System Compliance and ISO 6892-1:2009 Method A

A fundamental problem with mechanical tensile testing is that most material properties are not absolute values; they are often the result of interaction between the combined components of a test system. The specimen material & dimensions, testing machine, grips and procedure are all examples of contributing factors to the final result. The aim of testing standardization is to reduce the effect of variables such as these on the results, giving more comparable values between systems.

With the introduction of ISO 6892-1:2009, the principle of maintaining tight tolerances on the specimen strain rate during the test, to improve consistency of results, became more widely adopted. Previously, methods of this type had been mainly used within the aerospace industry. The method for maintaining the specimen strain rate in this manner is commonly referred to as "Method A". The new ISO 6892-1:2009 standard supersedes both ISO 6892:1998 and EN 10002-1:2001, the testing procedures from these standards, stress rates with a strain rate limit, remained in what is known as "Method B".

For both Method A & Method B system compliance is an important factor. During the calculations of yield properties, such as offset yield ($R_{p0.2}$), upper yield (R_{eH}) and lower yield (R_{eL}), the system sees a large change in compliance as the specimen yields, the rate at which load is applied reduces considerably during yield. This resultant change in compliance can lead to an increased strain rate being applied to the specimen if the system cannot react in time. The design of the entire testing system plays a significant role in the magnitude of this change. Some components have to deform to perform their function, such as load cells, which measure deformation via strain gauges and translate the signal into force. Others parts of the system, such as the grips, can perform a similar function with different designs, whilst having a significant variation in compliance.

Gripping techniques are often the largest source of system compliance variation when used in conjunction with high performance/high stiffness testing frame. For high capacity metals testing two main gripping techniques are prominently used, wedge effect and/or hydraulic gripping pressure, some grip designs use a combination of these techniques. Figure 1 shows the simplified resultant jaw face movement for these typical gripping techniques.

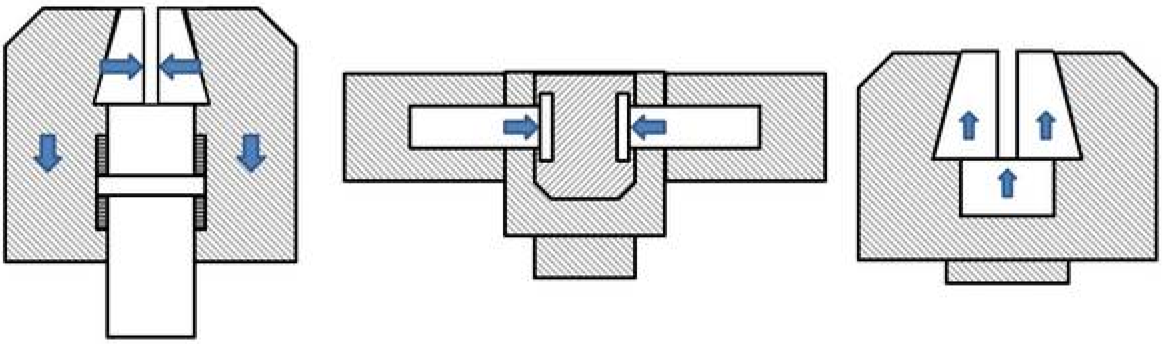

Figure 1 – Resultant jaw face and body movement for 'moving body wedge grips' (left), 'dual side acting hydraulic grips' (middle) and 'moving face wedge grips' (right)

Wedge grip designs can either use the tensile force of the test to apply the required clamping force, or use hydraulic/pneumatic pressure to apply a higher gripping force during the initial stages of the test. As the wedges move deeper into the grip pocket, the gripping force increases, and this movement is seen as compliance in the system. Moving body hydraulic wedge grips can apply a high gripping force to the specimen without damaging it (when used with appropriate loading mechanism such as specimen protect). This means there is far less grip movement as the tensile load increases. Figure 2 shows how using different gripping techniques can alter the required crosshead speed to stay within the ±20% bounds of ISO 6892-1 Method A in closed loop control through specimen yield. Moving body grips, with their stiff design, exhibit less deflection during elastic deformation of the specimen than other designs.

