

## MANUFACTURING AND INSTALLATION OF A HIGH CAPACITY DEADWEIGHT FORCE MACHINE

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**Abstract** – A deadweight force standard machine is a mechanical structure that generates force by subjecting deadweights to the local gravitational field. Korea Research Institute of Standards and Science (KRIS) maintains several deadweight force machines for national force standards. KRIS is developing a 1 MN deadweight force standard machine. The project is scheduled to be finished in 2015. This paper describes the concept and structure of the force machine. The manufacturing and installation of the force machine are also described in this paper.

**Keywords:** deadweight force machine, manufacturing, installation

### 1. INTRODUCTION

According to Newton's second law, force is a physical quantity that acts on a mass to accelerate it. In many industrial and scientific fields, force is often measured for quality control, characteristic evaluation of materials, and stress analysis of structures. Highly advanced measurement technology is an indispensable foundation for today's cutting-edge technologies and industrial applications. The reliability and compatibility of all the measurements related to force quantity are based on the national force standards.

The unit of force is defined by deadweights of standard masses subjected to the effect of the local gravitational field. The mechanical structure and apparatus to handle and control such deadweights is known as a deadweight force standard machine. Because of their high accuracy, deadweight force standard machines are widely used at most national metrology institutes (NMIs), to provide national standards for forces in the range of 0.1 N ~ 4.5 MN [1]. The Korean Research Institute of Standards and Science (KRIS) has installed six deadweight force standard machines with capacities of 20 N, 200 N, 5 kN, 20 kN, 100 kN, and 500 kN. Among them, the 500 kN deadweight force machine [2] is the largest one. But it was developed in 1926, hence is too old to be used as the national force standards. Therefore, KRIS has decided to develop a new deadweight force standard machine to replace the 500 kN deadweight force standard machine, and launched the project in 2011 with the period of 5 years. [3]

The first year of the project was devoted to design the force machine. And the second and third years were devoted to manufacturing and calibration of the main part of the deadweight force machine. In 2014, the machine was

installed in the newly constructed laboratory in KRIS. Concept and structure of the force machine are illustrated in the paper. And, the manufacturing, compensation/calibration of deadweights of the machine, and installation of the machine are illustrated in the paper.

### 2. STRUCTURE OF THE MACHINE

Fig. 1 represents the schematic diagram of the 1 MN deadweight force machine. The machine consists of a framework, a lifting frame, three force transducers, a loading frame, a weight supporter, an adjustable yoke, a tension coupling device, weights, a hydraulic supply system, an air supply system, and a control system.



Fig. 1. Schematic drawing of the 1 MN force standard machine.

The framework is composed of three columns, an upper crossbeam, a middle crossbeam, and a lower crossbeam. Each column's diameter is 250 mm. The three crossbeams are each made of three I-beams that have been welded together, providing the strength required for the machine.

The lifting frame consists of an upper crossbeam, a lower crossbeam, three columns, and a compression table. The compression table, which holds the force transducer to be calibrated, is mounted on the lower crossbeam, and can be rotated remotely by the operator.

Three force transducers, which are used to measure the force generated by the loading frame, the weight supporter, and the weights, were mounted between the adjustable yoke and the upper crossbeam of the lifting frame. The value measured from the force transducers is used as the reference value in the closed-loop control for maintaining the force applied to a force transducer under calibration, while the loading frame, the weight supporter, and all the weights are moved up by the lifting ram-cylinder when selecting a new weight set.

The loading frame consists of three rods, an upper crossbeam, a lower crossbeam, and six stoppers. Each rod has two adjustable stoppers. The upper stopper contacts the upper crossbeam of the weight supporter when the loading frame is moved up and down when placed on the weight supporter. The lower stopper also contacts the upper crossbeam of the weight supporter, in order to load the selected weight set, to provide the selected force to be applied to a force transducer. The loading frame has a capacity of 20 kN.

The weight supporter consists of three rods, an upper crossbeam, a lower crossbeam, and 51 stoppers. Each rod, which consists of four smaller rods, has 17 adjustable stoppers to support the weights. The adjustable stoppers are in the shape of a cone. The weight supporter has a capacity of 20 kN.

The hydraulic and air systems consist of a hydraulic supply system, an air supply system, a lifting ram-cylinder, a loading ram-cylinder, three cushion ram-cylinders, 51 weight-selecting systems, and 12 swing-protecting systems.

The weight combination of the force machine is as follows.

