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DERIVATION AND DETERMINATION ANALYSIS OF THE MASS OF STEEL ANVIL USED FOR VERIFYING REBOUND TEST HAMMER

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Abstract:
This paper describes the derivation process of steel anvil mass. According to the law of conservation of energy, through the analysis and calculation of impact dynamics in the impact verification process of rebound test hammer, the source of technical indicators of steel anvil for rebound test hammer is pointed out. According to the derivation, the mass of steel anvil is calculated to be 16.1 kg, which is consistent with the mass of steel anvil actually used. The scientific traceability is verified theoretically and practically. It is convenient for the measurement of the relevant indexes of the rebound instrument and the manufacture and use of the standard steel anvil.

Keywords: mass; anvil; impact; dynamics; conservation of energy

1. INTRODUCTION

The rebound test hammer uses the elastic potential energy of the spring to drive the hammer to form the impact kinetic energy. It impacts the concrete or the sample of the tested object through the impact rod and reflects the strength characteristics of the tested object with the feedback Q value or the rebound value.

At the same time, according to the corresponding relationship between Q value or rebound value and the intensity curve of the tested object, the relevant professional indicators of the tested object can be obtained. The device is simple, the application is convenient, and non-destructive testing can provide reference for the inspection and testing of engineering quality. There are many devices powered by the elastic potential energy of spring, but they are not as large as the number and range of the application of rebound test hammer. At the same time, there are many kinds of rebound test hammer. It is divided into mechanical type (or pointer type), digital type according to the structure; It is divided into three categories and six grades according to the nominal energy: heavy, medium and light. According to the use of spring test hammer, it is divided into concrete rebound test hammer, brick rebound test hammer, mortar rebound test hammer and high strength rebound test hammer.

The verification indexes of JJG 817-2011 rebound test hammer are mainly eleven indexes [1], such as pointer length, pointer friction and steel anvil rate setting, among which the steel anvil rate setting of rebound test hammer is the key index of all verification indexes and the most critical index to determine the compressive strength. However, JGJ/T 23-2011 technical specification for testing concrete compressive strength by rebound method stipulates that the steel anvil used in the calibration test of rebound test hammer should be sent to metrological verification institution for verification or calibration every two years [2], so as to ensure the verification of rebound instrument in daily use. The impact kinetic energy, the fixed value of the steel anvil rate, the mass of the spring hammer, the impact length, the pointer friction force, the spring stiffness and the technical requirements of the steel anvil used in the rebound test hammer are shown in Table 1 [3].

The mechanical structure and the names of the main parts of the concrete rebound test hammer are shown in Figure 1. At present, there are a variety of steel anvil used in engineering quality testing units, and a small part of them do not meet the technical requirements in Table 1, which brings uncertainty to the calibration of rebound test hammer.

For example, some users use steel anvils with a mass of 45.1 kg or 20.1 kg to calibrate M225 rebound test hammer, and the rebound value obtained is much larger than 80, so it is judged that the rebound test hammer itself does not meet the requirements. In order to meet the requirements, the user constantly adjusts the indexes of various parts of the rebound test hammer to seek a rebound value around 80. On the one hand, such use brings about a large deviation to the project quality detection, resulting in the high strength of the measured concrete, which brings risks to the continuous project construction. On the other hand, it also causes misunderstanding to the self-inspection judgment in daily project construction. Therefore, it must be effectively verified.