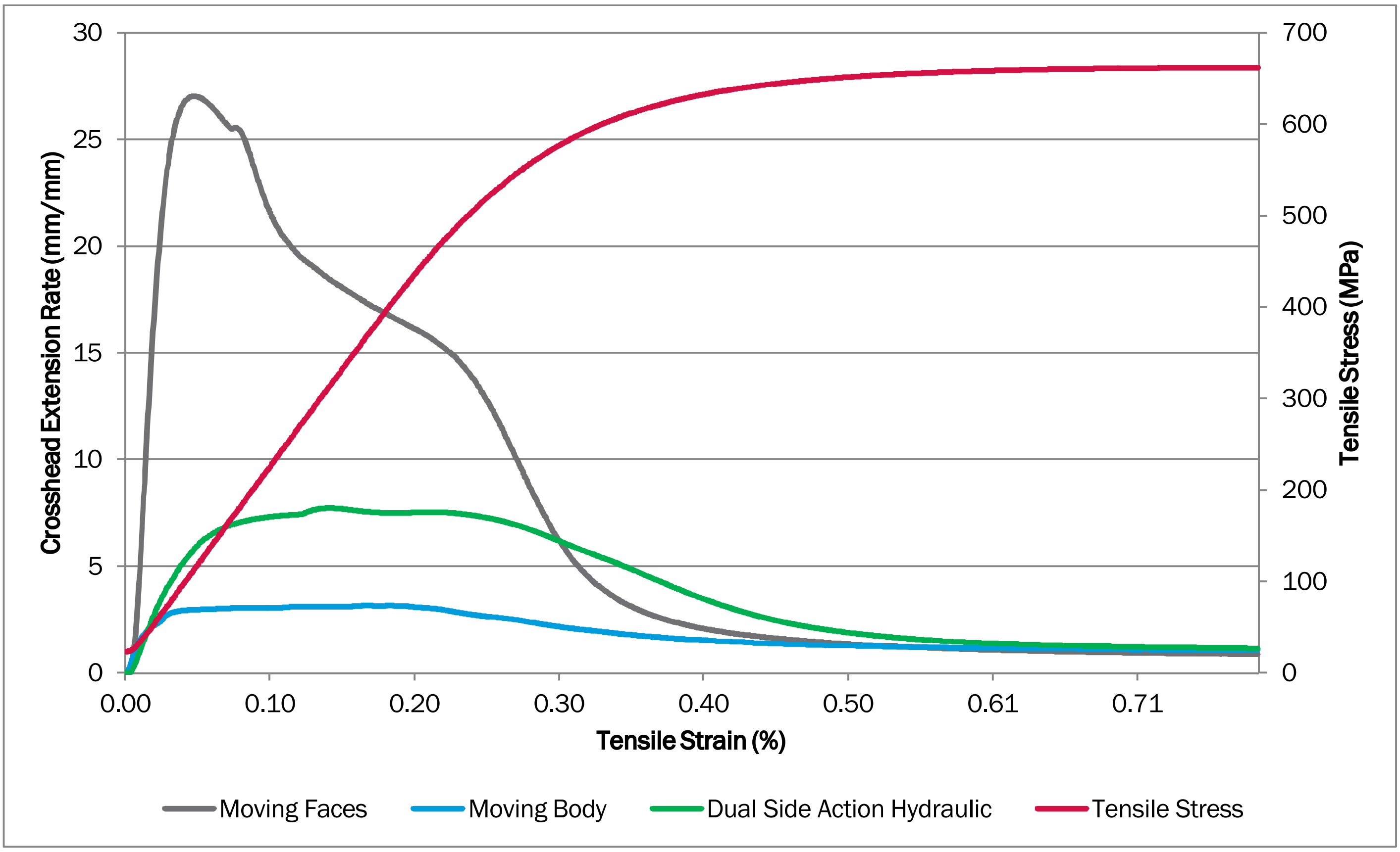

Figure 2 - Required Crosshead Speed to Achieve ISO 6892-1 'Method A' Rate 2 in Closed Loop Control

Reduced compliance often translates to tight tolerances on strain control being easier to achieve. To overcome such a rapid change in stiffness as seen with some grip designs and testing systems, the control terms used by the testing system need to adjust, or have different settings for each stage of the test. High performance control electronics supplied with Instron testing systems are capable of either approach and utilize adaptive control algorithms; these tune the system dynamically during the test, compensating for the changing compliance and achieving ISO 6892-1 compliant strain control.

Moving body wedge grips have historically been used mainly on fatigue machines, when performing cyclic testing specimen, alignment is critical to give consistent and repeatable results. When using a moving body grip design for static testing the same features which enabled them to excel in fatigue testing transfer into the static test (symmetrical body, on axis hydraulics, repeatable on axis jaw face closing). The design allows the system to meet the tight alignment specifications of standards such as ASTM E1012 and Nadcap.

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