METODOLOGIA PARA OBTER UM ALINHAMENTO PRECISO EM MÁQUINAS DE ENSAIOS MECÂNICOS*

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Resumo
Este trabalho discute várias metodologias para obter o alinhamento correto de ensaios mecânicos em máquinas servo-hidráulicas. São mostradas consequências causadas por alinhamentos inadequados, e procedimentos para mitigar danos subsequentes são debatidos. Além disso, são abordadas algumas dicas de manufatura para as peças de adaptação que permitem a montagem de equipamentos não projetados originalmente para a máquina a ser utilizada.
Palavras-chave: Precisão de alinhamento; Máquinas servo-hidráulicas; Ensaios mecânicos; Projeto de máquinas.

METHODOLOGY FOR OBTAINING PRECISE ALIGNMENTS ON SERVOHYDRAULIC TESTING MACHINES

Abstract
The present work discusses several methodologies to properly align mechanical tests on servohydraulic machines. Consequences of improper alignment are shown, and some procedures to mitigate subsequent damages are discussed. In addition, some manufacturing tips are addressed for the adaptation parts that allow the assembly of equipment not originally designed for the testing machine to be used.
Keywords: Alignment accuracy; Servohydraulic Testing Machines; Mechanical Testing; Mechanical Design.

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1 INTRODUCTION

An important step on the design of structural components is the selection of their materials. An accurate understanding of the material's mechanical behavior is a must to guarantee that the structure can withstand, within a given safety factor, the predicted constraints for the project. This highlight the importance of obtaining well-defined and well-known mechanical properties of such materials, which should be measured using proper and well-proven experimental testing methodologies. Many companies design and manufacture a variety of different machines to execute those experiments.

For example, the Instron 8874 Biaxial Servohydraulic Fatigue Testing System (Figure 1), is commonly used in medical prosthetics design and research, allowing a variety of grip designs and flexible testing protocols [1].

