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DESIGN OF THE 1 MN DEADWEIGHT FORCE STANDARD MACHINE IN KRISS

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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(KRISS) has launched a project to develop a 1 MN deadweight force standard machine in 2011. The project is scheduled to be finished in 2014. This paper describes the design of the deadweight force machine. Concept and structure of the force machine are illustrated in the paper.

Keywords: deadweight force machine, weight stack, structure, design

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 50 N ~ 4.5 MN [1]. The Korean Research Institute of Standards and Science (KRISS) has installed four 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, KRISS 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 4 years.

The first year of the project was devoted to design the force machine. This paper describes the design of the deadweight force machine. Concept and structure of the force machine are illustrated in the paper.

2. STRUCTURE OF THE MACHINE

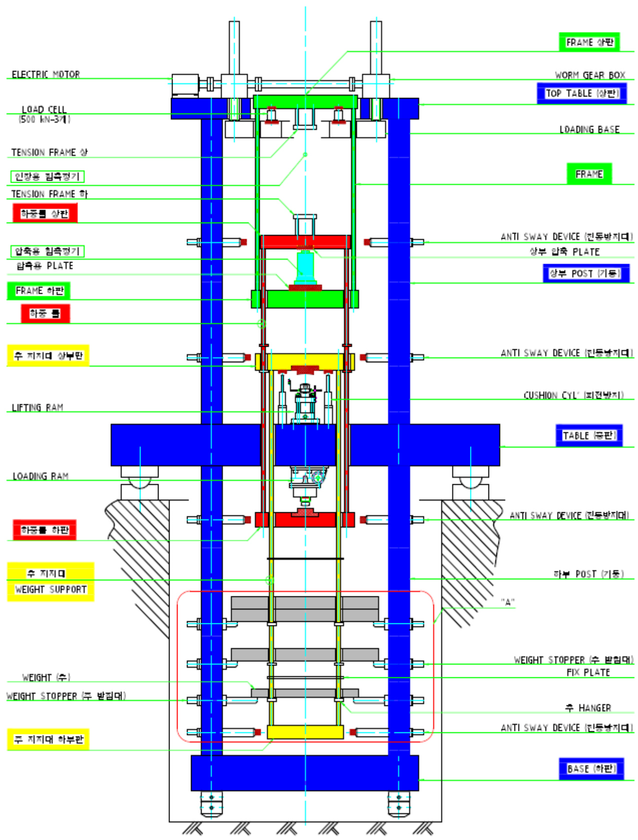

Figure 1. Schematic diagram of the 1 MN force standard machine

Figure. 1 represents the schematic diagram of the 100 kN 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.

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

Figure 2 represent an overall drawing of the 1 MN deadweight force standard machine. Its height is about 1.7 m.

3. CONTROL SYSTEM OF THE DEADWEIGHT FORCE MACHINE

The force standard machine is operated manually and semiautomatically by means of two potentiometers on the control panel. They control two servo valves. One controls the lifting ram-cylinder and the other controls the loading ram-cylinder. The machine can also operate semiautomatically or automatically depending on the specific software controlling the operation PC.

The control system consists of a control panel, a controller, an operation PC, and specific software. The control panel comprises the power control, mode selection, the ram-cylinder manual operator, and the weight selector. It has a screen with a schematic diagram that shows any error messages and indicates the setting conditions and any emergency situations.

