Improvement of dynamic pressure standard for calibration of dynamic pressure transducers

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Abstract. In dynamic pressure measurement phenomena, dynamic pressure calibration of the measurement chain including a pressure sensor, signal conditioning amplifier and data acquisition part is required. A drop mass dynamic calibration machine which is used for the dynamic calibration in hydraulic media was designed and developed. This study presents a research study and measurement results on the dynamic calibration of pressure transducers by using the newly developed machine.

1 Introduction

Dynamic pressure sensors have a wide area of usage both in measurement and in controlling process in lots of fields like aerospace, medicine production, food processing [1,2]. Some applications show time-invariant static characteristics, so certain types of transducers can be used to measure such static time-invariant value of pressure. If pressure value is changing by time or in other saying if it is time-dependent, it is defined as dynamic because it varies significantly in a short period of time demanding a dynamic calibration. The means of a dynamic calibration of a pressure sensor or a measurement system consisting of the evaluation of their dynamic treatment with sufficient and appropriate accuracy. In dynamic pressure calibration, the used calibration system should generate a dynamic pressure, which is a time-varying, reliable and controllable way and whose value is well known. The generated pressure is taken as the reference pressure value in the calibration of test pressure sensors.

2 Working principle of dynamic calibration machine

National Metrology Institute of Turkey (TUBITAK UME) has developed a measurement standard based on dropping mass principle for dynamic calibration machine of pressure transducers. It uses conservation of energy which is the well-known basic physical law. While the principle of the system is given in Figure 1. and the schematic diagram of the dynamic calibration machine is given in Figure 2. Drop mass system transfers the produced kinetic energy by free dropped mass to quartz-based dynamic reference and test sensors. The dynamic calibration machine is used to create a half-sinus signal with a width of around 5 ms for calibration of dynamic pressure transducers. The measurement range is

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from 50 MPa to 500 MPa in hydraulic media with targeted relative measurement uncertainty is 1 % [1].

In order to create the testing pressure, it uses a dropping mass on to a piston, increasing the pressure in the hydraulic medium by up to some hundreds of MPa in order to perform a quick and accurate check and calibration of high-pressure dynamic sensors as seen in Figure 1. The energy level is adjusted by changing the dropping height of the dropping mass [2].

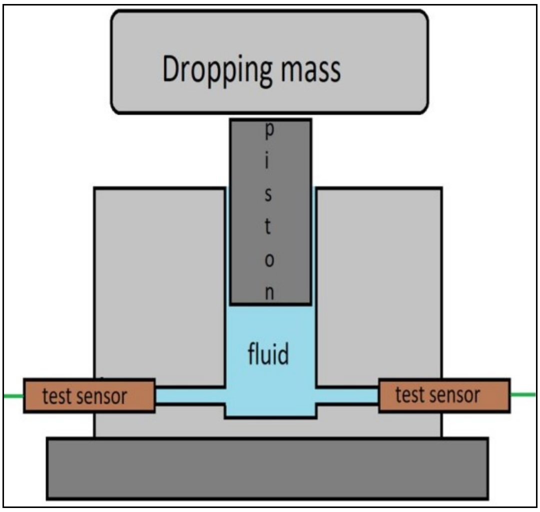

Fig. 1. General Principle of Dropping Mass System

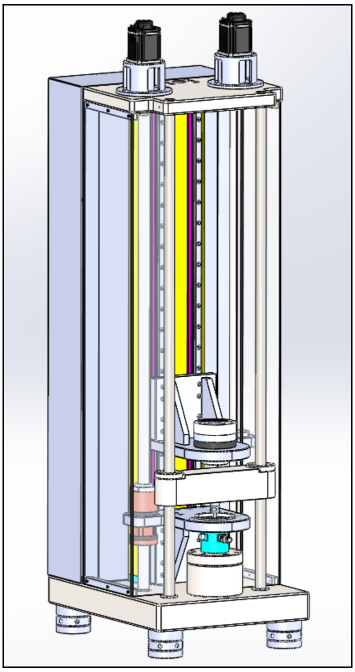

Fig. 2. General Principle of Dropping Mass System

The manufactured dynamic pressure standard based on dropping mass principle is given in Figure 3. There are two different step motors on the dynamic calibration machine. The first step motor is used to move a rebound system which is used to catch the dropping mass to prevent it repetitive hits on to the piston. The second motor is used to move the electromagnet which holds the mass and lift it to a certain height to be free fall.

