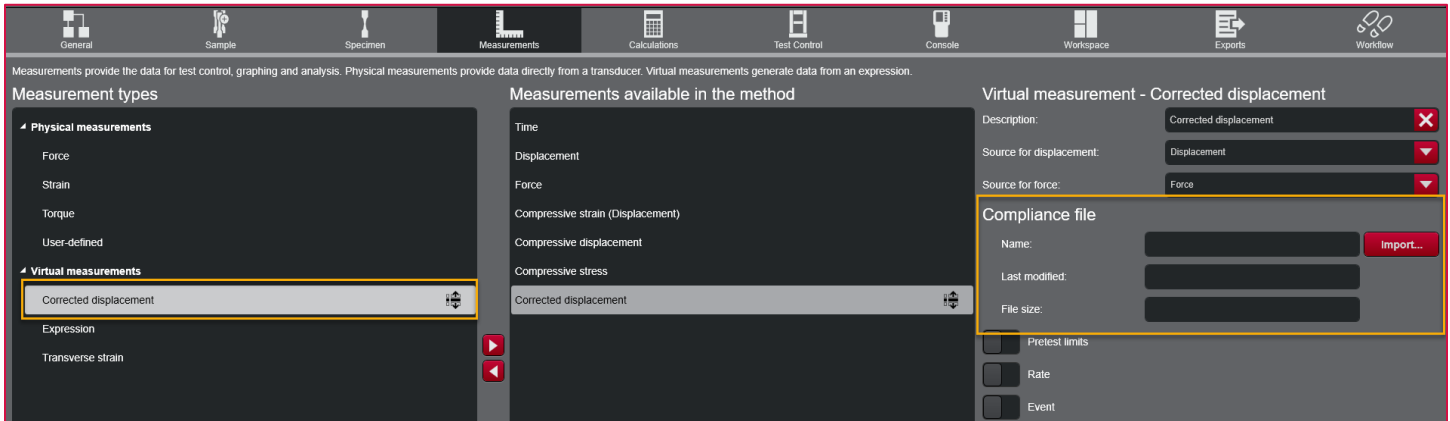


Figure 2 – Virtual measurement – Corrected Displacement in Bluehill Universal

- 1.1. Set up the system using the same load string that will be used to test the specimens in the sample.
- 1.2. On the Home screen, select Test > Create a new method, then select the same test type as the method used to test specimens.
- 1.3. Edit the test parameters to meet your testing requirements AND to capture data starting lower and ending higher than expected forces to ensure the correction can be applied to all test points. In particular:
 - 1.3.1. On the Measurements screen, edit the force measurement to select the force transducer configuration that will be used as the source in the Corrected Displacement measurement.
 - 1.3.2. On Test Control > Pre-Test, enable Preload and apply a small preload to ensure that there is no slack in the specimen. Preload value should be lower than preload used in method used to test specimens.
 - 1.3.3. On Test Control > End of Test, set the end of test criteria to a force higher than expected in a real test, but lower than the system capacity.
 - 1.3.4. On Test Control > Data, set up data capture to have a data rate equal to or greater than the rate used in the method used to test specimens. Minimum rate should ensure one data point is collected approximately every 1-2% of the testing force range.
- 1.4. Install a dummy specimen in the frame.
 - 1.4.1. A dummy specimen should represent an infinitely stiff specimen compared to the stiffness of the material being tested. The dummy specimen should deform very little at the maximum force.
- 1.5. Perform the test on the dummy specimen.
- 1.6. Finish the sample and note the name of the sample file and where it is saved. Note: including the load cell and fixtures in the file name will help identify the file for future use.

The raw data file for this sample is the compliance file that will be specified for Corrected Displacement in the test method.