- Loading frame: 20 kN
- Weight support: 20 kN
- 6 x 10 kN weights
- 2 x 50 kN weights
- 9 x 100 kN weights

The height of the 1 MN deadweight force standard machine is about 17 m, and the total weight of the machine is about 180 tons.

### 3. MANUFACTURING

Fig. 1 The deadweights of the force standard machine were manufactured. The manufacturing process is as follow.

- Cutting
- Forging
- Heat treatment
- Rough machining

- Fine machining
- Weight checking
- 2nd fine machining

Figs. 2 and 3 represent machining of a deadweight and a part constructing loading frame, respectively.



Fig. 2. Fine machining process of a deadweight.



Fig. 3. Manufacturing a upper plate constructing the loading frame.

The deadweights, loading frame, and weight support were compensated and calibrated by comparing with the national mass standards of KRISS.

### 4. INSTALLATION

Before the machine is installed in the laboratory in KRISS, it was installed in the factory to check the possible problem during the installation and to confirm the operation of the machine.

In the laboratory, the machine is supported by main floor through 3-points contacting the middle plate of the machine. For the pre-installation in the factory, a special structure on which the force machine is installed was built.

Fig. 4 shows the installed the force machine in the factory. After the installation, we have checked the operation and control performance of the force machine.



Fig. 4. Deadweight force machine pre-installed in the factory.

In 2014, KRISS has constructed a building to install the 1 MN deadweight force standard machine. The laboratory in the building was designed to mount the force machine. During Dec. 2014 ~ Jan. 2015, the hardware of the force machine was mounted in the new laboratory.

Fig. 5 represents deadweight part of the machine which was mounted under the main floor of the laboratory. Three moving stages were installed outside of the deadweight stack for the installation and further maintenance of the machine. Each stage can support two persons.

Fig. 6 shows upper part of the force machine which was mounted on the main floor of the laboratory. The middle plate of the machine is supported by three points of the laboratory's main floor.

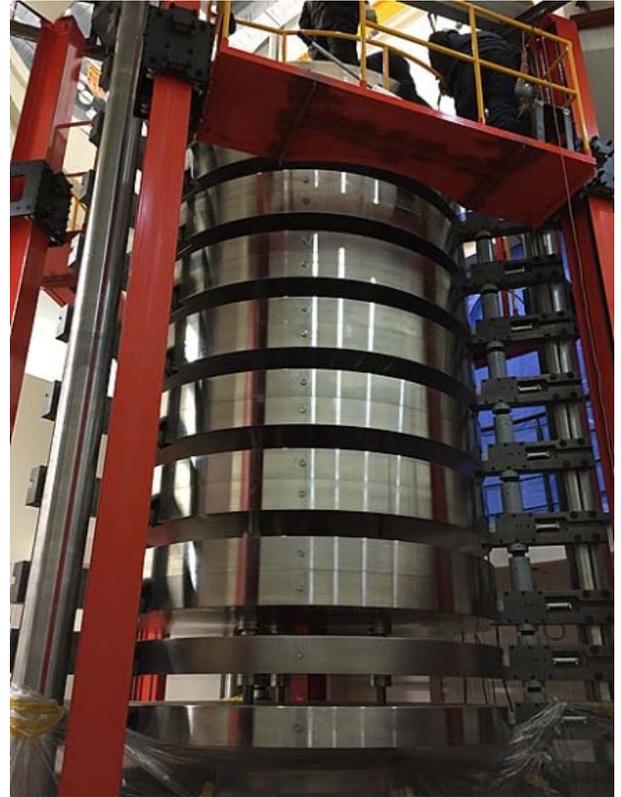


Fig. 5 Deadweight part under the main floor.



Fig. 6 Upper part of the deadweight force machine.

## 5. CONCLUSIONS AND FURTHER WORKS

KRISS has manufactured and installed a 1 MN deadweight force machine for the high capacity national force standards in Korea. In 2011, we have finished the design of the force machine. In 2012, we have done manufacturing the deadweights and other parts to generate gravitational force. In 2013, we have finished compensation and calibration of deadweights and manufacturing of whole parts of the force machine. At the end of 2013, we have assemble the force machine in the factory prior to the real mounting in the laboratory to check the possible problem during the mounting. Until Jan 2015, we have installed the hardware of the machine in the force laboratory of KRISS,

During 2015, we will install the control system of the machine, then perform the evaluation of the machine.

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