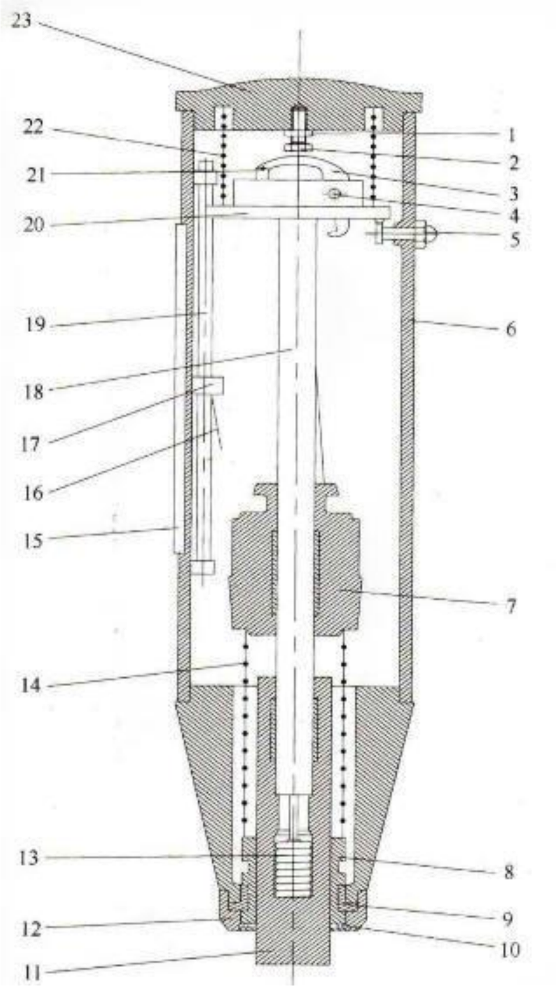

Figure 1: Concrete rebound test hammer: 1 - hard nut; 2 - unhook position adjustment screw; 3 - hook; 4 - hook pin; 5 - lock button; 6 - chassis; 7 - hammer; 8 - tension spring seat; 9 - snap ring; 10 - sealing felt ring; 11 - recoiling rod; 12 - blocks; 13 - buffer pressure spring; 14 - recoiling tension spring; 15 - scale; 16 - pointer piece; 17 - pointer block; 18 - centre guide; 19 - pointer shaft; 20 - guide flange; 21 - hook compression spring; 22 - press reset spring; 23 - end cap

In order to better confirm the technical requirements of the steel anvil from the theory and practice, and provide support for the calibration of the steel anvil itself and the daily check of the rebound instrument, the dynamics of the impact body of the rebound instrument are analysed and demonstrated below, in order to obtain the desired results. Due to daily use hammer belongs to medium rebound hammer namely, code-named M225 rebound hammer use accounted for more than eighty percent, so for medium-sized rebound hammer is analysed to deduce and other types of hammer its claim to check steel anvil so on, so as to fully grasp the various aspects of the rebound hammer traceability requirements, to ultimately ensure the quality of engineering test is reliable.

Table 1: The technical requirements

Code name	M225
Kinetic energy of the shock / J	$2.207^{+0}_{-0.207}$
Steel anvil rate constant value	80 ± 2
Hammer mass / g	370 ± 5
Impact length / mm	75.0 ± 0.3
Spring stiffness / (N/m)	785 ± 35
Pointer friction / N	0.65 ± 0.15
Mass of anvil / kg	$16.0^{+0.3}_{-0.1}$
Anvil core hardness / HRC	60 ± 2

2. DYNAMIC ANALYSIS OF IMPACT

The rebound energy is the elastic potential energy generated by the spring stretching, which is converted into the impact kinetic energy of the rebound test hammer when released. When the steel anvil is used for verification, part of the impact kinetic energy of the hammer is converted into rebound kinetic energy of the hammer after the hammer hits the steel anvil through the hammer, part of the kinetic energy is consumed by pointer friction to drive the pointer to rebound, and part of the energy is absorbed by the steel anvil and converted into heat or deformation energy dissipation. The rebound kinetic energy is converted into the elastic potential energy of the hammer after resistance to friction work consumption, and then freezes at the rate fixed value.

Under ideal conditions, it is assumed that the calibration process of the rebound test hammer is a completely elastic collision, and the collision process of the two objects is shown in Figure 2.

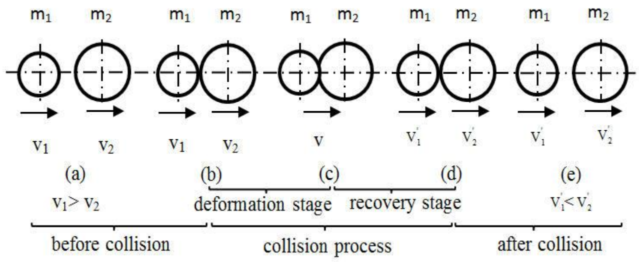

Figure 2: Completely elastic collision

The force diagram and force-time curve of the deformation and recovery stage of the positive impact of the two objects are shown in Figure 3.

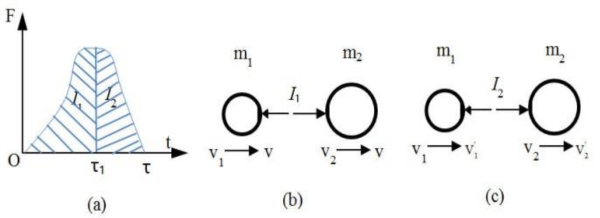

Figure 3: Stress curves of two bodies in the deformation and recovery stage of frontal collision

The ratio of the impact impulse of two objects in the recovery stage to the deformation stage, or the ratio of the relative separation velocity after the collision to the relative closing velocity before the collision, is called the recovery factor, as shown in equation (1).

$$e = \frac{I_1}{I_2} = \frac{V_1' - V_2'}{V_1 - V_2} . \quad (1)$$

The recovery factor is related to the material, speed and geometry of the colliding object. The recovery factor can be greater than or equal to zero, less than or equal to 1.