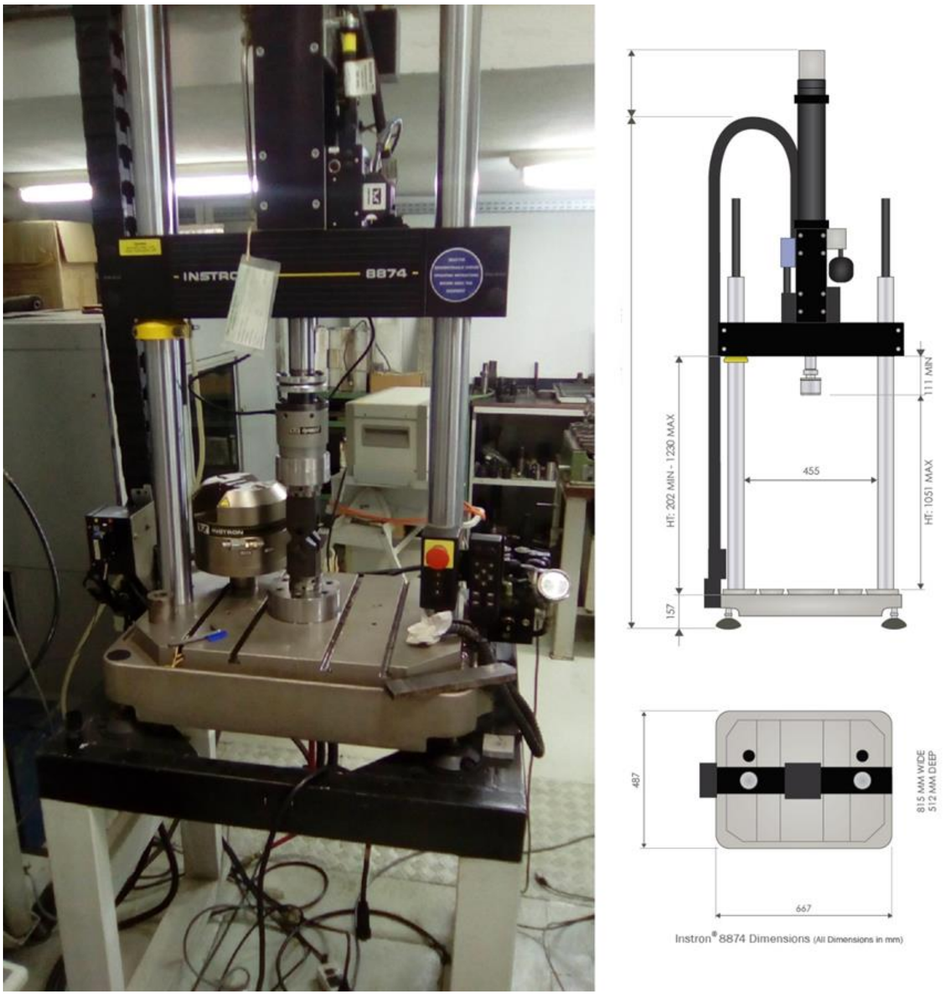

Figure 1. INSTRON 8874 Biaxial servohydraulic fatigue testing system (photo and schematic [1])

Although normally used on medical devices and prosthetics testing, its assembly flexibility allows for the possibility of a variety of other applications, especially for fatigue testing on structural materials and light structural components.

Standard fatigue mechanical properties and damage models of structural materials are evaluated assuming only axial constraints and selecting a proper Failure Criteria to calculate an equivalent uniaxial stress acting on the structure [2]. However, it is known that under the influence of out-of-phase shear and normal stresses, those models can be non-conservative [3]. The Instron 8874 biaxial testing machine can execute those combined axial-torsional tests, and this work describes the design and implementation of an adapter designed to allow the assembly on it of a pair of hydraulic grips originally designed for an Instron 8501 uniaxial servohydraulic testing machine.

2 ASSEMBLY PROTOCOL

One of the highest concerns on axial-torsional experimental testing is to maintain proper alignment between the upper and lower grips. As stated on ASTM E606 Standard Test Method for Strain-Controlled Fatigue Testing, a change in axial concentricity of less than or equal to 0.05 mm, measured between the bottom and top specimen fixture under cyclic force, is a measure of success with respect to minimizing lateral deflection of the loading train. Also, for a proper strain-controlled testing, no maximum bending strains (corroborated be misalignments) shall exceed 5% of the minimum axial range imposed during any test [2].

Neglecting proper maintenance to always keep the testing system in proper alignment constitutes a hazard to the system itself, besides the obvious consequences of incorrect readings for any experiment done on a system in such conditions.

2.1 Misalignment Consequences

A possible permanent consequence is damage to the hydraulic grips, since the misalignment can submit them to transverse forces they were not design to withstand. This can deform or even fracture the alignment plates of the jaw faces, which leads to tearing of the screws and springs used in the assembly, and in turn cause damage to the threaded hole where the screws are connected (Figure 2). Proper maintenance of the grips is necessary to identify those problems before the replacement of the screws and plates re-flattening (with a manual or hydraulic press, for example) is no longer possible.

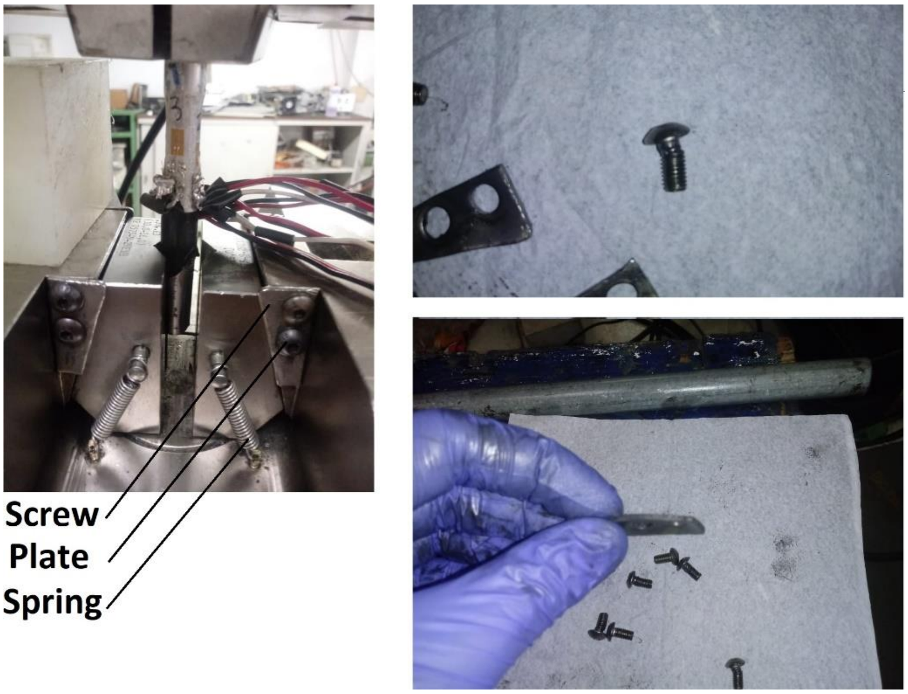

Figure 2. Bending of plates and shearing of screws, caused by the use of a misaligned system.

