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**Guidelines of energy efficiency evaluation for
industrial robots**

工业机器人能效评估导则

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Guidelines of energy efficiency evaluation for industrial robots

1 Scope

This Standard specifies terms and definitions, energy efficiency evaluation process, energy efficiency testing methods, energy efficiency evaluation indicators, energy efficiency analysis and preparation of evaluation reports for energy efficiency evaluation for industrial robots.

This Standard is applicable to energy efficiency evaluation for industrial robot body, excluding end effector energy efficiency.

NOTE: The end effector refers to the welding gun, spray gun, and cutting spindle installed on the mechanical interface of the robot.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

GB/T 12642-2013, *Industrial robots - Performance criteria and related test methods*

GB/T 12643-2013, *Robots and robotic devices - Vocabulary*

GB/T 12644-2001, *Industrial robots - Presentation of characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions defined in GB/T 12643-2013 as well as the followings apply.

3.1 industrial robot

an automatic control, reprogrammable, multi-purpose operating machine, which can program three and more than three axes; it can be fixed or mobile; it is used in industrial automation

cycles of an industrial robot under unloaded conditions

3.11 average power with rated load

the average value of the total power of all electrical devices in one or several cycles of the industrial robot under the rated load condition

3.12 total energy consumption without load

the total energy consumed by the industrial robot under unloaded conditions

3.13 body energy consumption

the energy consumed by the robot body of an industrial robot under unloaded conditions

3.14 total energy consumption with rated load

the total energy consumed by the robot body and the rated load of the industrial robot under the rated load condition

3.15 energy consumption with rated load

the energy consumed by the industrial robot at the rated load under the rated load condition

3.16 body energy efficiency

the ratio of the energy consumption of the industrial robot under unloaded conditions to the total energy consumption of the unloaded operation

3.17 energy efficiency with rated load

the ratio of the energy consumption of the robot's rated load to the total energy consumption of the rated load of the industrial robot under the rated load condition

3.18 energy efficiency evaluation for industrial robots

analysis and quantitative expression of the energy efficiency of industrial robots

NOTE: Including the determination of energy efficiency indicators, the acquisition of energy data and the calculation of energy efficiency indicators.

4 Energy efficiency evaluation process for industrial

- d) Access power detection equipment;
- e) According to 5.6~5.8, carry out the power-on state test, unloaded operation test and rated load operation test of the industrial robot. Obtain the power-on curve, unloaded operation power curve, and average power with rated load curve of the industrial robot when it is powered on;
- f) According to formula (1) ~ formula (3), calculate the power data of industrial robot power-on average power, average power without load, and average power with rated load;
- g) On the basis of the power data, according to the formula (4) ~ formula (7), calculate the total energy consumption without load, the body energy consumption, the total energy consumption with rated load and the energy consumption with rated load of the industrial robot;
- h) Based on the energy consumption data, according to formula (8) and formula (9), calculate the body energy efficiency and energy efficiency with rated load of the industrial robot;
- i) Focus on indicators such as power-on average power, average power without load, average power with rated load, body energy efficiency and energy efficiency with rated load to analyze the energy efficiency level of the industrial robot;
- j) Prepare an energy efficiency evaluation report for the industrial robot.

See Annex A for an example of energy efficiency evaluation of the industrial robot.

5 Test methods for energy efficiency of industrial robots

5.1 General requirements

5.1.1 Units

For the voltage, energy, power, time, length, speed involved in the test, the unit shall adopt the International System of Units (SI).

5.1.2 Power detection equipment

Before testing, the power testing equipment shall be calibrated. Indicate the error of the power detection equipment in the evaluation report.

5.1.3 Test temperature

The ambient temperature of the test shall be kept within the range of $(20\pm 2)^{\circ}\text{C}$. The use of other ambient temperatures shall be indicated and explained in the evaluation report.

In order to make the robot and the test equipment in a thermally stable state before the experiment, they shall be placed in the test environment for a long enough time (preferably one day and night). It shall also prevent ventilation and external heat radiation (such as sunlight, heaters).

5.1.4 Operating conditions

The normal operating conditions in the test shall be specified by the industrial robot manufacturer. Normal operating conditions include power requirements, maximum single-axis speed requirements, load limits and so on.

5.2 Warming up requirements

Industrial robots shall be warmed up before energy efficiency test. The operation of the warming up shall meet the requirements in GB/T 12642-2013.

5.3 Rated load of mechanical interface

The rated load operation test shall be carried out under 100% rated load condition, that is, the mass, the position of the center of gravity and the moment of inertia specified by the manufacturer. The position of the center of gravity of the rated load shall comply with the load center of gravity offset parameters given in Annex A of GB/T 12644-2001.

5.4 Device connection

The power detection equipment shall be connected to the main power supply of the industrial robot according to the product manual.

5.5 Cyclic exercise test requirements

5.5.1 Test path requirements

The shape of the test path is a curve on the test plane, which is composed of multiple straight lines and is located in the test cube. The largest cube with side lengths of 250mm, 400mm, 630mm, and 1000mm shall be used. The test path is shown in Figure 2.

the movement speed and cycle times specified in 5.5.3. Write cyclic motion program.

