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CIDEC Condumex – Redesign of the Creep Test Machine

TEAM MEMBERS

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ABSTRACT

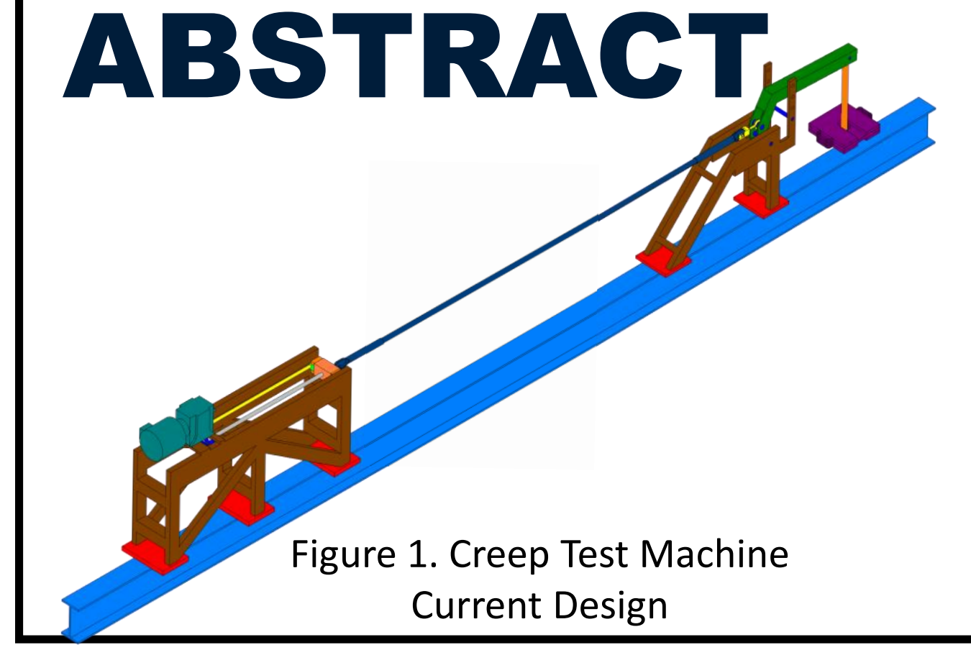


Figure 1. Creep Test Machine Current Design

This poster describes the design process and validation required for the Creep Test Machine for overhead conductor cables. In order to automate the process, improve operator's safety and improve tension control while complying with the standard testing procedure set by the IEC 61395 norm.

BACKGROUND

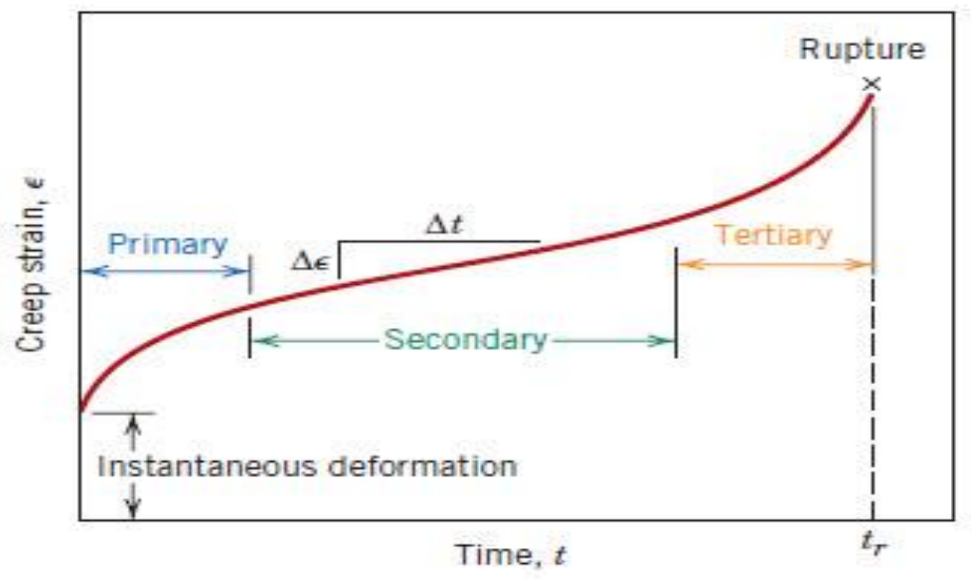


Figure 2. Creep Curve

Overhead conductors used for transmission lines, cables made of twisted aluminum wire with an inner core of twisted steel wire, when installed are subject to a constant tension due to their own weight. With this constant stress thought their lifetime and minimal maintenance, the deformation they have must be as small as possible and accounted for.

