Implement and application of ultra-high pressures environment

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Abstract: A hydraulic system was designed which was used to generate hydrostatic ultra-high pressure environment. The functions and roles of the main elements in the hydraulic system were introduced. Deformation theory based on ultrahigh pressure cylinder was analyzed. The principle and method about measuring ultra-high pressure cylinder radial and circumferential elastic line-strain by a dial indicator were illustrated. A practical example was given to illustrate the practicability and validity of this method. The measures to decrease the measurement error were pointed out. The described principles and methods have a certain theoretical and practical significance in engineering research and application of ultra-high pressure.

1. The method to realize the hydraulic ultra-high pressure environment

1.1 method and principle
Figure 1 is the principle realized diagram of the hydrostatic ultra-high pressure environment, the pressure oil generated from pump1 through supercharger3 into cylinder 6, the stress of the pressure oil could be adjusted by overflow valve 2. When the adjust stress of overflow valve is constant, the system pressure can be magnify up to a ultra-high pressure value with the help of supercharger3 (stress more than 100MPa will be called ultra-high pressure), the ultra-high pressure oil through check valve4 into ultra-high pressure cylinder6. The oil inlet and outlet of ultra-high pressure cylinder link with check valve and unloading valve respectively, so that we can make the pressure in cylinder6 keep a static seal state relatively, so the system will realize ultra-high pressure environment.

1-oil pump
2-overflow valve
3-supercharger
4-check valve
5- accumulator
6-cylinder
7-unloading valve

Figure 1. The realiz principle of the ultra-high pressure environment

1.2 Main component function introduction
In figure 1, main components are following: oil pump 1, supercharger 3, overflow valve 2, accumulator 5, check valve 4, ultra-high cylinder 6, unloading valve 7.

The main function for every parts: Oil pump 1 is the pressure source for the system, the author use 20MPa rated pressure pump in practical application. Supercharger 3 increase the outlet pressure of pump 2 to ultra-high pressure. The author use 1:20 pressure ratio in practical application, so the outlet pressure of supercharger can get 400MPa. Overflow valve 2, when we give it a setting pressure, it will achieve the overflow function and the outlet stress of oil pump 1 will be limited. Accumulator 5 is used to maintain the ultra-high pressure environment, because the cylinder 6 pressure will decrease as the pressure oil divulge, so the accumulator 5 is used to add the divulge oil to make the cylinder 6 keep basically stable. Check valve 4 was to prevent the oil backflow from accumulator 5 and ultra-high pressure cylinder. Unloading valve 7, when the system need remove ultra-high pressure environment, we can achieve it through open valve 7. In addition, through set up the valve 2 and valve 7 to the new setting values, we can get the different pressure value system. Ultra-high pressure cylinder 6 is the container of ultra-high pressure environment.

2 A measuring principle for elastic line-strain of the ultra-high pressure cylinder

Assume “d” is the cylinder’s outer diameter, "Δd” is the increase value of the cylinder 6. According to the definition of linear-strain, the radial linear strain $\varepsilon_r$ and circumferential linear strain $\varepsilon_d$, respectively are

$$\varepsilon_r = \frac{\Delta d}{d} \quad (1)$$

$$\varepsilon_d = \frac{\pi \cdot \Delta d}{\pi \cdot d} = \frac{\Delta d}{d} \quad (2)$$

From formula (1),(2) obtained

$$\varepsilon_r = \varepsilon_d = \frac{\Delta d}{d} \quad (3)$$

By above formula we known: for a given ultra-high pressure cylinder, as long as measure the decrease value $\Delta d$ of the cylinder diameter, we will get $\varepsilon_r$ and $\varepsilon_d$ through formula (3).

3 Instance

3.1 The experimental principle

Figure 2 is the schematic diagram for use ultra-high pressure environment to measure the elastic line-strain of ultra-high pressure cylinder, from figure 2(a) we know, the dial indicator 8 install on the outside surface of the cylinder 6, it’s installation method as shown in figure 6.
3.2 Experimental conditions
The specimen is a ultra-high pressure cylinder used in the experiment, material for 2Cr13, outer diameter D=80mm, inner diameter d=23mm. Pressurized equipment is CNC universal water cutting machine.

3.3 The experimental process
We can know from analysis the strength theory of ultra-high pressure container(pipe, cylinder), the elastic failure stress of ultra-high pressure cylinder is $250MPa^{[5]}$, which means the cylinder distortion is elastic deformation when the pressure under 250MPa. At this time the cylinder diameter increase measured by dial indicator and the corresponding linear-strain are elastic line strain of the cylinder. According to the test precision of the dial indicator we known, the stress in ultra-high pressure cylinder can’t be too small, otherwise, the distortion too small will lead the measurement error too large. So the eventual result will inaccuracy, In this experiment, firstly, we need adjust the work pressure to 16MPa of the overflow valve, meanwhile the oil pump will increase to this stress and remain 10mintues, in this process, the reading from dial indicator should be recorded (this data reflect the whole elastic distortion of the cylinder diameter, what means the diameter increase value),then the system will unload pressure slowly and keep unused about 10 minutes to insure the cylinder can recovery from elastic distortion, after that, the overflow valve increase 10MPa every steps until the pressure arrive 240MPa. In every step, the data of the cylinder’s diameter change should be recorded carefully. What need remind is: we need wait at least 10 min after remove pressure, as far as possible to eliminate the previous affection.