Moreover, if the specimen’s buckles, the resulting misalignment increases the chance of a grip to rotate and, therefore, the hydraulic piston column to bend. If subjected to enough bending moment, the column deformation can be irreversible, causing machine malfunction (Figure 3).

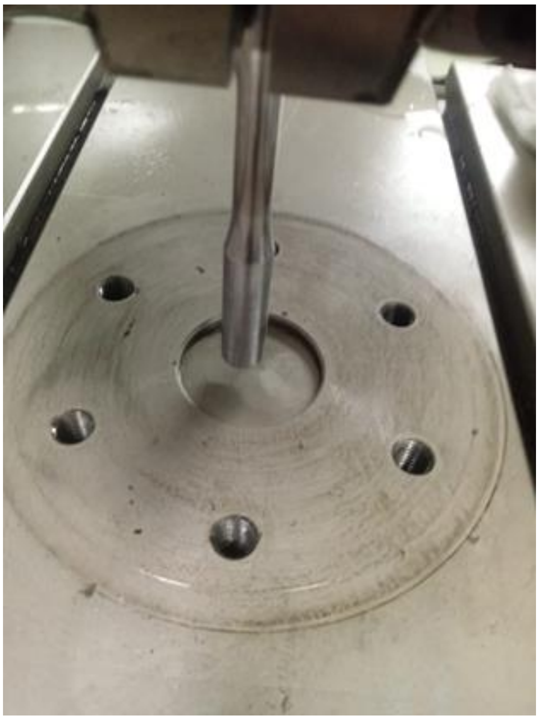

Figure 3. Misalignment caused be a bent hydraulic piston column. The specimen should be pointing towards the center of this circle.

Therefore, it is strongly advisable to configure and activate the maximum and minimum limits of both force and position before activating the hydraulic piston. With a properly defined minimum position limit, the machine will stop before buckling is enough to damage the grips and/or the testing machine.

2.2 Adapters Design and Manufacturing

In this work, the Instron 8874 was used with a pair of grips originally designed for the Instron 8502 Fatigue Testing System. The chosen grip was designed for a 250kN capacity machine [4], while being used on a 25kN one [1], which only exacerbates all the aforementioned problems. Still, even when the machine and all the test equipment were chosen in accordance to each other, these problems can be present and must be taken into account.

To enable the assembly of the grip in the new servo-hydraulic testing system, we built a pair of adapters that emulates the base and top of the machine in which the grips were originally utilized. Both adapters have a M30x2.0 left-handed threaded bore in its center, which mates with the double-screwed thread required for the grip's assembly. Around this bore there are 6 concentric holes for the screws to fix the lower adapter to the table and the upper one on the hydraulic actuator (Figure 4).

