Calibration Device Designed for proof ring used in SCC Experiment

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Abstract. In this paper, a calibration device for proof ring used in SCC (Stress Corrosion Cracking) experiment was designed. A compact size loading device was developed to replace traditional force standard machine or a long screw nut. The deformation of the proof ring was measured by a CCD (Charge-Coupled Device) during the calibration instead of digital caliper or a dial gauge. The calibration device was verified at laboratory that the precision of force loading is ±0.1% and the precision of deformation measurement is ±0.002mm.

1. Introduction
The stress corrosion crack of material is common in the field of chemical industry, power station, petroleum and ocean exploitation [1-3]. It causes abnormal operation of equipment and large economic loss every year. SCC experiment is a vital method to test the performance of material resistant to SCC. Among the experiment methods recommended by NACE (National Association of Corrosion Engineers) standard TM0177-96, sustained-load method achieved by a proof ring is most widely used for its low cost. The proof ring is used as a loading device, and the load is controlled by measuring its deformation. The new proof ring has a good linearity, and the force load can be measured according to the factory inspection report. After a long-term service, proof ring always has a nonlinearity. The relationship between deformation and force should be verified by fixed interval calibration [4].

![Figure 1. Traditional calibration device](image)

The traditional calibration device is shown in figure 1. The proof ring is deformed by a nut. The force is detected by a force sensor and the deformation $\Delta L$ is measured manually by a digital caliper. The traditional method is always unsatisfied [5-6]. The first reason is the proof ring is not made from anti-corrosion material. The measuring surface is easily corroded, increasing the error. The second is that...
the deformation is measured manually, so the manual error is inevitable and working efficiency is low. Therefore, an automatic calibration device for proof ring is proposed in this paper. The structure and working principle is depicted and its performance is verified.

2. Design of loading device

![Diagram of the loading device]

1. Trapezoidal screw 2. Driven wheel 3. Force sensor 4. Driving wheel 5. Planetary reducer 6. Servo 7. Electrical control box

Figure 2. Structure of the loading device

The schematic map of the loading device is shown in figure 2. It is composed of trapezoidal screw, driven wheel, force sensor, driving wheel, planetary reducer, servo and electrical control box. Two wheels are driven by servo through synchronous belt, the advantages of which are low noise and high efficiency. The trapezoidal screw moves along with the driven wheel to realize the force loading, which is measured by the force sensor amounted on the end of the screw. A planetary reducer is applied to achieve precision loading. Two pressure plates are made of heat-treated high carbon alloy tool steel possessing high hardness. The support parts and wheels are made of 2A12 aviation aluminium in order to reduce weight. The dimension of the device is 300*430*800mm and the weight is 46kg. The loading device possesses the merits of compact structure, high efficiency and low weight.

3. Deformation Measurement of the Device

The working principle of the device is shown in figure 3. The calibration plate which has a circular feature symbol is mounted on the upper part of the proof ring by a magnet. The CCD camera is located on a tripod. The mounting height of the CCD camera has no special requirement as long as the feature symbol is in the view of CCD before and after the deformation. The proof ring is loaded by the loading device. When loaded, the underpart of the proof ring is fixed on the pressure plate and the upper part with the calibration plate has a displacement. The position of the feature symbol in the CCD camera changes and the value can be measured by correlating two images before and after loading.
1. Proof ring 2. Calibration plate 3. CCD camera

**Figure 3. Deformation Measurement of the Proof Ring**

4. Verification of the Calibration Device

4.1 Loading Force

To verify the performance of the loading device, a lever-type force standard machine is employed. The parameters of the force standard machine is listed in table 1. The calibration procedure is in accordance with “JJG 144-2007 Verification Regulation of Standard Dynamometers”. The whole loading process is divided into 6 steps. For each step, a 5kN force loading is applied. The result is shown in figure 4 that the max error is less than 0.08%.

| Model   | Measurement Range | Max Permitted Error |
|---------|-------------------|---------------------|
| EE1-10  | (1~100)kN         | ±0.03%              |

**Table 1. Parameters of Force Standard Machine**

![Figure 4. Measurement Error of the Loading Device]

4.2 Deformation Measurement

The deformation measurement of the device is verified by a laser interferometer. The parameters of the CCD camera and the laser interferometer is listed in table 2 and table 3. The loading device is located on a desk. The proof ring with the calibration plate is put between the upper and under pressure plates. The CCD camera on the tripod aims at the feature symbol. The interference mirror of the laser interferometer is put on the desk and the reflector is fixed on the force sensor magnetically. The position of the interference mirror is adjusted according to the reflector to make sure that the
receiver can detect the distance information. When the proof ring is loaded, the force sensor moves along with the upper pressure plate. The displacement of the force sensor which is equal to the deformation of the proof ring can be measured by the interferometer mirror. Take result of the laser interferometer as benchmark, the error of the designed device is shown in figure 5. The maximum error is 1.9μm.

### Table 2. Parameters of CCD Camera

| Manufacturer | Resolution | Sensor   |
|--------------|------------|----------|
| DALSA        | 1600*1200  | 1/3 inch |

### Table 3. Parameters of Laser Interferometer

| Manufacturer | Model | Measurement Range | Max Permitted Error |
|--------------|-------|-------------------|---------------------|
| Renishaw     | XL-80 | (0–40)m           | ±0.5*10^{-6}L       |

![Figure 5. Measurement Error of the Deformation](image)

5. Conclusions:
In this paper, a calibration device for proof ring is designed and verified. A compact size loading device is developed. The CCD is introduced to realize automatic deformation measurement. The designed calibration device is verified by the force standard machine and laser interferometer. The result shows that the maximum error of force measurement is 0.08% and that of deformation measurement is 1.9μm.

References
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