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Design for an arrangement to convert tensile force to compressive force

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ABSTRACT

Load cells are used to verify compressive, bending and tensile testing machines. A load cell can be designed to measure either compressive or tensile forces; other load cells can be designed to measure both forces. Compressive load cells are more compact and can be handled easily rather than tensile load cells. This article present the conceptual design and proposes three designs as an approach to use compressive load cells instead of tensile ones in verifying tensile testing machines. A prototype is manufactured and evaluated using universal calibration machine and force testing machines. This approach can be considered as an addition in force measurment as it make calibration of tensile testing machines more easy.

KEYWORDS: *Load cell, strain gauges, testing machine, tensile accessories,*

1. INTRODUCTION

Force testing machines are designed to perform compression or tension tests and sometimes both. Worldwide; material testing machines are the common uniaxial force testing machine. Material testing machines are traceable to SI units through calibrated load cells [1-4]. To calibrate testing machines; an appropriate load cell is placed in the force action place, placing a load cell in compressive testing machine is easier than hinging a load cell in tensile testing machines with the same capacity, this makes calibrating testing machines in compressive mode easier than calibrating in tensile mode, as calibration of tensile mode require using a load cell designed to measure tension forces which is normally bigger in dimension and more heavy. Dimensions of a load cell measuring tensile force increase than that measuring compressive force using the same loading principle for the same manufacturer, this is mainly due to the threaded bosses required to attach tension accessories (threaded pulling rods). Table (1) shows the difference between dimension and weights for Rever 250 kN load cell owned by the Egyptian National Institute for Standards (NIS).

Table 1. Load cell dimensions

Man.	**Capacity**	**Working mode**	**Diameter(mm)**	**Height (mm)**	**Width (mm)**
Rever	250 kN	Comp.	73.0	82.2	128.5
		Comp. & Tens.	158.75	292.1	190.5

2. TESTING MACHINES

Three different types of testing machines are available right now in the markets. Type A; a machine works to carry out compression or tension tests. Type B; a machine works to carry out compression and tension tests by changing the moving head direction. Type C; a machine works to carry out compression and tension tests without changing the moving head direction known as universal testing machines.(Figure.1).

To calibrate testing machines; an appropriate load cell is placed in the force action place. Calibrating compression testing machines and the universal testing machine is easier than calibrating tensile testing machine as for tensile testing machine a load cell designed to measure tension forces has to be used. Placing a load cell in compressive testing machine is easier than hinging a load cell in tensile testing machines.

Figure 1. Three different types of force testing machines

3. CONCEPTUAL DESIGN

The research ignites from the obstacles raised in calibrating uniaxial testing machines in tensile mode. The concept is to design an arrangement which can be fitted to a tensile testing machine to convert the generated tensile load to a compressive load in order to permit measuring the tensile force using compressive load cell. The interested parties by this arrangement are the laboratories which provide calibration services for tensile testing machines, which reflects the need for a universal arrangement universal to suit different load cells and allow supplying the calibration service for a wide range of tensile testing machines.
Figure (2) shows a schematic for an arrangement reflect discussed concept, where two parts - rectangles – move in opposite directions (D_1 & D_2) relatively to each other's, this motion is a result of tensile load (F_1 & F_2). As a compressive load cell is placed between the two parts and as a result of the relative motion resulted from tension load; a compressive load (F_3&F_4) is generated on the load cell (see figure (3)).

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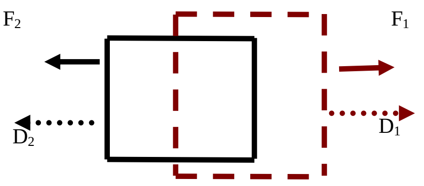

Figure 2. Arrangement under tensile forces

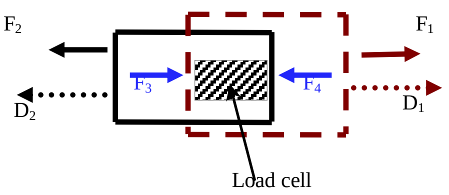

Figure 3. L.C. under compressive load

4. PROPOSED DESIGN

The main frame of the proposed design is to use four plates, tightening rods and fixing rods. Each two plates are similar and are assembled together using tightening rods (A & B in figure (4)). And the two assemblies are assembled together as shown in figure (4).