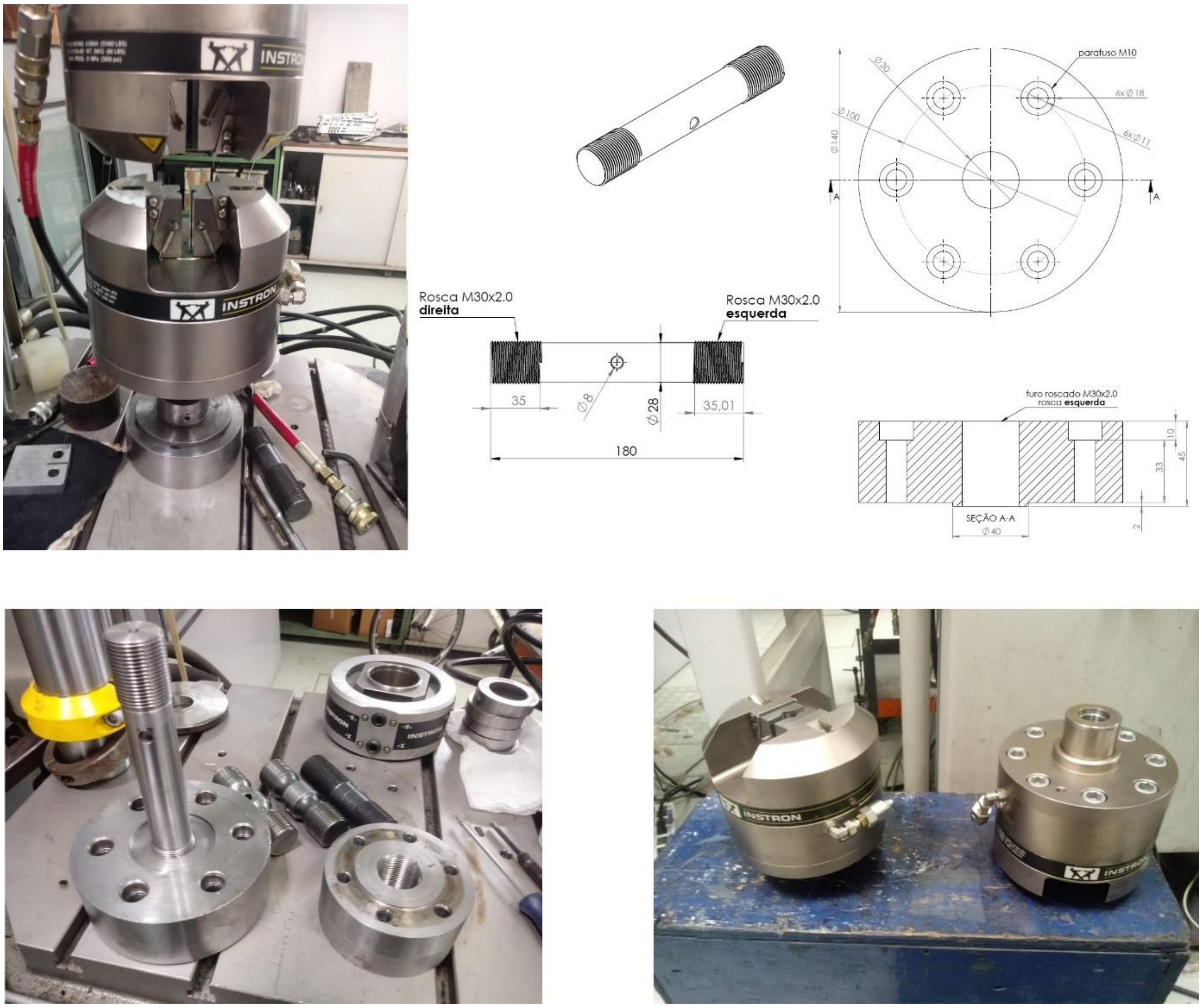

Figure 4. The assembly used, as well as its individual pieces and schematics.

Assuming the piece will be machined mostly on a lathe, a reliable way to guarantee proper alignment between the adapters is to machine both from the same workpiece. After finishing the first piece, the center hole for the second piece can be made without changing the position of the workpiece, guaranteeing that both adapters will be concentric. Also, the initial mark of the 6 concentric holes should be done on the lathe before the workpiece is moved to a drilling machine.

Such procedures assure that the corresponding threaded holes will be concentrically aligned within the tolerance applied during the machining, which normally is enough for later fine adjustments.

2.3 Alignment Methodology

All the hydraulic testing systems evaluated during this work were designed with its hydraulic actuators either under the base table or above the crosshead top. All methods presented next assume as perfectly aligned the grip fixed on the actuator, and the alignment procedures should be conducted on the other grip. Instron 8874 has two actuators above its crosshead top, and for that reason all protocol listed in this work was conducted on the grip assembled onto the base.

2.3.1 Visual Identification of Misalignment

First, it is necessary to qualitatively assess the misalignment. An easy method for this primary evaluation is to simply clip a new specimen (or any piece that is guaranteed to be straight) on the upper grip and observe its eccentricity within the lower grip. Any considerable misalignment will be identified without the use of measuring tools (Figure 5).

Figure 5. Example of a considerably misaligned assembly. The specimen should be within the same distance from each jaw face.

To correct the misalignment, it is necessary to proceed in two steps, starting by loosening the screws that hold the assembly onto the base. Once the lower grip (or adapter, in this work's case) is in place but not tight, one can fix the specimen onto both grips. The very transverse force of the jaw faces will push the structure towards a better alignment position, and the way the specimen deforms visually indicates the location of this position.

