HAGIWARA ELECTRIC

ULTRASONIC BOLT CLAMPING FORCE METER

制御部品・電子計測

萩原電気

THE IMPROVED RELIABILITY

There are a number of structures using bolted connections for joining their members together, and their structural strength is closely associated with the reliability of tightening operation.

The exact, offhand knowledge of the " initial tension " or the stress or load induced in a bolt when tightened is a pre-requisite for reliable bolt load control and satisfactory tightening operation accomplished through precise control over torque wrench settings and power tool outputs.

Offered as a bolt clamping force meter, this HAGIWARA computerized bolt load meter utilizes an ultrasonic wave and is designed for easy and accurate measurement of bolt load inducted by the tightening operation. A digital display reads direct in metric tons.

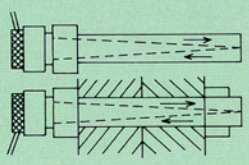
Being a compact, lightweight unit, it can be easily transported for spot checks on an assembly line, or integrated into an inspection process, so as to increase the capability of your plant and guarantee the reliability of your products.

HOW IT WORKS

This instrument operates on the principle of ultrasonic wave transmission.

Tightening a bolt or turning a nut on it induces a tensile stress in the bolt, causing an elongation. An ultrasonic wave, introduced at the bolt head by a probe, travels through the bolt and reaches the other end of the bolt or the solid-air interface where the wave is reflected back toward the head end.

The speeds of wave transmission decrease with increasing stresses, and the elongation of the bolt lengthens the echo time intervals between introduction of the ingoing wave and reception of the returning wave.



The instrument makes good use of a combined effect of these two characteristics of ultrasonic wave transmission in the bolt when tightened for direct and accurate reading of the stress or load induced by the tighening operation, which is called "initial tension."

Let a span of time required for the wave to travel through the bolt and return to the point of probe application before tightening be To and let a span of time after tightening be Tp.

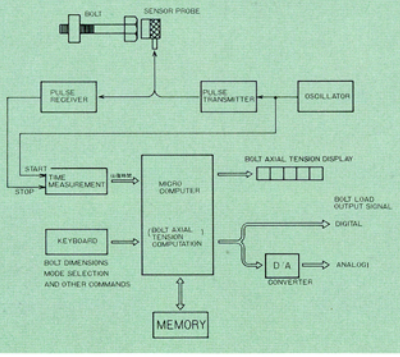
Then the amount of initial tension Q is given by;

$$Q = K (Tp - To) / To \quad \cdots\cdots\cdots\cdots\cdots (1)$$

Where K is a constant whose value is determined by the dimensions of the bolt to be tested. Prior to the testing operation, the value K is calculated and stored in the memory of the unit by entry of dimensional data for a given bolt.

Before the bolt is tightened, the probe of a sensor is applied to the head end of the bolt to measure the time To and after it has been tightened, the probe is again applied in the same way as before to measure the time Tp. The built-in microcomputer is programmed to give a value for Q according to Equation (1) and the digital display shows the result of computation, giving a direct reading of the bolt load as an initial tension.

BLOCK DIAGRAM



CONTOROL SYSTEM

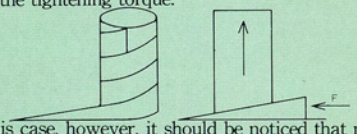
A torque wrench or other adjustable power tool is the most widely used means of inducing the approximate desired initial tension in small bolts. This method is based on the linear or propotionate relation between the applied torque Tf and the initial tension Q as follows;

$$Tf = K d Q \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

Where "d" is the nominal bolt size and "K", called the torque co-efficient, is taken as a constant for a particular set of conditions.

It is intended to ensure the tightness of the joint by controlling the amount of tightening torque.

Threads of the bolt is merely an inclined plane wrapped around a cylinder so that spiral forms result as shown in Fig.3, whereas a wedge is acutally a double inclined plane. When the wedge is driven in, the cylinder is forced upward, and this screw principle is used in the design of common screw jacks for jacking up heavy things. In the tightening of bolts and screws, the effort F to drive the wedge corresponds to the tightening torque.

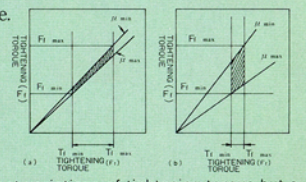


In this case, however, it should be noticed that not all effort applied turns out to be a working force the bolt has for jacking up things or clamping parts together in place, but only a fraction of the applied effort (torque) can be converted into the effective force due to fricitional losses on contact surfaces of threads, bearing surfaces of the bolt, etc.