Figure 3 – Dummy Specimen - Hardened Steel Disc, Compression Test

2. Import compliance file to the test method used to test specimens.

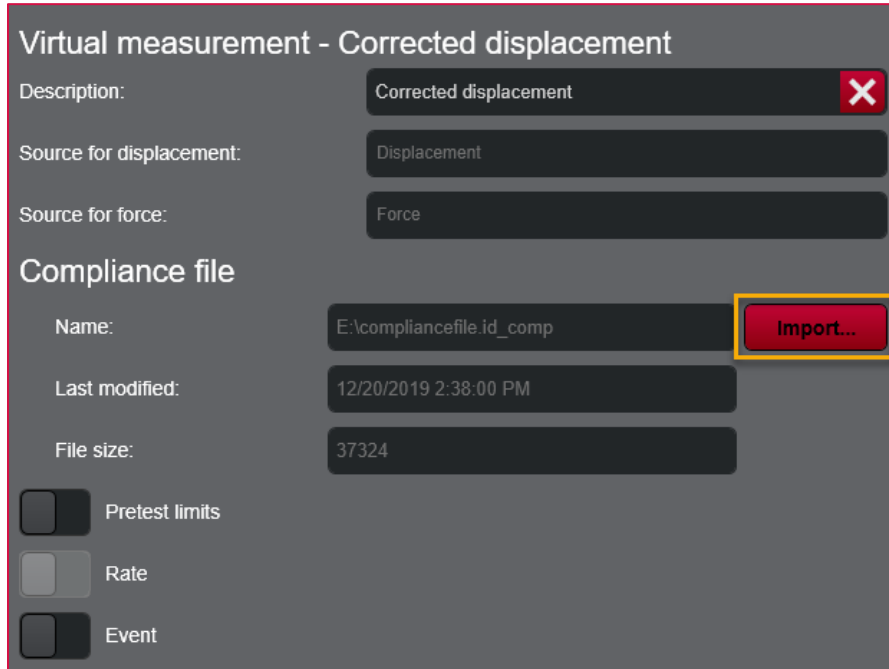


Figure 4 - Screenshot of Corrected Displacement measurement in Bluehill Universal

- 2.1. Create or open a test method of the same test type that was used to create the compliance file.
 - 2.2. In the Method menu, go to Measurements > Virtual measurements, and select Corrected displacement
 - 2.3. In the Description field, either keep the default name or enter a new name.
 - 2.4. Select the measurement source for displacement and the measurement source for force. The source for both displacement and force should be the same measurements used to create the compliance file.
 - 2.5. Select Import... to browse to the compliance file. The compliance file is the raw data file from the sample file created when testing the dummy specimen. Raw data files have “.id_XXX” extensions followed by the test type (for example, a compression raw data file has the “.id_comp” extension).
 - 2.6. If using Corrected Displacement for strain calculations, go to Test Control > Strain > Primary Source, select Corrected Displacement.
 - 2.7. Save the test method.
 - 2.8. Before using this test method for a sample, verify that the system has the same setup and same load string that was used to test the dummy specimen.
3. Test samples and if desired, compare Displacement vs. Corrected Displacement data.
 - 3.1. For each data point captured:

$$X_{corrected_F} = X_{test_F} - X_{compliance_F}$$

where:

$X_{corrected_F}$ = Corrected Displacement of real test at force F

X_{test_F} = Displacement of real test at force F

$X_{compliance_F}$ = Displacement of compliance file test at force F



Figure 5 - Plastic component, ready for test

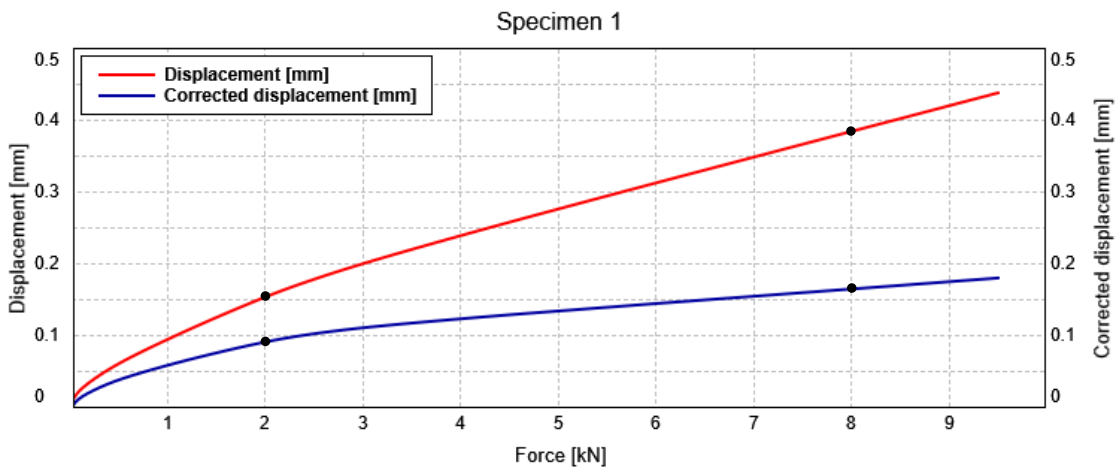


Figure 6 - Displacement & Corrected Displacement (Double Y-axis) vs. Force

Results 1						
	Raw Displacement @ 2 kN [mm]	Corrected displacement @ 2 kN [mm]	% Error in Raw Displacement @ 2kN	Raw Displacement @ 8 kN [mm]	Corrected displacement @ 8 kN [mm]	% Error in Raw Displacement @ 8kN
1	0.1529	0.0902	69.5	0.3836	0.1640	133.9

Figure 7 - Raw Displacement Error, Compression Test on plastic component

Displacement [mm]	Force [kN]
0.0626	1.9960
0.0627	2.0024
0.0629	2.0088
0.0631	2.0151

Figure 8 - Displacement @ 2kN in compliance file

$$X_{corrected_{2kN}} = X_{test_{2kN}} - X_{compliance_{2kN}} = 0.1529 \text{ mm} - 0.0627 \text{ mm} = 0.0902 \text{ mm}$$

As shown in Results 1 above, the % error in displacement data when including a universal testing machine's compliance can be significant. Being aware of machine compliance and knowing when and how to correct for it will make any lab more proficient.