Following the initial placement, the use of a rubber hammer is recommended to gently push the lower adapter in the directions necessary for alignment. This procedure generates an acceptable primary result, which should be followed by quantitative procedure to assure that the alignment is within the required tolerance of the experiments. Some of those methodologies are discussed next.

2.3.2 Dial Indicator Method

A standard method to quantify misalignments is using a dial indicator. For the setting of this procedure, one needs to attach the magnetic base of the dial onto the grip assembled on the actuator (top in our case) and the contact tip to the surface of the other grip (Figure 6). It is important that the tip is substantially pressed against the surface, in such a way that no vibration is enough to cause the loss of contact between the tip and the surface.

Figure 6. Example of an assembly for the Dial Indicator Method.

To execute the measurement, the top grip is rotated around its central axle (the screwed thread in our case), and the points of maximum positive and negative deviations are marker and later corrected by gently hammering the assembly towards the negative and against the positive deviations. When the dial readings are within the tolerance needed, one can proceed to tighten both grips and begin the testing.

One important point to remember, in order to prevent an unfortunate loss of expensive delicate equipment, is to always remove the dial indicator before, not after, hammering the structure and then reinserting the dial afterwards for further readings.

2.3.3 Strain Reading Method

If necessary, a more precisely misalignment quantification can be done using strain gauges. The specimen instrumentation is conducted fixing four strain gauges parallel to its neutral axis and spaced 90 degrees between each other (Figure 7).

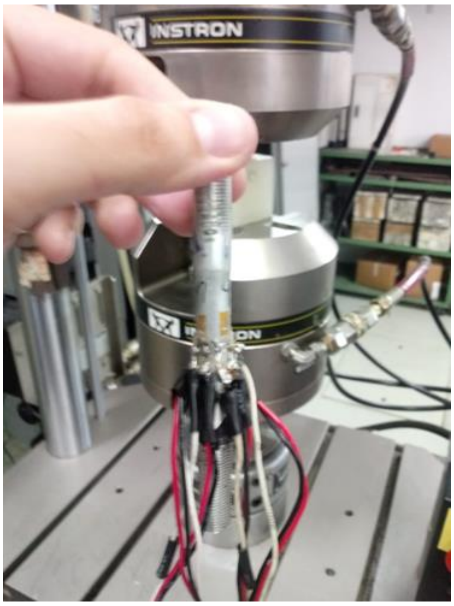

Figure 7. Specimen instrumentation.

The reference reading, where strains are considered zero, is when the specimen is clipped onto only one grip.

Through the readings of the strain gauges after the second grip clips the specimen, it is possible to determine the strain variation of 4 points on the horizontal cross-section of the specimen. Pure axial force yields the specimen equally, and any deviant reading on the strain gauges is an indication that the specimen is suffering intrusive tensions caused by misalignment.

The advantage of this method is that a data acquisition system (Daq) can give a real time reading of those strains while adjustments are being conducted, which helps to better visualize in which directions the assemble needs to be pushed (Figure 8).

Figure 8. Experimental setup, as well as the Daq reading on the computer screen.

2.3.4 External Alignment Fixture Method

All the previously discussed methods correct concentric misalignment, which normally is enough since it is expected that a testing machine from a trustworthy company will have its table and crosshead precisely parallel, and the hydraulic grips are assembled perpendicular to then. The inclusion of a pair of adapters on the assembly can be a source of angular misalignment, since their faces might not have been machined with the required parallelism. For those and similar cases, an advisable solution is the use of an external alignment tool. In this work we will discuss the Instron Alignment Fixture Model 8000-073 and information used on this section is referenced to the Model's manual [5]. Similar system can be used, or even built, to deal with this type of misalignment.

This alignment fixture consists of a central housing with upper and lower rings inside, which can slide on each other. The upper ring has a spherical surface that mates with the spherical upper surface of the central housing, and a variation on its position changes the angle of the Fixture's top. On the other hand, the lower ring has a flat surface, so a change on its position only varies the Fixture's horizontal location (Figure 9).