In practical bolted connections, 80 to 90 % of the applied torque accounts for frictional loss, and only 20 to 10 % of it is converted into the force that works in the bolt.

A co-efficient of friction depends on the finish of the seating and thread surfaces and their lubricated condition. Where there are many variables involved, the variations of frictional loss being as high as 80 to 90 % of applied torque, the initial tension in the bolt is not reliable, however precisely the tightening torque may be controlled.

It can be said that when testing a bolted connection for the tightness, what you do with a torque wrench is merely to measure or evaluate the amount of fricitional resistance.



(a) : There are great variations of tightening torque but a co-efficient of friction is relatively stable in its value.

(b) : The bolt is torqued exactly to specifications with a range but there are considerable variations in values for co-efficient of friction.

These two conditions when evaluated in terms of reliability of bolted, connection, are much the same.

TEST PROCEDURE

①With a POWER switch ON, turn on the " SET " mode switch and the " CH " channel switch. Key in the desired channel number, using the ten-key board.

②Enter the initial data values, using the key-key and function key-board switches. The function key-board switches are marked with symbols as follows:

Lo : Overall bolt length including head portion (mm)

D_1 : Diameter of shank portion (bolt grip) under head (mm)

D_2 : Effective diameter of threads

L_1 : Length of shank portion (bolt grip) under head (mm)

L_2 : Effective length of threads (mm)

P : Thread pitch (mm)

For bolts threaded throughout their length under head, use the following keys instead of D_1, L_1 and L_2 :

D_3 : Effective diameter of threads (mm)

L_3 : Effective length of threads (mm)

The entry of these initial data values enables the unit to compute the value of a constant K automatic-ally, which is then stored in memory and displayed. Keep a record of the constant value K for a given bolt, and you can key it in again during the initial setup for testing joints with the bolts of the same size and shape, thus saving the setting time.

③When testing bolts of different sizes on a continuous point-to-point basis, select the channels and enter the necessary data for each different size of bolt by repeating operations at Step 2.

④Select the channel number assigned to the bolt to be tested. Be sure that the mode switch, either

OF BOLTED STRUCTURES.

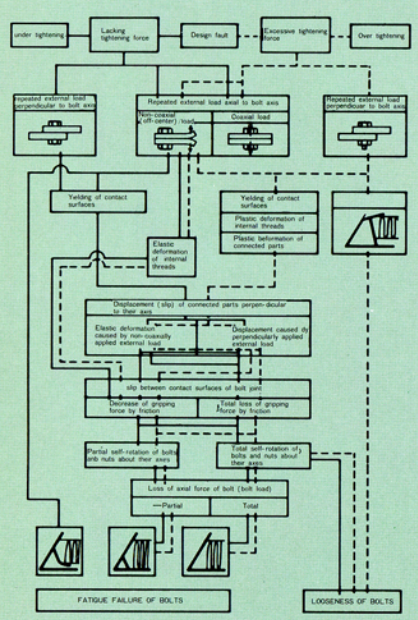
WHY IS BOLT LOAD AXIAL TENSION CONTROL SO IMPORTANT?

It should be stressed here that the constructional strength of a structure or an assembly with bolted connections depends greatly on the tightness of the bolts installed, not much on the strength of bolt. The design and installation could not be said to be highly reliable, even with the use of high-tension bolts, if they should lack anything in terms of the reliability or characteristic that is concerned with minimizing bolt looseness and failure.

The bolt provides the most reliable means of joining the parts firmly together, only when given an optimum amount of tightening effort. Properly loaded, it gains in resistance to looseness and failure. When the tightening effort is too low, the loss of loading on the bolt itself not only renders it slackened quickly, failing to serve its function, but also can easily give rise to fatigue failure with an increased factor of the internal force, when subjected to external oscillating loads under alternating stresses.

Conversely, when the tightening effort is too high, the bolt, nut or connected members are so heavily stressed that a plastic deformation results, with an elastic range reached, and the joint becomes loose.

Adequate utilization of the strength grading in the ISO standard (TC2/R898) will help make the structural design even more compact but due care should be exercised to give a proper amount of tightening effort with the bolt load controlled precisely to match the strength grade for the bolt.



FEATURES OF "PULSE" TYPE ULTRASONIC BOLT LOAD MATER

①ACCURATE BOLT LOAD MEASUREMENT

The unit permits accurate measurement of bolt load regardless of co-efficients of friction on thread contact and seating surfaces and other variables that prevent accurate calculation of bolt tension.

②COMPLETE FREEDOM FROM TEMPERATURE VARIATIONS

The automatic temperature-compensating circuit makes the readings free from possible errors due to temperature variations.

