INSTRON®

# ISO 6892-1:2016
# Ambient Tensile Testing of Metallic Materials

## What Changed?

In 2009, ISO 6892-1 replaced and combined both the previous ISO 6892 and the widely used EN10002-1:2001 standards. It incorporated many changes, but most notably, it introduced the testing rates based on strain rate (Method A).

Method A was the recommended approach and was based on maintaining a strain rate. The traditional test method from EN10002:2001, based on maintaining a stress rate during the elastic region, became Method B. The introduction of Method A caused confusion. Many understood this as only being achievable using equipment capable of closed-loop strain control, but this is not true. It is possible to conform to Method A using a constant crosshead speed.

To better clarify, the requirements of Method A, ISO 6892-1:2016 now includes two clearly defined approaches, Method A1 (Closed-Loop Strain Control) and Method A2 (Constant Crosshead Separation Rate).

Since Method A is the recommended test method, this further clarification will assist test labs that are transitioning from Method B to Method A and monitoring the specimen strain rate. The benefits remain the same: Method A minimizes the variation of the test rates during the moment when strain-rate sensitive parameters are determined and to minimize the measurement uncertainty of the test results.

During a tensile test there are many sources for uncertainty and error; maintaining the strain rate on the specimen eliminates the effect that the machine's stiffness/compliance has on the results. Figure 1 shows the difference in yield results run at the same machine crosshead separation rate: the upper (red) stress/strain curve was tested on a high stiffness testing machine and the lower (orange) stress/strain curve was on a less stiff (more compliant) testing machine. Both systems were controlled at a constant crosshead speed of 2.25 mm/min. Figure 2 shows the specimen ‘speed’ expressed in mm/min. On the stiffer system, the strain rate was higher and transferred to the specimen faster. On the less stiff (more compliant) system, the strain rate was 21% lower and took longer to transfer to the specimen. This meant there was a 5% difference in the yield result for this material on these two different systems.

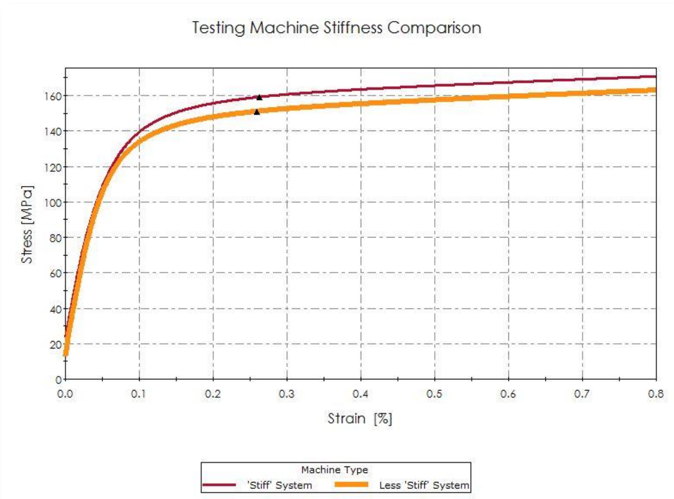


Figure 1 Testing Machine Stiffness Comparison – Two tests are carried out using the same material but on two different machines at the same crosshead speed.