Creep is a phenomenon which affects most materials exposed for a protracted period to a load. It manifests by an inelastic stretch (or permanent elongation) of the materials in the direction of the stress.

The tests at CIDEC, the research center of Condumex, are carried out as follows:

1) The cables are attached on one end to a load cell, stress sensor.
2) The cable is loaded pulling with an AC motor until the cable parallel to the ground.
3) The test load is applied by a lever arm through blocks of sheet metal until the desired load is reached.
4) The data is then recorded by a data logger, NI cDAQ, and then taken by LAPEM (Laboratorio de Pruebas de Equipos y Materiales) who then uses specialized software to predict the elongation of the cable over time.

The test has certain criteria specified by the IEC 61395 standard. The criteria includes:

- Temperature must be 20 ^{o}C ± 2 ^{o}C
- Load applied linearly in 5 min ± 10 s
- Test load at 15%, 20%, 25%, 30% of ultimate fracture strength (± 1% or 120N which ever is greater).
- Data from sensors must be spaced equally on the logarithmic time scale.

Figure 3. NI cDAQ 9172

OBJECTIVES

Propose an alternate mechanical design to control the load at the start and end of the test, during primary creep.

- Characterize the mechanical advantage of the existing lever arm
- Design an alternate mechanism to not handle weights directly (eliminate risk of injury to the operator) and have a constant mechanical advantage during secondary creep.

Propose the necessary elements to automate the creep test mechanism.

- Propose a system to automate the existing induction motor to control the tension it applies to the cable.
- Determine which actuator to employ along with the necessary controller, sensors, etc.

METHODS AND APPROACH

CIDEC's only requirements are eliminating the blocks of sheet metal and automating the machine to be operated by just one person while obtaining equal results. The current testing methodology complies with the IEC 61395 standard but has certain problems:

Mechanical advantage

- The lever arm's mechanical advantage changes depending on its position.

Automation

- The test requires 3 people to be performed and during the 1'000 hours they must supervise the tension and make the necessary adjustments.
- Actuators are manually controlled as a ON/OFF system.

Operators Safety

- The machine requires the, up to 20 Kg, blocks of sheet metal to be applied to the lever arm manually.
- The system has no guards, nor emergency stop.

Documentation

- The documentation on the machine is non existent.