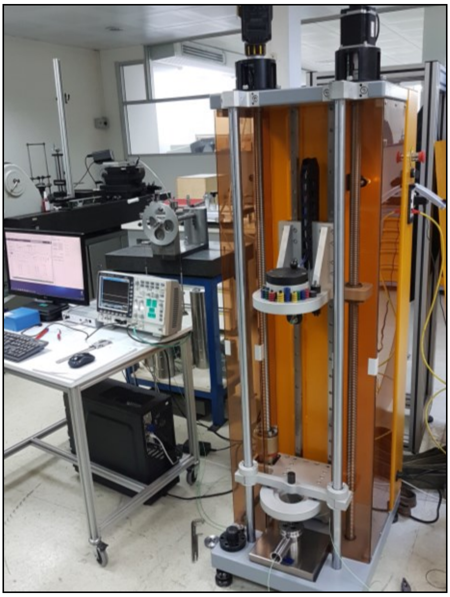

Fig. 3. Dynamic calibration machine

There are different apparatus on the machine where allowing to connect the different pistons. The nominal drop height is 800 mm. The weight of dropping mass is also adjustable by replacing it. The mass is lifted to a specified height by an electromagnet. The height of free fallen is set via a computer program which is given in Figure 3. There are two guiding rods for drop mass. These rods ensure the drop mass to make a vertical movement and repeatable hits on to the piston. Test sensors and piston are connected to a cavity which is filled with a pressure transmitting fluid as seen in Figure 1. This part totally called as measuring head assembly. Once the hit comes on to the piston this hitting effect is delivered to both sensors. Measuring head assembly is fixed tightly onto the base of the standard to prevent any movement of the assembly. The machine is designed to make the central position of mass and piston.

After some measurements, it is necessary to re-charge fluid into the measuring head assembly. For such a purpose an additional spare fluid room added to head assembly. Measuring fluid and spare fluid is separated with a needle valve. Whenever the re-charge is necessary, the needle valve is opened and by rotating a screw located into the spare room, fluid re-charge action is completed. The easy re-charge system is given in Figure 4.

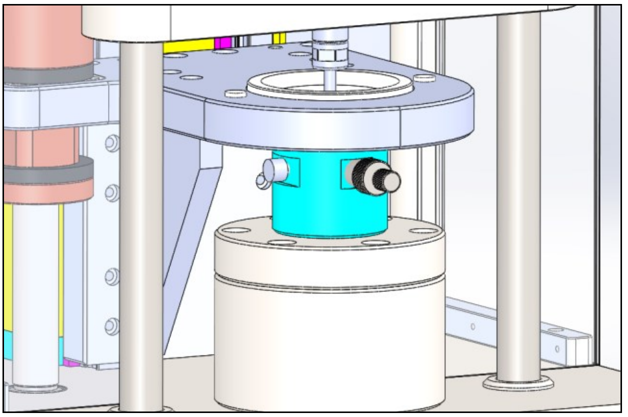

Fig. 4. Fluid re-charging part

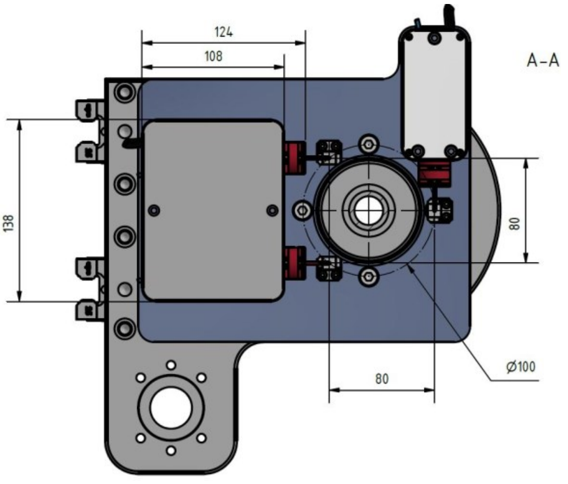

Fig. 5. Placement of the laser heads

The reference pressure is calculated as pressure is a force over a specific area of the piston. Area of the piston is calculated based on dimensional form measurements of absolute diameter, roundness and straightness. Mass is the total mass of dropping mass, the mass of piston and mass of fluid under operation. Acceleration of the dropping mass is calculated as the addition of two acceleration values they are local gravity of acceleration value and acceleration of dropping mass [3]. Acceleration of the dropping mass is measured by a laser interferometer system from three different points of dropping mass as seen in figure 5.

Control of the system is performed by a computer program as seen in Figure 6. On this software, it is possible to set dropping height and number of an experiment to be repeated. When the area of the piston, the weight of the calibrated mass and acceleration of gravity is specified it is possible to set the nominal pressure value for calibration.