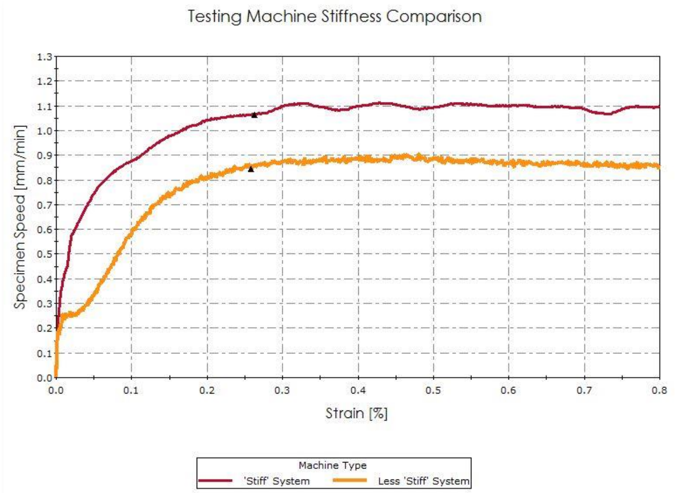


Figure 2 Testing Machine Stiffness Comparison – Specimen speed (or strain rate) expressed in mm/min can be seen to be considerably lower than the machine speed of 2.25 mm/min. ‘Speed’ is lost in the compliance of the testing machine setup.

Switching from Method B towards Method A will make results much more comparable between sites, as well as between different machines. Method A2 may increase testing times slightly (when compared to method B), so the additional benefit from utilizing Method A1 is that test times can be reduced by up to 40% per test. This will vary from machine and specimen type, but you may see significant reduction in test times, which will help to increase laboratory efficiency.

## Method A1 & A2 Rates

The defined rates in ISO 6892:2016 are the same as Method A in ISO 6892-1:2009, which are dependent on the results that are being determined. Figure 3 shows how the ranges are defined from ISO 6892-1. Range 2 is the recommended rate for determining yield (Rp) and Range 4 is recommended for determining Rm, Agt, Ag, At & A. Figure 4 shows where these calculations are determined and where the ranges would be.

Range 1: 0.00007s$^{-1}$ ± 20%

**Range 2: 0.00025s$^{-1}$ ± 20% (Recommended)**

Range 3: 0.002s$^{-1}$ ± 20%

**Range 4: 0.0067s$^{-1}$ ± 20% (Recommended)**

Method A1 closed-loop control of the strain rate based on feedback from the extensometer, with a 'tight' ±20% tolerance.

Method A2 'open-loop' constant crosshead speed (obtained by multiplying the required strain rate by the parallel length).

$$Crosshead\ Speed = Strain\ Rate\ \ x\ Parallel\ Length$$

This calculation does NOT take into account the effect of the testing machine compliance. As can be seen in Figure 2, some of the strain rate will be 'lost' in the system. Annex F from ISO 6892:2016 gives additional guidance for the 'Estimation of the crosshead separation rate in consideration of the stiffness (or compliance) of the testing equipment)'.