③UNMATCHED EASE OF OPERATION

The built-in microcomputer makes the operation extremely easy and the digital display allows the measured bolt load to be read off directly in tons.

④NO NEED TO TURN BOLTS OR NUTS

The unit measures and displays the bolt load without turning the bolt or nut, allowing for convenient spot checks on an assembly line and for analysis and evaluation of the tightness of bolts.

⑤NONDESTRUCTIVE TESTING

The use of ultrasonic waves provides a nondescructive method of testing, which does not involve damaging or destroying the joint.

⑥SELF-DIAGNOSTICS

This microcomputer-based measuring system has a self-checking function to insure that the unit works properly and that the test is carried out correctly.

⑦CONTINUOUS POINT-TO-POINT MEASUREMENT FOR DIFFERENT BOLT SIZES

The computer memory permits entry and storage of initial data for several different sizes of bolts to be tested at one time. A selection of the desired channel allows for continuous measurement of bolt loads from one bolt size to another at one setting.

⑧DIGITAL SIGNAL OUTPUT TERMINALS

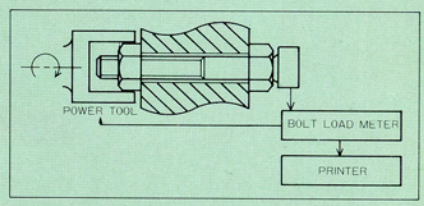
The unit has a set of pin connectors or terminals for outputs of signals in digital form, allowing for preparation of human-readable test date in hard-copy form for storage or analysis when conected to a printer.

TYPICAL APPLICATIONS

The bolt load meter has proven a reliable instrument for improving the reliability of bolted connections and joints and is expected to expand the range of applications. Here are some typical examples of technique applied to bolt load control.

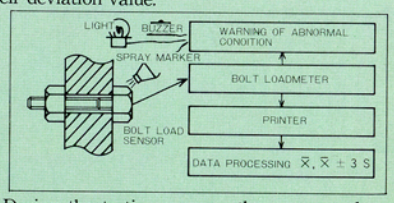
BOLT LOAD CONTROL FOR WELL-TIGHTEND BOLTS

At almost all mass production plants, the torque measurement method is used for bolt tightening operations but it can hardly be said that the tightening torque is calibrated exactly to the desired tension in a bolt. This instrument connected to a power tool may be connected to a power tool to give a signal to stop its action at the exact moment that the bolt head or not is turned to a known safe bolt load, allowing for close control of the bolt load to be induced by the tightening operation at each joint. This optimizes the initial tightening stress to obtain well-tightened bolts with the improved reliability of bolted structures. It also makes the design compact, reduces the number of bolted connections, and saves assembly costs.



ASSURANCE OF STRUCTURAL STRENGTH

A system has been developed with the unit to insure the strength of some important joints by taking the initial tension in the bolt for the major characteristic of bolted connection. In the structures that are subjected to internal pressures and those whose members are joined by friction, the strength of the overall structure can be evaluated by the total sum of initial tension values for individual bolted connections with their deviation value.

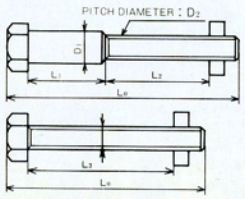


During the testing process, the operator does not have to observe the data displayed in the instrument panel on each of test points but he is warned against the presence of an improperly tightened joint through actuation of a buzzer, light or spray marker that is interconnected with the unit for transmission of signals output from it. It can also be interfaced to a printer for data processing and storage.

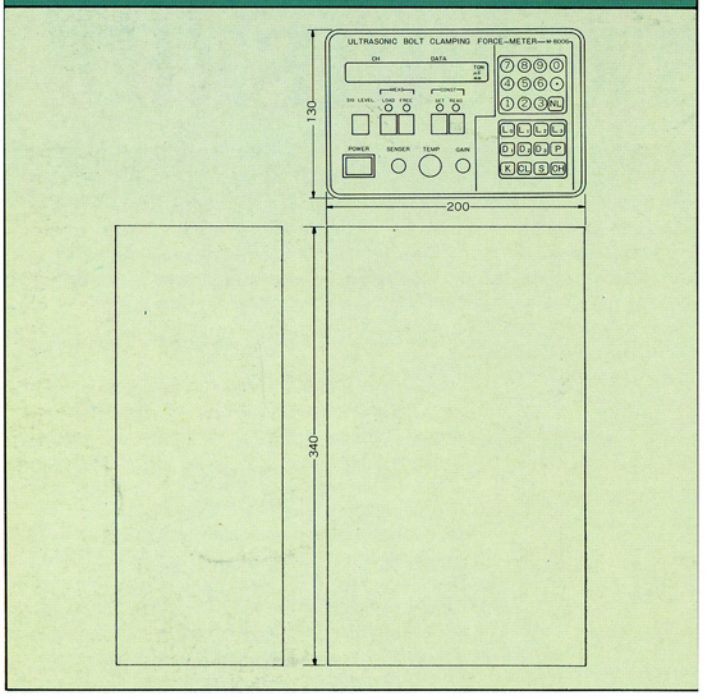
" SET " or " READ," is selected.