3.4 experimental data
Based on the experimental process and requirement, record the experimental data as table1

| pressure / MPa | 160   | 170   | 180   | 190   | 200   | 210   | 220   | 230   | 240   |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Δd / 0.01 mm   | 29.0  | 31.0  | 32.0  | 33.1  | 34.0  | 34.6  | 35.0  | 35.3  | 36.6  |

3.5 experimental data analysis
From formula(3) we can calculate the radial and circumferential linear-strain of the cylinder in different stress value. Show in table2.

| pressure / MPa | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| radial strain  | 0.363 | 0.388 | 0.400 | 0.414 | 0.425 | 0.433 | 0.434 | 0.441 | 0.458 |
| circumferential strain | 0.363 | 0.388 | 0.400 | 0.414 | 0.425 | 0.433 | 0.434 | 0.441 | 0.458 |

4 conclusion analysis
According Hooke's law, the elastic deformation of material is proportional to the load, but start from the experimental data, no matter table1 or table 2 we can’t found obvious linear relationship. This situation mainly caused by several reasons:(1) the cylinder belongs to ultra-high pressure thick wall, the diameter ration $K=80/23=3.48$,so the stress distribute in three-way not a simple unidirectional way and the stresses calculated on equivalent. The stress and the internal pressure is not a simple linear relationship $^{[6-11]}$. (2) The distortion of the cylinder is slightly and the measure system error have a certain influence to the measurement.$^{(3)}$ in the measurement process, the fluid dynamic stress and thermal effect also will bring measurement error $^{[12]}$.Although above factors lead error to the measurement results, but for the utility of this method, the corresponding linear strain compared with slightly deformation is not more than 0.5%, The corresponding linear strain error compared with
deviation is far less than 0.5%. Therefore, the proposed way to measure the elastic linear-strain of ultra-high pressure cylinder can completely satisfy the actual requirement.

5 conclusion
The system contains oil pump, supercharger and ultra-high pressure cylinder. They are the core of the system, with the addition of overflow valve, check valve, unloading valve, accumulator, control and auxiliary components, we designed a static hydraulic system which can reach 400MPa pressure, meanwhile, the paper introduced a principle and method for how to measure the elastic linear-strain of the cylinder. It base on static ultra-high pressure environment measurement. The method is simple and reliable, which especially suitable for high alloy steel material. Besides, the system and measurement have certain reference to study the shrink-fit high pressure vessel, self reinforced high pressure container and ultra-high pressure cylinder.

Appendix
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References
[1] Mao Genxin, Gu Sulan, He Lei. Application of Ultrasonic Guided Wave Testing Technology in Pipe Examination and Inspection[J]. Chemical equipment technology,2011,32(6):53-55.
[2] Lin Meng,Niu Yingzhan.Magnetic flux leakage detection technology in the application of the product oil pipeline[J] Chemical machinery,2011,38(5):618-619.
[3] Li Hong, Wang Lanlan, Zhang dongsheng, etc. Study on technology of oil pipeline leakage detection based on negative pressure wave[J]. Science, technology and engineering,2011,11(2):340-342.
[4] Teng Yanping, Han Shuqiang, Jiang Guohui,etc. Application of PCM on Buried Steel Pipelines[J]. Pipeline technology and equipment, 2010(4): 18-20.
[5] Zhang Yuxian ,Wang Hong, Laboratorial Research on Yield Strength of Materials[J].materials engineering,2005(11):43-45.
[6] Zhang Yuxian, Wang Hong. The research of thick-wall columnar pressure vessel with auto-enganced[J].mechanical,2004,31(8):43-45.
[7] Zhang yuxian. A Hydraulic Method of Determining Elastic Failure Pressure for Thick Wall Cylinder [J]. Hydraulic and pneumatic,2006(8):78-79.
[8] Wang hong. A Hydraulic Method for Determining Elastic Limiting Pressure of Thick Wall Cylinder[J]. Machine with hydraulic,2007,35(2):140-141.
[9] Wang hong. A simple method for determination the material yield limit[J]. Weapon of materials science and engineering,2005,29(6):40-42.
[10] Zhang yuxian, Wang hong. A thick wall cylinder elastic failure pressure measuring method.[J]. Mining machinery,2006,35(4):102-103.
[11] Zhang yuxian, Wang hong, Liao Zhen fang. An experimental method use to determine the initial yield pressure thick wall cylinder.[J]. China engineering science,2005,7(11):72-75.
[12] Zhan Renrui, Tao Chunda, Lv ruidian, Numerical analysis of autofrettaged vessel for optimum overstrain extent[J]. Petrochemical equipment,2003(11):23-26.