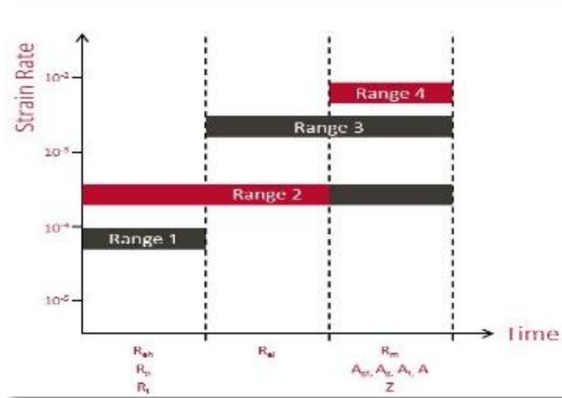


Figure 3: ISO 6892-1:2016 Rates

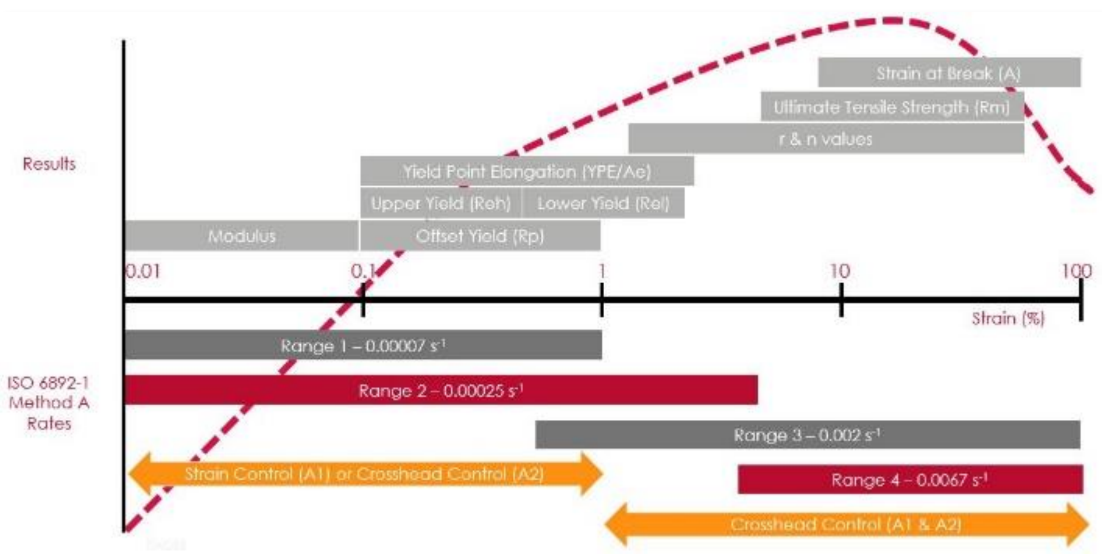


Figure 4: ISO 6892-1:2016 Method A Rates – Expressed graphically in comparison with the required results

## Method A1 – Strain Control

For metals that demonstrate a smooth transition from the elastic to plastic region, the strain distribution in the gauge length of the material is uniform through the offset yield ($R_p$) and up to the maximum tensile stress ($R_m$). In this case, strain control can be achieved using the signal from the extensometer. The challenge with controlling from feedback from the extensometer is that tuning is required, (typically for the 'PID' gain settings) because the control loop is affected by the specimen stiffness. This can be time consuming and requires skilled operators. Tuning may need to be performed for each material tested with adjustments being made between tests of different materials. If tuned for the elastic region, the stiffness change in the specimen when it yields may adversely affect the control and allow the strain rate to go out of the ±20% tolerance. Every aspect of the testing system will affect the suitability for strain control including testing machine stiffness, load cell stiffness, as well as the specimen gripping mechanics.

Strain control is not suitable for metals that display yield point elongation (YPE/Ae) as the strain distribution along the parallel length is no longer uniform. Instead, it is localized in narrow regions known as Luders bands, which often occur outside of the extensometer gauge length. When this happens, strain measured by an extensometer can actually decrease despite strain over the entire parallel section of the specimen is increasing.

## Method A2 – Crosshead Control

Method A2 is suitable for all material types, and most machine configurations are capable of performing a closed loop constant crosshead speed. Therefore, it is much simpler to install and run in your lab, especially when using older equipment without a current upgrade. However, going at a constant crosshead speed typically makes the test slower. To assist with this, ISO 6892-1:2016 allows you to test at any suitable speed up to 50% of yield strength (Rp) because, in the elastic region, metals are typically not as strain-rate sensitive.

The exact crosshead speed necessary to stay within the ±20% tolerance may be different for each material type and for different cross sections. In order to stay compliant you may need to fine tune the speed when you change specimen types. The system compliance means the strain rate decreases, not increases. Therefore, if you use a rate higher than the target rate, but still within the ±20% tolerance, it is likely to be compliant. In other words, you may comply to the standard if you calculate based on 0.0003 mm/mm/s (high limit of ±20% tolerance) to achieve 0.00025 mm/mm/s ±20%.

## Benefits of Using Strain Control

✓ More repeatable and comparable results; test results reliable from machine to machine

✓ Improved efficiency; time per test minimized and setup time reduced

✓ Future proofing your laboratory

✓ Less operator training when using 5900 automatic gain tuning

## Considerations to Using Strain Control

May need to use specimens to tune gain settings

Minimizing compliance in the testing machine configuration will help achieve closed-loop strain control

High-precision extensometer is required

Lab environment must be free of vibration or the test system is isolated so that it can't be transmitted to the specimen

Requires a responsive controller with high data collection rate and loop update rate response rate

A proportional specimen and a proportional gauge length extensometer are ideal. In reality, a specimen with good gauge length to parallel length ratio is well suited to minimize the strain seen outside of the gauge length, allowing the control to be more stable.