In order to facilitate derivation and calculation, the calibration process of the spring-back instrument is assumed to be a completely elastic collision between two objects, as shown in Figure 2. After the collision, the deformation of the object disappears completely, and no energy is lost. If satisfy the initial conditions, the collision system composed of two objects, regardless of all friction and air resistance, because the collision is internal force, momentum conservation before and after the collision gives:

$$m_1 V_1 + m_2 V_2 = m_1 V_1' + m_2 V_2' \quad (2)$$

$$V_2 = 0 . \quad (3)$$

Equation (2) and equation (3) can be obtained simultaneously equation (4).

$$V_1' = \frac{m_1 + e m_2}{m_1 + m_2} V_1 . \quad (4)$$

The fixed value of the steel anvil ratio of the medium-sized rebound test hammer is 80, that is, the impact kinetic energy of rebound should reach 80 % of the impact energy, then the kinetic energy of rebound hammer should be the elastic potential energy of rebound to R value of 80 and the work done to overcome pointer friction at the moment after the elastic collision, and the work done to overcome pointer friction is as follows:

$$w = f\, l_2 . \quad (5)$$

In equation (5), l_2 is the displacement caused by the spring hammer driving the pointer to overcome friction, and f is the pointer friction. Then, the kinetic energy of rebound at the moment after the elastic collision of the hammer is:

$$\frac{1}{2} m_1 V_1'^2 = f\, l_2 + \frac{1}{2} k\, l_1^2 . \quad (6)$$

In equation (6), l_1 is the displacement of bouncing the tension spring to the limit position, and k is the spring stiffness. Substitute the parameters in Table 1 into equation (6) to obtain the rebound velocity as follows:

$$V_1' = \sqrt{\frac{2 f\, l_2 + k\, l_1^2}{m_1}} = 2.798 \text{ m/s} . \quad (7)$$

The kinetic energy of the hammer before the moment of impact is completely converted from the elastic potential energy, so the two values should be equal, so:

$$V = \sqrt{\frac{k l_1^2}{m_1}} = 3.455 \text{ m/s} . \quad (8)$$

Equation (9) can be derived from equation (4) by transformation.

$$m_2 = \frac{m_1 (V_1 - V_1')}{V_1' - e V_1} . \quad (9)$$

The recovery factor is taken to be near the commonly used low value 0.635, and the calculated values of equation (7) and equation (8) are substituted into equation (9), then we can obtain:

$$m_2 = 0.4019 \text{ kg} . \quad (10)$$

Because the steel anvil is placed on the solid ground for direct application, reference impact testing machine base installation requirements, if installed on the movable base, the base mass should be greater than 40 times the impact testing machine pendulum mass, and there should be enough stiffness [4]. Therefore, the steel anvil similar impact testing machine quality requirements to meet the requirements of 40 times, and take a valid number after the decimal point, that is the final quality.

$$m_2' = 40 \times 0.4019 = 16.1 \text{ kg} \quad (11)$$

3. CONCLUSIONS

On the premise of complete elastic collision, through dynamic analysis of the rebound value calibration process of the rebound test hammer, the actual parameters in Table 1 are substituted into the corresponding calculation formula, and the recovery factor is taken as the commonly used lower value of 0.635, so that the mass of the steel anvil is 16.1 kg. On the one hand, the acquisition of this value provides theoretical support for our daily calibration, Steel anvils that do not meet the requirements of 16.1 kg need to be reprocessed or cannot be used again. On the other hand, it provides a reference for our manufacturers. Only steel anvils that meet the requirements of 16.1 kg can be sold for use.

In fact, the collision process is complex and changeable, and there are many influencing factors, such as the magnitude of friction work between the hammer and the central guide rod when the horizontal velocity is fixed. The impact bar is not perpendicular to the surface of the steel anvil core; the non-uniformity of the surface hardness of the anvil core leads to the transition from the complete elastic collision in theory to the incomplete elastic collision in practice. However, theoretical dynamic analysis and derivation provide reference for production practice and calibration test. More effective derivation and verification should be based on direct measurement of energy absorption or consumption. Calibration test should be used as an intermediate means, and impact force sensors or other forms of energy absorption devices should be installed at both ends. Complete and accurate inference can be obtained through energy response, which also needs further demonstration and discussion.

4. REFERENCES

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