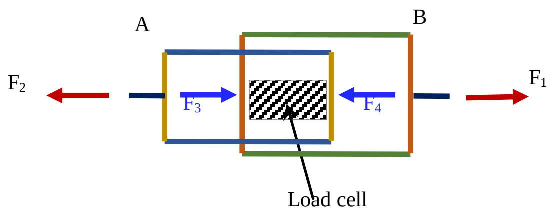

Figure 4. Schematic for the proposed design

Number of tightening rods, dimensions and materials are determined according to the maximum stress resulted on the assembly under load taking into consideration the design safety factor.

Three proposed designs may result from the conceptual design (Design (A), (B) and (C)). Table (2) define main difference between the proposed designs.

Each design of the three proposed designs shown in Table (2) is composed of two parts; one on which the compressive load cell is placed (see (A) in Figure (4)) and the other one will be in contact with the load cell load button (see (B) in Figure (4)). The fixing rods which are used to hinge (A) and (B) arrangements to upper and lower jaws of the tensile testing machine may be designed as integrated part to the arrangement or as a replaceable parts in order to fit different jaws of tensile testing machines according to the machine capacity. As the tensile load is applied and due to the inverse motion of the two parts the tensile load is changed into compressive load on the load cell, which can be measured easily.

Designs (B) and (C) are distinguished from design (A) as the tightening rods in (B) and (C) are guided through the plates to keep aligning, however this may cause friction if the total arrangement is hinged to the tensile testing machine without ensuring contact less between movable parts before start loading. Design (C) is more directed suit high force ranges.

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Table 2. Three proposed designs

		Design (A)	Design (B)	Design (C)
3-D Ass.				
No. of tightening rods (T)		Two	Two	More than Two
Plate (P)	**Profile**	Strip	Strip	Any profile (square, circular,…etc)
	No. of holes (H)	H= T	Two plates, where H = T Two plates Where H= 2 T	Two plates, where H = T Two plates Where H= 2 T
Fixing rods		Set of twos, changeable, to suit the calibrated machine		

5. EXPERIMENTAL WORK

A prototype of design (B) was designed and manufactured to measure the concept efficiency. Figure (5) shows the engineering drawing with the actual dimensions for the prototype which was designed to suit compressive load cell with capacity 45 kN (Rever, Serial no.: 4688). Figure (6) shows the manufactured prototype to convert tensile force to compressive one.

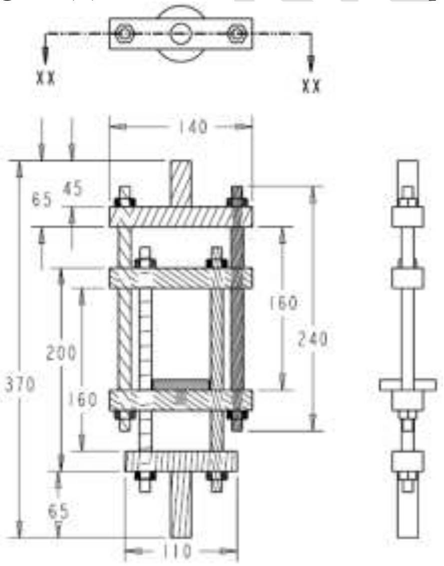

Figure 5. Engineering drawing- Prototype

Figure 6. Tensile arrangement-Prototype

6. EVALUATION PHASE

Two approaches were selected to evaluate the measurement efficiency of the manufactured converter using universal calibration machine and force testing machine.

6.1 Measurements on universal calibration machine

ISO 376 and ASTM E74 are international standards used to calibrate force proving instruments [5-6]. To check the effectiveness of the proposed arrangement a 5000 lbf load cell was calibrated according to ASTM E74 using NIS universal calibration machine with 10000 lbf load cell as secondary reference standard two times; one time in compression mode (Table (3)), the second time in compression mode by using the proposed arrangement (Table (4)). Results of the two calibrations are compared to each other in Table (5).