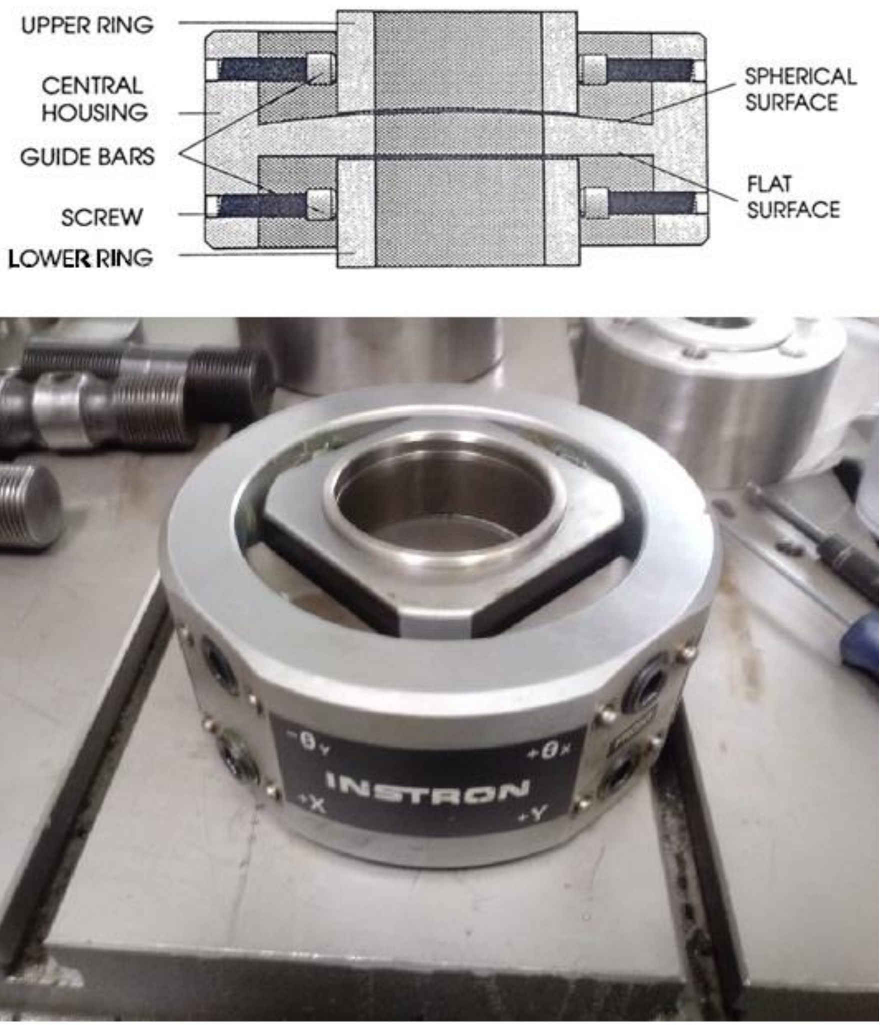

Figura 9. Instron Alignment Fixture Model 8000-073 (photo and schematic [5]).

The rings are dislocated by four pairs of screws arranged at 90 degrees intervals around the circumference of the central housing, and guide bars on their tips are supported against the rings to hold then on the desired position.

Deciding the position of both rings requires a better understanding of how both types of misalignments affects the specimen. Concentric and angular misalignments cause different patterns of deformation on the specimen. For example, assuming that the lower grip is parallel, when the upper grip is rotated through some angle, the resulting strain is positive all along the outer curvature of the specimen, and negative on the inner curvature (Figure 10 - left). On the other hand, when the upper grip is offset through some distance, the resulting strain is zero in the center of a section, with symmetric values between the top and bottom strains, but with opposite sign (Figure 10 - right).