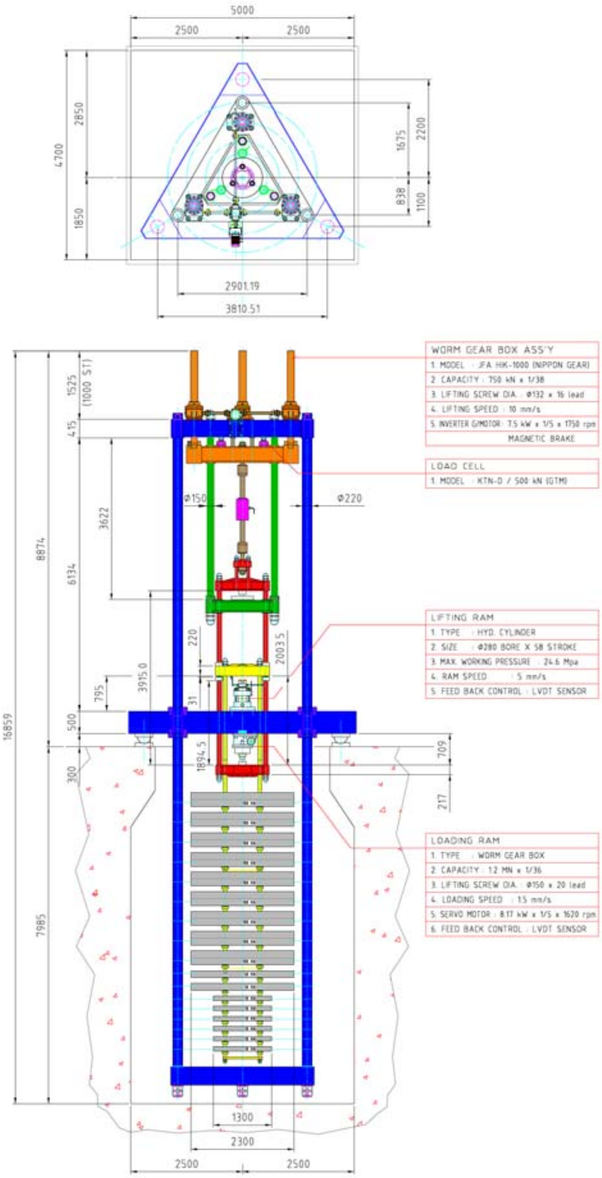

Figure 2. Drawing of the 1 MN force standard machine

The controller consists of a CPU, I/O unit for the input and output modules, a power supply unit for both the CPU and the I/O units. The CPU is connected to the operation PC, the input and output modules, and the stepping motor drive. It receives a command from the operation PC and retrieves information from the input I/O modules, such as: the status of the pumps, any emergency condition, the weight selection, etc. The controller in turn issues commands to the stepping motor drive, the loading pump, the lifting pump, the error message, the schematic diagram, etc. through the output I/O modules.

The operation PC controls the servo valves and the controller. It receives the output signal from the measuring amplifier through a serial interface line, and manages the output signals of the pressure transducer, three force transducers, and two potentiometers through a digital to analogDA converter.Major headings(14-point) are placed on a separate line, bold and centered in the column.

4. FORCE-GENERATING PROCEDURE

The procedure for generating the force is as follows:

(1) apply the force generated by the loading frame (20 kN) to a force transducer;

(2) apply the force generated by the weight supporter (20 kN) through the lower stopper of the loading frame, to a force transducer; and

(3) apply the force generated by the weights through the stoppers of the weight supporter, to a force transducer.

To generate the force of a step produced by all the weights, four steps are needed:

(1) in order to apply a new force to a force transducer, the applied force by the loading frame should be maintained by the loading-ram cylinder;

(2) in order to select a weight set, all the weights should be separated from the weight-selecting systems by raising the weight supporter;

(3) a weight set for generating the force is selected by the weight-selecting systems; and

(4) the newly selected force is applied to a force transducer by lowering the weight supporter with the selected weights.

Table 1. Combination of weights

Load	Loaded weights
100 kN	L + W + 1 × 10 kN + 1 × 50 kN
200 kN	L + W + 1 × 10 kN + 1 × 50 kN + 1 × 100 kN
210 kN	L + W + 2 × 10 kN + 1 × 50 kN + 1 × 100 kN
800 kN	L + W + 1 × 10 kN + 1 × 50 kN + 7 × 100 kN
1000 kN	L + W + 1 × 10 kN + 1 × 50 kN + 9 × 100 kN

Each force step can be adjusted by appropriately combining the deadweights. For example, forces of 200, 400, 600, 800, and 1000 kN can be generated by the combination listed in Table 1.

5. MANUFACTURING OF WEIGHTS

At the moment, the deadweights are under manufacturing. The manufacturing process is as follow.

- Cutting
- Forging
- Heat treatment
- Rough machining
- Fine machining
- Weight checking
- 2nd fine machining
- Compensation
- Calibration

Figures 3 and 4 represent forging and fine machining of the weights, respectively. Figure 5 shows a final weight of 50 kN.

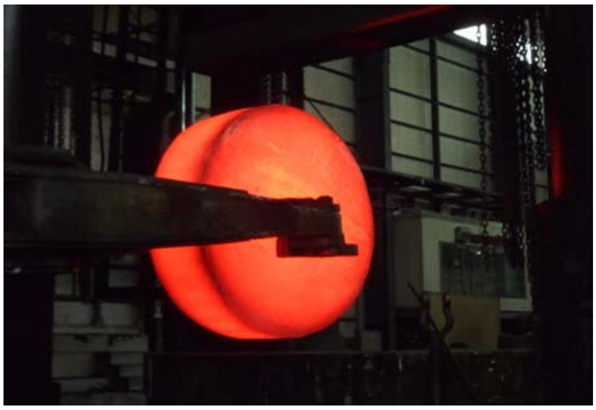

Figure 3. Forging process of a deadweight

Figure 4. Fine machining process of a deadweight

Figure 5. A final weight of 50 kN

6. CONCLUSIONS AND FUTURE WORKS

We has designed a 1 MN deadweight force standard machine. It has a loading frame, a weight support, and 17 weights. The machine can generate force by combining weights arbitrarily. Its height is about 18 meters and its diameter is about 4.5 meters.

The development of the 1 MN force machine is scheduled to be finished in 2014. In 2012, we will finish detail design of the machine and manufacturing the deadweights. In 2013, we will finish manufacturing all parts of the machine, and modify force building in KRISS. In 2014, we will assemble the parts to establish the force machine, and perform evaluation of the machine. Finally, we will perform an international comparison of the force machine with other NMIS to evaluate it.

7. REFERENCES

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