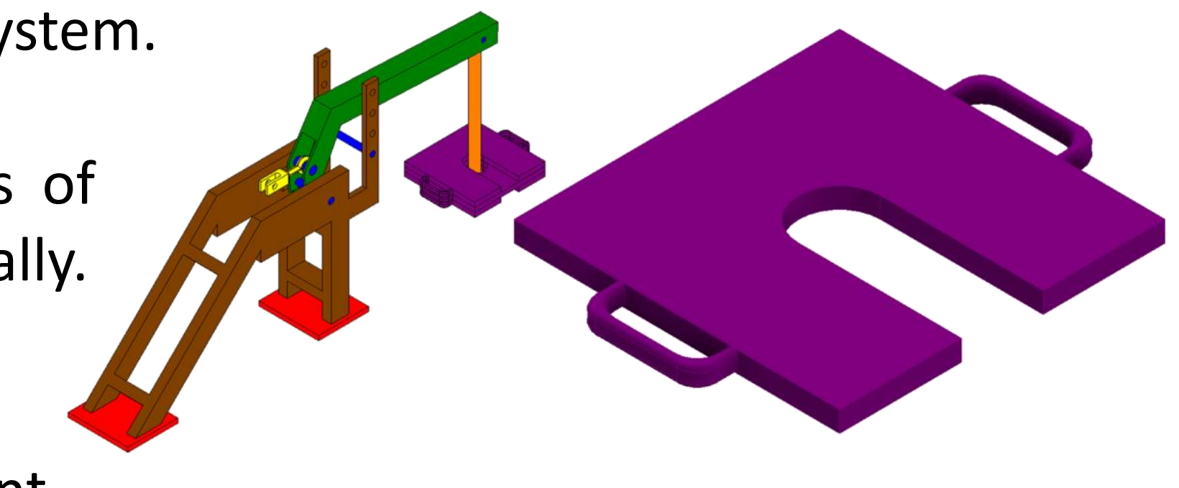


Figure 4. Lever Arm Design and Block of Sheet Metal

PROJECT RESULTS

MECHANICAL DESIGN

The mechanical design was carried out in three stages documentation, proposal development and validation. Documentation on the current design of the machine was nonexistent. Calculating the mechanical advantage of the lever arm the following model was obtained.

$$MA = \frac{F}{W} = \frac{\mathrm{a} * \cos(\theta_a)}{r * \sin(\theta_r)}$$

$$\sum\nolimits_M W * a * \cos(\theta_a) - F * r * \sin(\theta_r) = 0$$

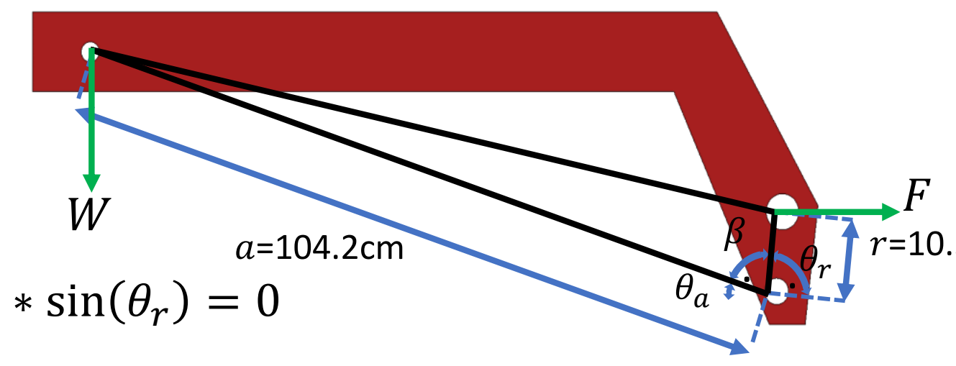


Figure 5. Lever Arm Current Design Mathematical Model

The previous lever arm design has a linearly variable mechanical advantage from 8.51 to 12.36. With the CAD models, different ideas for an advantage mechanism and weight replacement system were analyzed to determine the best solution for the new design. The selected design was a lever arm based on a bell crank to easily integrate to the mechanism and obtain a constant mechanical advantage.