Table 3. Calibration results of 5000 lbf load cell under compression load (normal mode)

Applied Force	Response Values			Average Response	Interpolated response
	Series 1	Series 2	Series 3		
kN	mV/V	mV/V	mV/V	mV/V	kN
5	0.22550	0.22620	0.22382	0.225173	4.997
10	0.45106	0.45263	0.45196	0.451883	10.000
15	0.67679	0.67608	0.67732	0.67673	15.001
20	0.90259	0.90291	0.90201	0.902503	20.001
25	1.12824	1.12839	1.12645	1.127693	25.001
30	1.35357	1.35461	1.3526	1.353593	30.000
35	1.57712	1.57753	1.57829	1.577647	34.999
40	1.80421	1.80362	1.80561	1.80448	39.999
45	2.02946	2.03083	2.02831	2.029533	45.001

Table 4. Calibration results of 5000 lbf load cell under compression load using tensile arrangement

Applied Force	Response Values			Average Response	Interpolated response
	Series 1	Series 2	Series 3		
kN	mV/V	mV/V	mV/V	mV/V	kN
5	0.22590	0.22532	0.22463	0.225283	4.983
10	0.45056	0.45266	0.45361	0.452277	10.011
15	0.67579	0.67808	0.67719	0.67702	14.993
20	0.90409	0.90361	0.90181	0.90317	20.011
25	1.12932	1.12733	1.12544	1.127363	24.987
30	1.35403	1.35499	1.35366	1.354227	30.022
35	1.57931	1.57835	1.57629	1.577983	34.988
40	1.80222	1.80369	1.80484	1.803584	39.992
45	2.03091	2.03001	2.02864	2.029853	45.006

Table 5. Difference between calibration of load cell with and without tensile arrangement**.**

Applied Force	Average Response			Interpolated response		
	Without tensile arrangement	With tensile arrangement	Deviation	Without tensile arrangement	With tensile arrangement	Deviation
kN	**mV/V**	**mV/V**	**(%)**	**kN**	**kN**	**(%)**
5	0.225173	0.225283	-0.05	4.997	4.983	0.28
10	0.451883	0.452277	-0.09	10.000	10.011	-0.11
15	0.676730	0.677020	-0.04	15.001	14.993	0.05
20	0.902503	0.903170	-0.07	20.001	20.011	-0.05
25	1.127693	1.127363	0.03	25.001	24.987	0.06
30	1.353593	1.354227	-0.05	30.000	30.022	-0.07
35	1.577647	1.577983	-0.02	34.999	34.988	0.03
40	1.804480	1.803584	0.05	39.999	39.992	0.02
45	2.029533	2.029853	-0.02	45.001	45.006	-0.01

6.2 Measurements on force testing machine

ISO 7500-1 and ASTM E4 are international standards used to calibrate uniaxial force testing machines [7-8]. To check the effectiveness of the proposed arrangement a 50 kN tensile testing machine was calibrated according to ISO 7500 two times; one time using a tensile 10000 lbf load cell as reference standard (Table (6)), the second time using a compressive 10000 lbf load cell assembled with the manufactured converter (Table (7)). Results of the two calibrations are compared to each other in Table (8).

Table 6 Calibration of 50 kN tensile testing machine using 10000 lbf (45 kN) load cell (s.n. 7801).

Applied load (kN)	Series (1) (mV/V)	Series (2) (mV/V)	Series (3) (mV/V)	Average (mV/V)	Interpolated load (kN)
5	0.34301	0.34283	0.34398	0.343277	5.080
10	0.67901	0.67989	0.67998	0.679628	10.058
15	1.01848	1.01781	1.01760	1.017964	15.068
20	1.35716	1.35732	1.35998	1.358155	20.106
25	1.69931	1.69721	1.69832	1.698282	25.145
30	2.03664	2.03426	2.03761	2.036173	30.154
35	2.37506	2.37633	2.37801	2.376466	35.202
40	2.71720	2.71258	2.71564	2.715139	40.229
43	2.91660	2.91466	2.91832	2.916528	43.220
45	3.05685	3.05165	3.05428	3.054257	45.266
Machine is class 1			Relative zero error= 0 %		

Table 7 Calibration of 50 kN tensile testing machine using 10000 lbf (45 kN) load cell (s.n. 4688) and the proposed tensile arrangement.