For a six-degree-of-freedom industrial robot, a fixed posture shall be maintained during movement. For industrial robots with less than six degrees of freedom, it is advisable to use as few gesture commands as possible during the movement. In the test report, the number, position and programming method (teaching programming, manual data input or offline programming) of the command poses shall be stated.

5.5.3 Cyclic motion test speed and frequency

The cyclic motion test shall be carried out at 100%, 50% and 10% of the rated trajectory speed specified by the manufacturer. In each trajectory segment, the industrial robot can reach the specified speed within 50% of the line segment length, and the cyclic test is effective. In the unloaded operation test and the rated loaded operation test, the number of cycles shall be 10 times at different operating speeds. The cyclic movement mode and time are the same.

5.6 Power-on state test steps

Use power detection equipment to test the energy consumption of industrial robots when they are powered on. The specific steps are as follows:

- a) Turn on the main power of the industrial robot;
- b) After waiting for the reading of the power detection device to stabilize, turn off the main power supply of the industrial robot.

5.7 Unloaded operation test steps

Use power detection equipment to test the energy consumption of industrial robots under unloaded operation state. The specific steps are as follows:

- a) Turn on the main power of the industrial robot;
- b) Enable the industrial robot motor;
- c) Run the cyclic motion program according to the requirements of 5.5. Carry out unloaded cyclic movement;
- d) Cancel the enabling of the industrial robot motor;
- e) Turn off the main power supply of the industrial robot.

The duration of each step in the test process shall be long enough. Wait for the reading of the power detection device to stabilize before proceeding to the next step.

Annex A

(informative)

Examples of energy efficiency evaluation of industrial robots

The example of the energy efficiency evaluation steps of the industrial robot is as follows:

1. Determine the cyclic motion trajectory and write the cyclic motion program

The maximum working radius of the industrial robot is 1550 mm. However, due to the singularity of the workspace, the test cube with a side length of 1000mm cannot be selected. Therefore, a test cube with a side length of 630mm is selected. Determine the test path according to the position and side length of the test cube. Use offline programming to write cyclic motion programs. Download to industrial robot controller.

2. Measure the determined load center of gravity offset parameters and energy efficiency test environment temperature

Record the rated load of the industrial robot. According to the specifications in Annex A of GB/T 12643-2013, determine the load center of gravity offset parameters. Measure and record the environmental temperature of the energy efficiency test.

3. Warming up operation

Turn on the main power. Enable the robot motor. Warm up the engine for 8h according to the requirements of 7.6 in GB/T 12642-2013. Measure whether it meets the thermal engine requirements of 7.6 in GB/T 12642. Turn off the main power.

4. Access power detection equipment

Choose a power analyzer. According to the power analyzer product manual, connect the power analyzer to the main power supply of the industrial robot.

5 Obtain power curve

- 1) Power-on state test. Turn on the main power of the industrial robot. Turn off the main power of the industrial robot after 100s. Record the power curve of the power-on test through the power analyzer.
- 2) Unloaded operation test. Turn on the main power of the industrial robot.

Enable the motor of the industrial robot. Run the cyclic motion program of the industrial robot. After the operation is completed, disable the industrial robot motor. Turn off the main power of the industrial robot. Record the unloaded operation power curve through the power analyzer.

- 3) Rated loaded operation test. Install the rated load on the mechanical interface of the industrial robot. Turn on the main power of the industrial robot. Enable the motor of the industrial robot. Run the cyclic motion program of the industrial robot. After the operation is completed, disable the motor of the industrial robot. Turn off the main power of the industrial robot. Record the rated loaded operation power curve through the power analyzer.

6 Calculate power data

Calculate the power-on average power $\overline{P}_s=39.7\text{W}$. According to the unloaded operation power curve, calculate the unloaded operation average power $\overline{P}_u=453.5\text{W}$. According to the power curve of loaded rated operation, calculate the rated loaded operation average power $\overline{P}_L=487.0\text{W}$.

7 Calculate energy consumption data

Calculate the total energy consumption without load $E_U=44150.0\text{J}$, the body energy consumption of the industrial robot $E_B=40140.6\text{J}$. According to the rated loaded operation power, calculate the total energy consumption with rated load $E_{LS}=47407.0\text{J}$ and the energy consumption with rated load $E_{LS}=3257.0\text{J}$.

8 Calculate energy efficiency data

According to the energy consumption data, the body energy efficiency $\eta_B=90.92\%$ and the energy efficiency with rated load $\eta_L=6.87\%$ are calculated, respectively.

9 Preparation of energy efficiency evaluation report

Prepare energy efficiency evaluation report based on test and calculation results. The format of the energy efficiency evaluation report of the industrial robot is as follows:

Energy efficiency evaluation report of the industrial robot

1) Industrial robot information

Manufacturer: _____ Model: _____
 Manufacturing time: _____ Software version number: _____

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