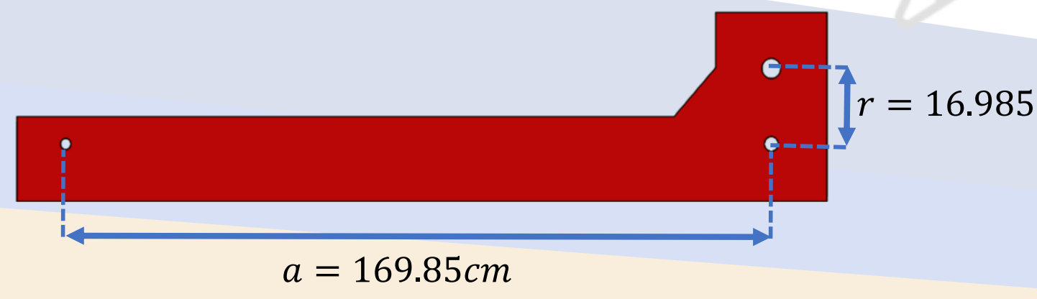
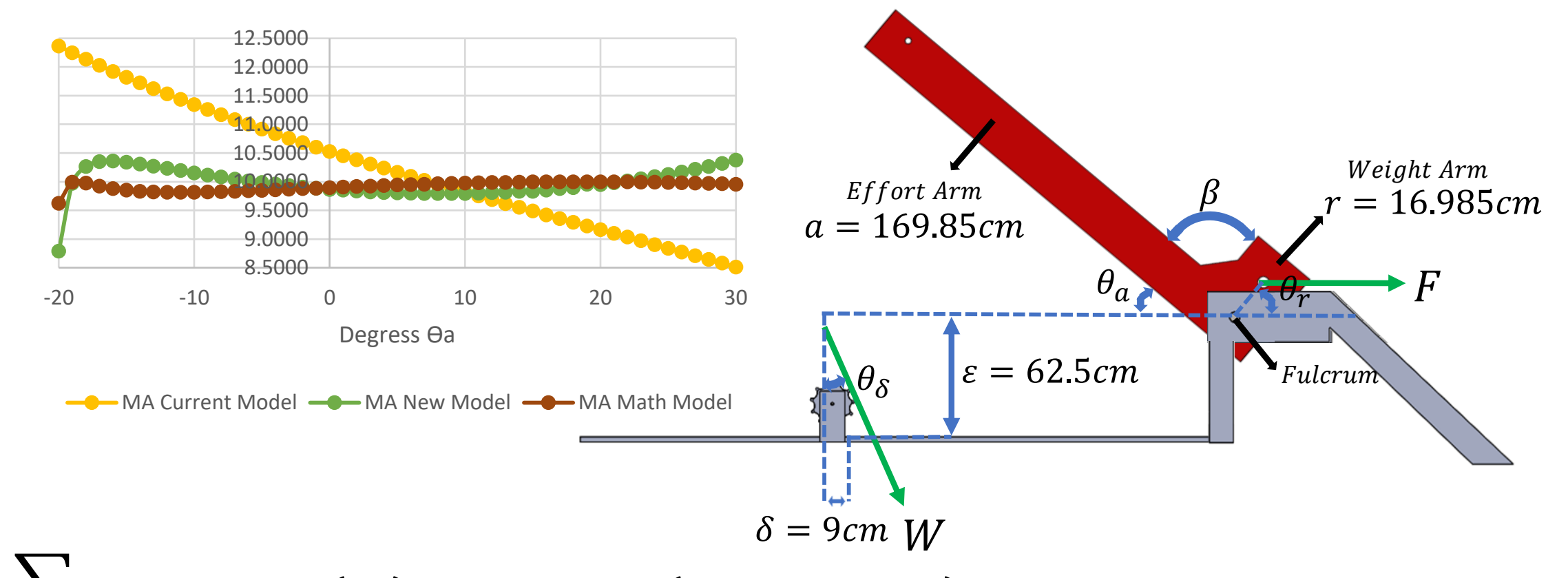


Figure 6. Lever Arm New Design (Bell Crank Model)

The lever arm is controlled by an electric piston cylinder attached by a chain to it. The following equations model the mechanical advantage as the arm rotates.