If your specimens vary from discontinuous yielding to continuous yielding, it is important to change control methods for each type. Discontinuous yielding materials must be in crosshead speed control during YPE.

## Instron Solution

Instron testing machines are able to meet the demanding requirements of ISO 6892-1:2016: Method A1, based on strain rate control, Method A2 based on constant crosshead speed, and Method B based on stress rate.

## Materials Testing Machines

Our electromechanical or static-hydraulic machines can be equipped with a range of clip-on or high-resolution automatic extensometers for strain rate control. With many gripping solutions available, Instron has a suitable gripping mechanism for almost all material types. Advanced 5900 digital control electronics provide a 5 kHz loop update rate and self-adaptive strain control ensuring stable and accurate strain control under a wide range of conditions.

## Method A1

### Materials with no Yield Point

Figure 5 shows a typical test curve of a specimen that exhibits no distinct yield point. This is known as continuously yielding behavior. Construction lines show points where typical calculations for ISO 6892-1 have been determined, including $R_{p0.2}$ and $R_m$. Construction lines or markers are available for almost all calculations in Bluehill® 3 for a quick and easy visual indication of the correct result being calculated.

ISO 6892-1 details test speeds that must be adhered to within a tolerance of ±20% while certain material properties are calculated. There are four speed ranges in total, with recommendations as to which should be used at each point of the test. Figure 5 focuses on the yield region of the test curve. The orange line show the strain rate being maintained well within the ±20% allowable limits (tolerance indicated by red dotted line).

### Materials with Distinct Yield Point

Figure 6 shows a typical curve for a specimen that exhibits abrupt yield point behavior. This is known as discontinuously yielding behavior. Construction lines show points where typical calculations for ISO 6892-1 have been determined, including $R_{eH}$ and $R_{eL}$.

A discontinuously yielding material elastically deforms up until $R_{eH}$. Following $R_{eH}$ the force typically drops dramatically as the strain continues to increase. In addition, local yielding can occur outside the extensometer gauge length. If the testing machine remained in strain control, the testing speed would change dramatically to counter this yielding characteristic resulting in an incorrect strain rate and non-compliance with the standard. Using an intelligent algorithm, the Instron machine swaps to position control, as detailed in the standard, allowing it to maintain the standard defined estimated strain rate through the discontinuous yielding region. At the end of this yielding region with the onset of strain hardening the machine then moves to a final rate that it maintains until the conclusion of the test.

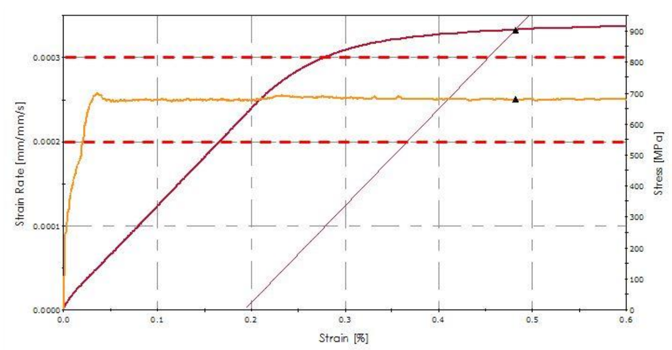


Figure 5: Bluehill 3 Stress/Strain graph with additional y-axis for strain rate plotted, with ±20% tolerance indicated