⑤Select the " FREE " mode switch. Apply the sensor probe to the head end of the bolt. After making sure that the OK light is lit, indicating that the unit has been properly set up, then depress the " NL " key switch. This enables the initial input data [To] (time interval between instruction of ingoing ultrasonic wave and reception of returning wave) to be stored in computer memory. The value To is displayed in μs (10^{-6} seconds).

⑥Select the " LOAD " mode switch. Tighten the bolt. Apply the sensor probe to the head end of the tightened bolt. Now the unit display the amount of load in the bolt in terms of tons.



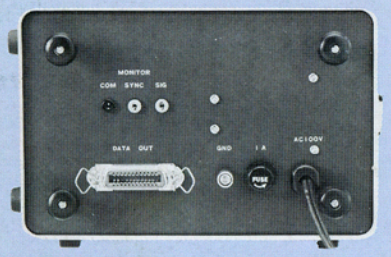
DIMENSIONS

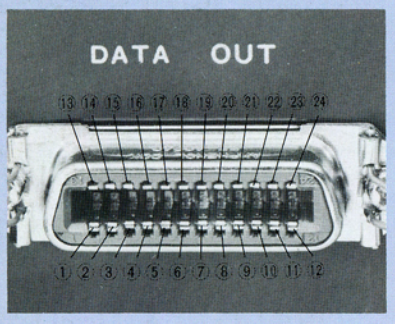


SPECIFICATIONS

1. Ultrasonic Wave Frequency	5 MHz
2. Measuring Accuracy	5 % of breaking load L = 100 mm and D = 14 mm
3. Bolt Sizes and Lengths	D = 8 to 20 mm L = 50 to 200 mm
4. Sensor (Probe)	Piezoelectric ceramics
5. Ambient Temperatures	0 to 45 °C
6. Power Supply	100-volt 50/60-Hz AC
7. Weight	5 kg
8. Standard Accessories	Standard bolt load sensor Temperature sensor Power cable Output connector Machine oil Service tools Light bulbs Fuse elements
9. Options	Oscilloscope for wave - from monitoring Special sensor (probe)

PIN CONNECTOR





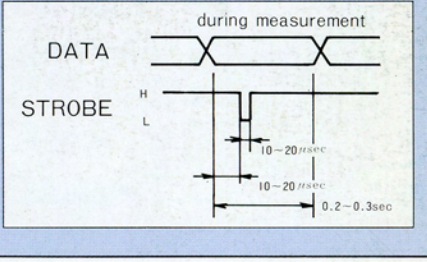
PIN CONNECTORS (OUTPUT TERMINALS)

pin No.	Signal		pin No.	Signal	
1	ANALOGboltload output(option)		13	B	×0.1
2	ANALOG bolt load output - GND		14	C	
3			15	D	
4	DIGITAL bolt load output A	×10	16	DIGITAL bolt load output strobe	
5	B		17	DIGITAL bolt load output - GND	
6	C		18		
7	D		19		
8	A	×1	20		
9	B		21		
10	C		22		
11	D		23		
12	A		24		

(2) ANALOG BOLT LOAD OUTPUT (OPTION)
Output Voltage Level : 0.1 V/ton
Output Impedance : 10Ω max.
Output Current : 1 mA

(3) DIGITAL BOLT LOAD OUTPUT
Data Code : BCD - negative logic
Level : TTL
Fan-out (loading factor : 1)

● DATA TIMING CHART



hagiwara electric

HEAD OFFICE:
HAGIWARA ELECTRIC CO., LTD.
2-3-3 HIGASHI SAKURA, HIGASHI-KU, NAGOYA, 461, JAPAN
TEL: NAGOYA (052) 931-3511
NAGOYA FACTORY
7 SHIMO KOFUKADA ASADA NISSHINCHO, AICHI-GUN, AICHI-PREF., 470-01, JAPAN
TEL: NAGOYA (052) 804-1151
TOKYO BRANCH:
HIGH LIFE NISHI-SHINJYUKU BLDG.
7-7-7, NISHISHINJYUKU, SHINJYUKU-KU, TOKYO, 160, JAPAN
TEL: TOKYO (03) 365-2681