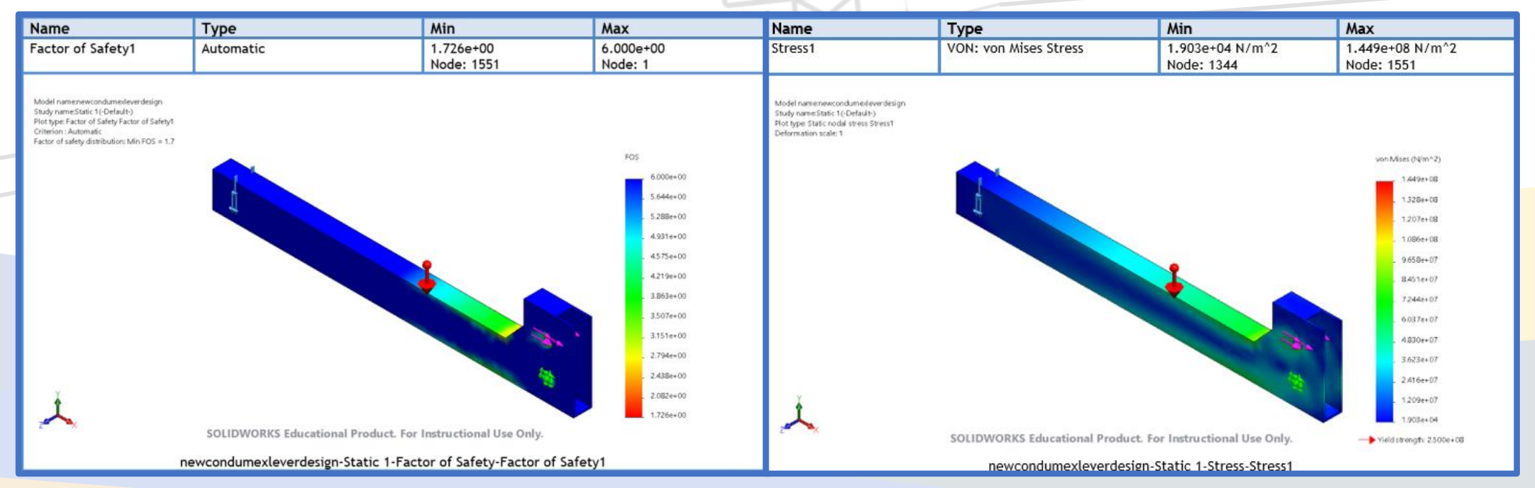


$$\sum\nolimits_M W * a * \cos(\theta_a) - F * r * \sin(180 - \beta - \theta_a) = 0$$

$$\theta_\delta = \tan^{-1}\left(\frac{a - a * \cos(\theta_a) \pm \delta}{a * \sin(\theta_a) \pm \varepsilon}\right) \quad MA = \frac{F}{W} = \frac{a * \cos(\theta_a)\cos(\theta_\delta)}{r * \sin(180 - \beta - \theta_a)}$$

Figure 6. Lever Arm New Design

Based on the stress analysis the bell crank was modified to obtain a safety factor 1.726 and reduce the stress concentration on the junction of the effort arm and the weight arm, maximum of $1.449x10^{-8}\ N/m^2$.



Name	Type	Min	Max
Factor of Safety1	Automatic	1.726e+00 Node: 1551	6.000e+00 Node: 1

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.903e+04 N/m^2 Node: 1344	1.449e+08 N/m^2 Node: 1551