Applied load (kN)	Series (1) (mV/V)	Series (2) (mV/V)	Series (3) (mV/V)	Average (mV/V)	Interpolated load (kN)
5	0.22855	0.22832	0.22967	0.22885	5.073
10	0.45226	0.45367	0.45332	0.45308	10.044
15	0.67897	0.67845	0.67843	0.67862	15.043
20	0.90476	0.90688	0.90465	0.90543	20.070
25	1.13247	1.13187	1.13211	1.13215	25.096
30	1.35676	1.35817	1.35741	1.35745	30.092
35	1.58373	1.58412	1.58539	1.58442	35.125
40	1.81049	1.80838	1.81167	1.81018	40.134
43	1.94340	1.94507	1.94455	1.94434	43.112
45	2.03743	2.03490	2.03638	2.03624	45.152
Machine is class 1			Relative zero error= 0 %		

Table 8. Difference between calibrations of the force testing machine using.

Applied force	Interpolated response		Deviation
	Tensile L.C.	Compressive L.C & Converter	
kN	**kN**	**kN**	**(%)**
5	5.08	5.073	0.14
10	10.058	10.044	0.14
15	15.068	15.043	0.17
20	20.106	20.07	0.18
25	25.145	25.096	0.19
30	30.154	30.092	0.21
35	35.202	35.125	0.22
40	40.229	40.134	0.24
43	43.22	43.112	0.25
45	45.266	45.152	0.25

7. CONCLUSION

Concepts to convert compressive force to tensile force were presented and three proposed designed were suggested. One prototype out of the three proposed designed were manufactured, tested and evaluated. Measurements for evaluation were performed using universal calibration machine and force testing machine to compare results from normal calibration to that resulted using the new tensile arrangements. Results on UCM show 0.7 % maximum deviation between actual values from calibration and 0.11 % between interpolated force values from 20 – 100 % of the load cell nominal value. Deviations on force testing machine range from 0.14 -0.25%. it is concluded that the proposal is an approach to be used in calibrating tensile testing machines, ignoring the must of having the used force transducers being calibrated in tension mode which is almost more difficult.

8. REFERENCE

i. Falk L. Tegtmeier , Alex W. Gutsch, “Calibration of a 30 MN Material Testing Machine According to ISO 7500- 1 Using a Force-Transducer Build-Up System”, Journal of Physics: Conf. Series 1065 (2018) 042018, doi:10.1088/1742-6596/1065/4/042018

ii. David Kimetto, “calibration procedure of material testing machines in Kenya”, Proceeding of the IMEKO TC 3 conference, Cairo, Egypt, 19 - 23 February 2005. http://www.imeko.org/publications/tc3-2005/IMEKO-TC3-2005-001u.pdf

iii. Bulent Aydemir, Sinan Fank, Baris Cal, “Effect of test speed on verification of material testing machine”, April 2007, Measurement 40(3):343-346, DOI:10.1016/j.measurement.2006.05.0

iv. Boris Katz , Peter Kornhauser , Shlomi Bitas, Calibration of hydraulic force machines – requirements, concepts, problems, solutions, proceedings of XIX IMEKO World Congress Fundamental and Applied Metrology September 6-11, 2009,Lisbon, Portugal.

v. ISO 376:2011; “Metallic materials-Calibration of force proving instruments used for the verification of uniaxial testing machines”. https://www.iso.org/standard/44661.html

vi. ASTM E74-18; “Standard Practices for Calibration and Verification for Force-Measuring Instruments". https://www.astm.org/Standards/E74.htm

vii. ISO 7500-1:2018; Metallic materials-Calibration and Verification of static uniaxial testing machines- Part 1: Tension/compression testing machines – Calibration and verification of the force-measuring system”. https://www.iso.org/standard/72572.html

viii. ASTM E4-20; “Standard Practices for Force Verification of Testing Machines”.

ix. https://www.astm.org/search/fullsite-search.html?query=E4&