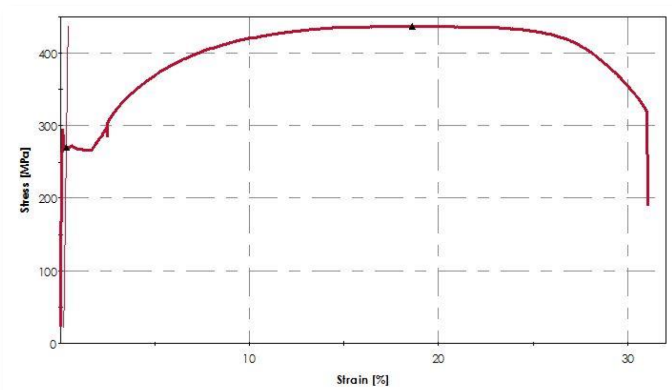


Figure 6: Bluehill 3 Stress/Strain graph of discontinuously yielding material.

## Method B – Stress Control

The defined rates in IS06892-1:2016 are as shown in Figure 7 and remain the same as Method B from ISO 6892:1:2009, and include two allowable ranges based on the modulus of elasticity of materials.

| Modulus of elasticity of the material (Mpa) | Stress Rate (MPa/s) | |
|---|---|---|
| | min. | max. |
| <150 000 | 2 | 20 |
| ≥150 000 | 6 | 60 |

Figure 7: ISO 6892-1:2016 Method B Rates

The primary change for Method B in ISO 6892-1:2016 is the addition of a note addressing the region of the test where Method B or the stress rate shall be maintained. It is NOT intended to maintain a stress rate for determining yield parameters. As a material yields the 'stress rate' will drop or even go negative (with discontinuously yielding material). Maintaining a stress rate in closed-loop control stress or load control will cause the machine to accelerate rapidly during yielding. This is NOT compliant to IS06892-1 and can result in giving higher yield strengths and much shorter test times. It may even cause the upper yield point to be hidden for discontinuous yielding materials.

When using testing machines capable of closed-loop load/stress control the stress rate should be achieved in the elastic region and then switched before 80% of expected Rp0.2 to maintain a constant crosshead speed. During the elastic region of a metals test the load should be proportional. Once in stable, closed-loop stress control a constant crosshead will achieve the stress rate throughout the rest of the elastic region and be suitable for yield determination.

Method B is still the most common control mode used within industry, but there is a large variation of the rates that means there will be some intrinsic variation on results that are compared when testing to Method B. This can be increased further using different machine configurations.

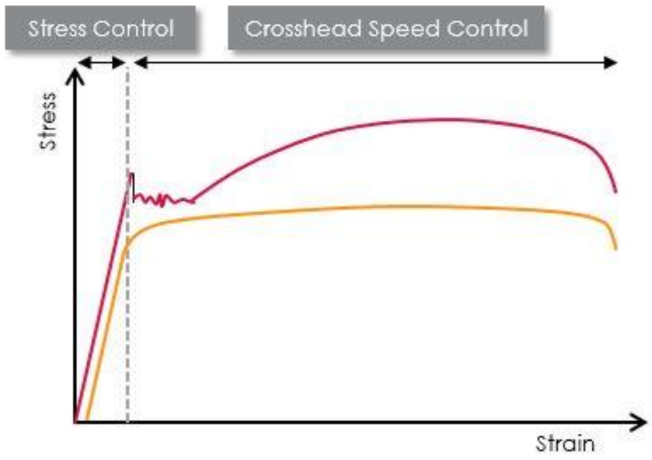


Figure 8: Region of stress control on continuous and discontinuously yielding material.

## References


International Organization for Standardization, Metallic materials -- Tensile Testing -- Part 1: Method of test at room temperature, ISO 6892-1:2009, International Organization for Standardization, Geneva.


## Disclaimer

This document has been prepared in accordance to the international testing standard at the date of issue. This document combines the standards, together with Instron's application knowledge. Should there be any errors or any changes in the standard this is not the responsibility of Instron. However we will endeavor to maintain this document where appropriate. It is important that you own an official and current copy of the standard to ensure you're in compliance with this standard

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To learn more about the upcoming changes to ISO 6892-1:2016