Figure 7. Lever Arm New Design Mathematical Model

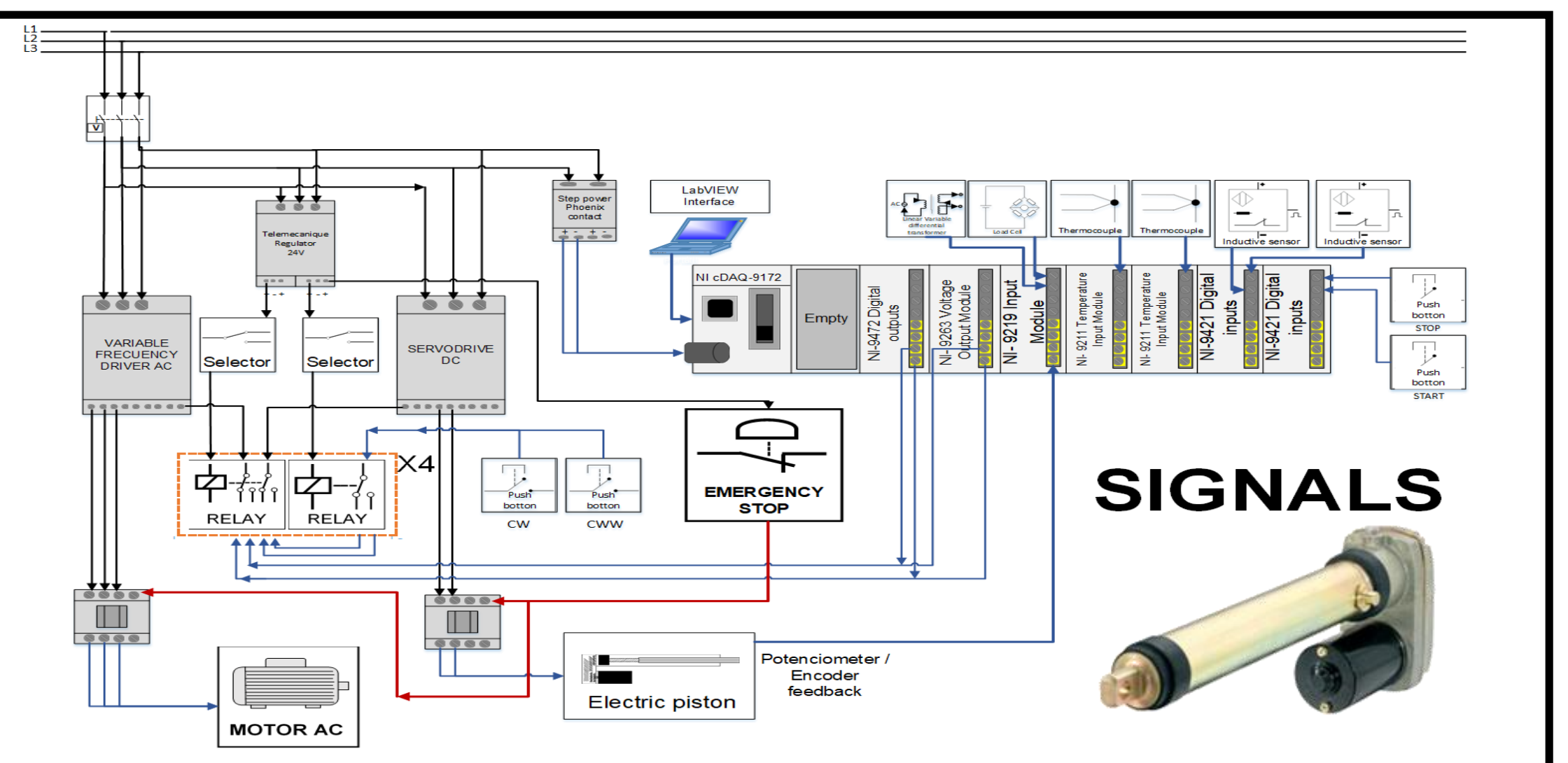


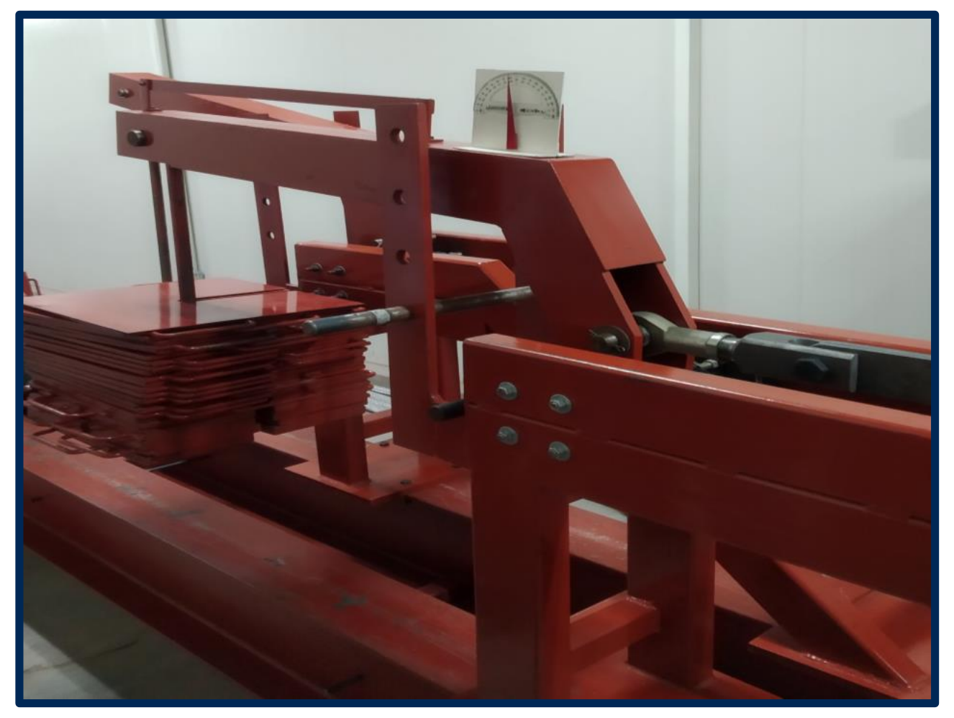
Figure 7. Automation Schematic Diagram

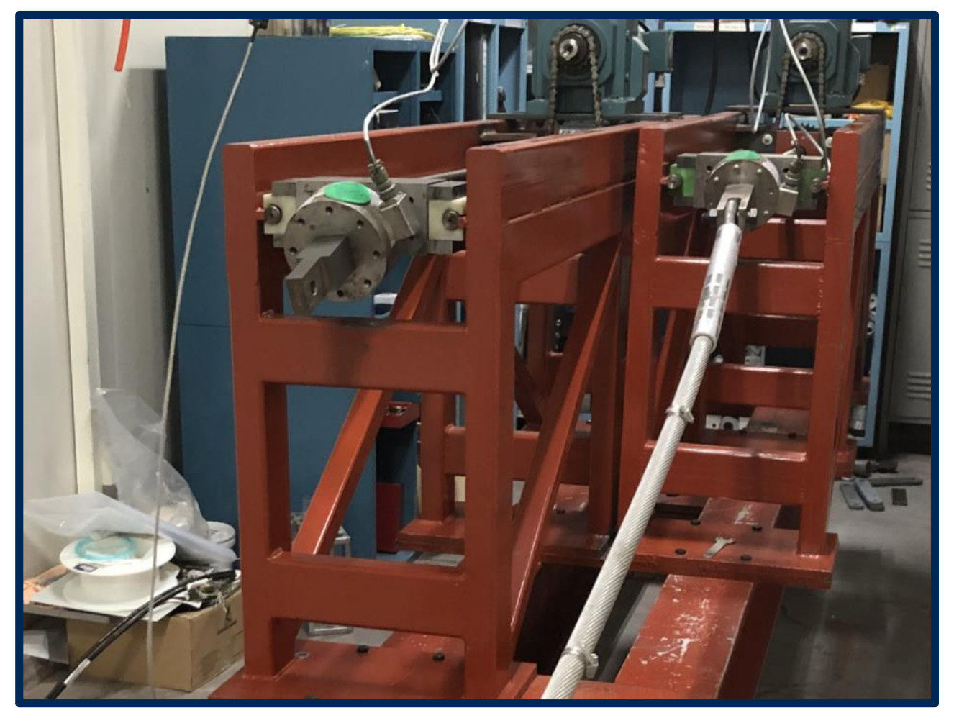
The system is controlled with digital signals and an analogue reference from the cDAQ with a servodrive and VFD to regulate the actuators movement

Signals proposal				
Qty	Component	Model	Brand	Cost (Dollars)
1	Electric piston	PPA24-58B65-36NPOX	Thomson Linear	$954.86
1	Servodrive	2097-V31PR0	Allen Bradley	$856.51
2	Inductive Sensor	NBB4-12GM50-E3-5M	Pepperl+Fuchs	$145.88
2	Connector	V1-G-5M-PUR	Pepperl+Fuchs	$30.20
2	Selector	XB5AD53	Telemecanique	$14.04
1	NI-9421	Digital inputs	National Instruments	$108.45
1	NI-9472	Digital outputs	National Instruments	$117.10
1	Chain	#120 Roller Chain - 10ft	USA Roller Chain	$313.00
1	Sprocket	120A11 Sprocket	USA Roller Chain	$50.10
6	Relay	55.34.9.024.5040	Finder	$51.54
6	Relay Base	94.04.SPA	Finder	$16.74
5	4 Contact Base	M22-A	Moller	$11.20
4	Button	M22-CK10	Moller	$10.56
4	Button	M22-CKC01	Moller	$12.28
1	Push Button	M22-D-R	Moller	$3.34
1	Push Button	M22-D-G	Moller	$3.34
2	Push Button	M22-D-S	Moller	$6.68
1	Push Button	M22-PV	Moller	$14.11
			Total	$2,719.93

CLOSING REMARKS

The proposed design complies with the specifications set by the IEC standard and with further research and development can later be implemented on the Creep test machine. Development was guided with feedback and instruction on CAD modeling and simulation of the engineers at CIDEC in order to comply with their requests for the design. Decisions on which system to develop were taken according to the benefits and compromises of each, resulting in the bell crank design which proved to have a changing mechanical advantage but being easy to deploy without major modifications on the machine and the electric piston cylinder which provides a fine control over the tension.





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