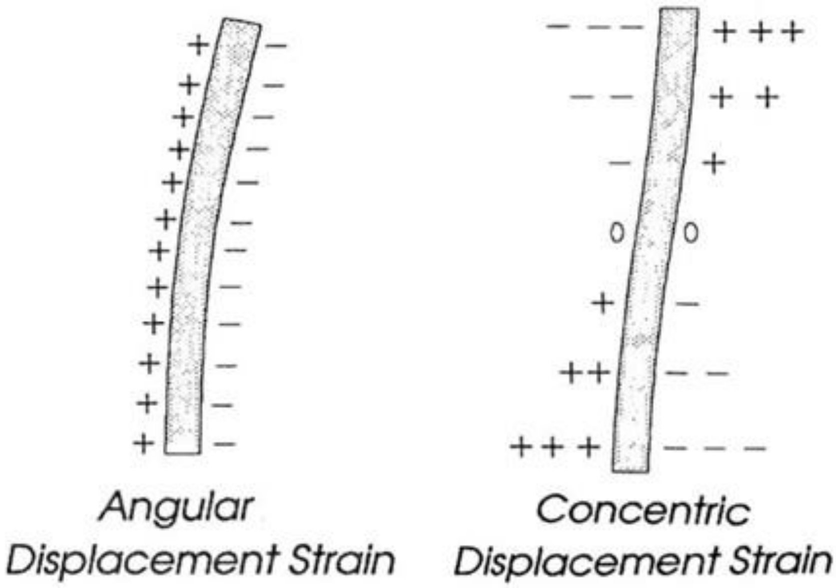

Figure 10. Types of strain displacement on the specimen [5].

All misalignment will be quantified by a combined displacement strain. So, assuming that only elastic deformations are applied to the specimen (which is easily achieved using a ductile metal specimen only constrained by the clipping forces of the grip), the superposition principle is valid and the combined displacement can be decomposed into a sum of an angular and a concentric one.

To align the assembly with this fixation model, four reading are necessary, one coinciding with the position of each pair of screws. The information of those readings shows how much each ring has to me moved.

Instron Alignment Fixture manual [5] recommends the strain gauge method to quantify the misalignment, which is adapted in order to also detect angular misalignment. For that, it is necessary to use 8 strain gauges to read the strains on the top on bottom of the 4 position (Figure 11). With this information being shown on the screen via Daq, it is possible to decompose those displacements into its concentric and angular counterparts and adjust the screws accordingly, while observing the strain variations.

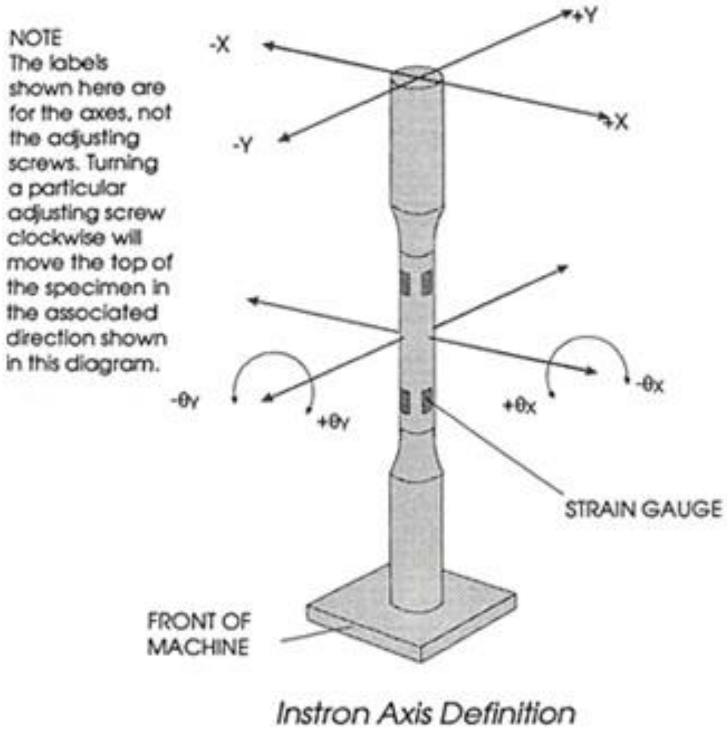

Figura 11. Schematic of the strain gauge configuration for this reading [5].

A more time-consuming reading can be done using the dial indicator. With the magnetic base stuck on the upper grip, put the pointer on one of the four upper positions of the specimen (where the upper strain gauges would be) and move the actuator down until the pointer reaches the lower position (where the lower strain gauges would be). The dial variation of the four readings shows how the specimen deformed, and the screws can be adjusted accordingly.

3 CONCLUSION

We have shown in this work that it is possible to adapt Instron 8874 Axial-Torsion System to perform cyclic torsion fatigue tests using the grips from Instron 8502 Fatigue Testing System. The adaptation requires the manufacturing of a pair of adapters which allows the grips of one machine to be assembled to the other.

Nevertheless, using a grip designed for a higher capacity system into a lower one exacerbates all the usual difficulties related to system alignment and equipment preservation. Not operating a properly aligned system can produce incorrect results and lead to loss of equipment.

The methods discussed in this work, alongside with its recommendations and precautions, are valuable for many experimental measurements, and can be useful as a guide for the setup of future multiaxial or tension-compression testing.

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