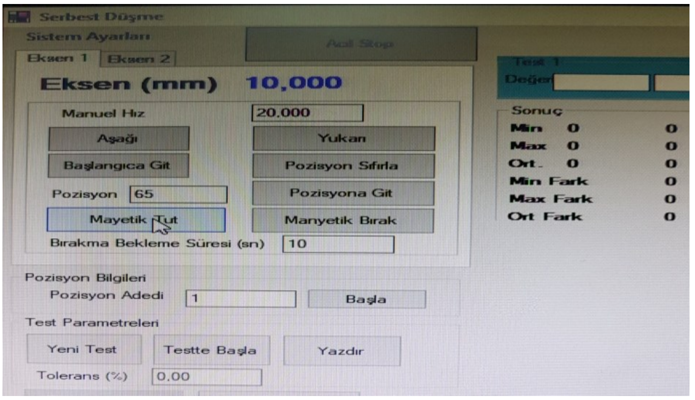

Fig. 6. Software program interface for controlling dynamic calibration machine

Before each free fall, there is a pre-set action is taken. Electromagnet holds the mass and moves it down to the piston. As soon as the mass touches to the top end of the piston, this point is taken as the zero points or reference point of free fall height. This pre-set action is provided better repeatability in measurement results. Starting from this zero point mass is moved up to the set height point for free fall. The set height point is measured by the counter of the motor. In order to have correct height distance measurement, the position on the machine is calibrated according to ISO 9513 standard.

3 Performance test

Equations Dynamic calibration machine provides us with a computer controlled and repeatable dynamic calibration. Dynamic pressure constituted in the closed cavity is sensed and measured by means of two piezoelectric pressure transducers, named reference and test sensors. Piston, test and reference sensors are mounted on to a closed volume (cavity). This volume was filled with different types of oils as a pressure transmitting media. Kistler 1053 was used as the liquid in this measurement. The piston is directly located in line the vertical axis of free dropped mass. (Yasin Durgut et al., 2015). Produced charge values by hitting effect of the mass on to the piston are carried through the green charge cables to channel 1 and channel 2 of the Signal Conditioner/Amplifier Kistler Type 6907B. Analogue outputs of sensors from the amplifier are connected to an oscilloscope to see the signal shape. The sensor Kistler Model 6213BK up to 800 MPa was used as a reference and a test sensor was used from Kistler of model 6229AK up to 500 MPa. The reference sensor is calibrated against conventional deadweight tester under the static pressure for traceability. Measurements have been performed at 50 MPa, 100 MPa and 200 MPa reference values five times at decreasing direction. The measurement results are given in Table 1.

Table 1. Experimental measurement results for reference values

Nominal Pressure (bar)	Measured Pressure (bar)	Repeatability (%)
2000	1990	0.50
	1980	
	1990	
	1980	
	1990	
1000	1000	1.00
	1000	
	995	
	1005	
	1000	
500	505	1.00
	505	
	500	
	500	
	505	

Output signals show half sinus wave characteristic with a width of 5 ms. The amplitude of the produced signal output of sensors is measured nominally 1 mV per 1 bar as given in Figure 7.

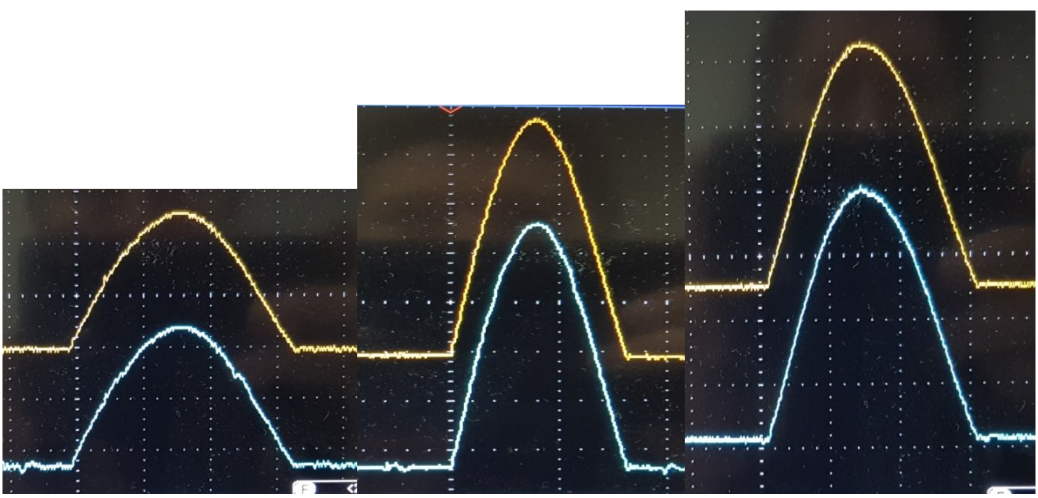

Fig. 7. The analogue output signal on an oscilloscope for 500 bar, 1000 bar, 2000 bar respectively from left to right

4 Conclusion

In this paper, newly designed and established drop mass dynamic calibration machine for pressure measurement and also the dynamic pressure calibration of dynamic pressure sensors was presented. The basic working principle, components of the standard were introduced. The performance test results are given in Table 1. Dynamic calibration machine of the repeatability [4] value is found less equal 1% which is targeted at the beginning of the calibration.

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