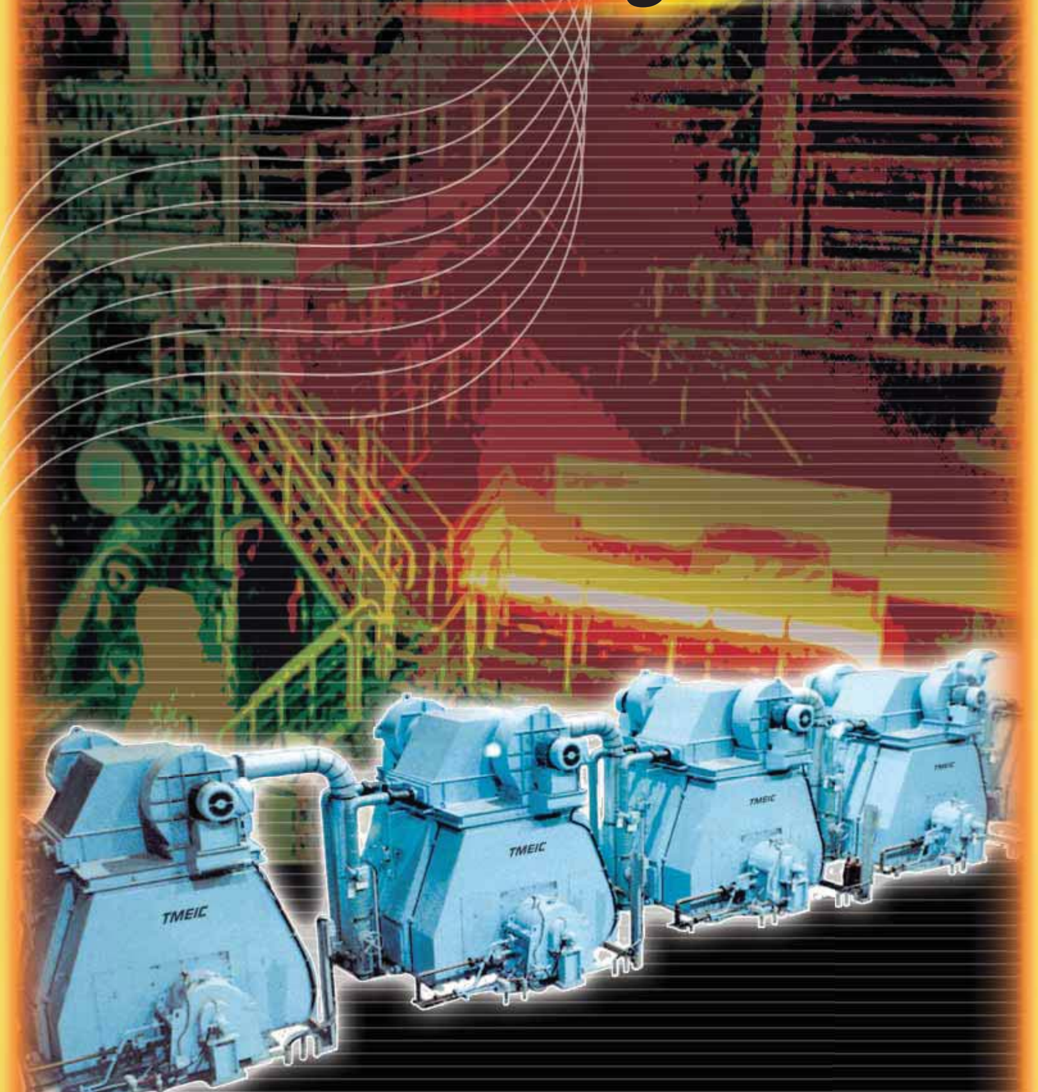
TMEIC

Large AC Adjustable Speed Motors for Metal Rolling Mills



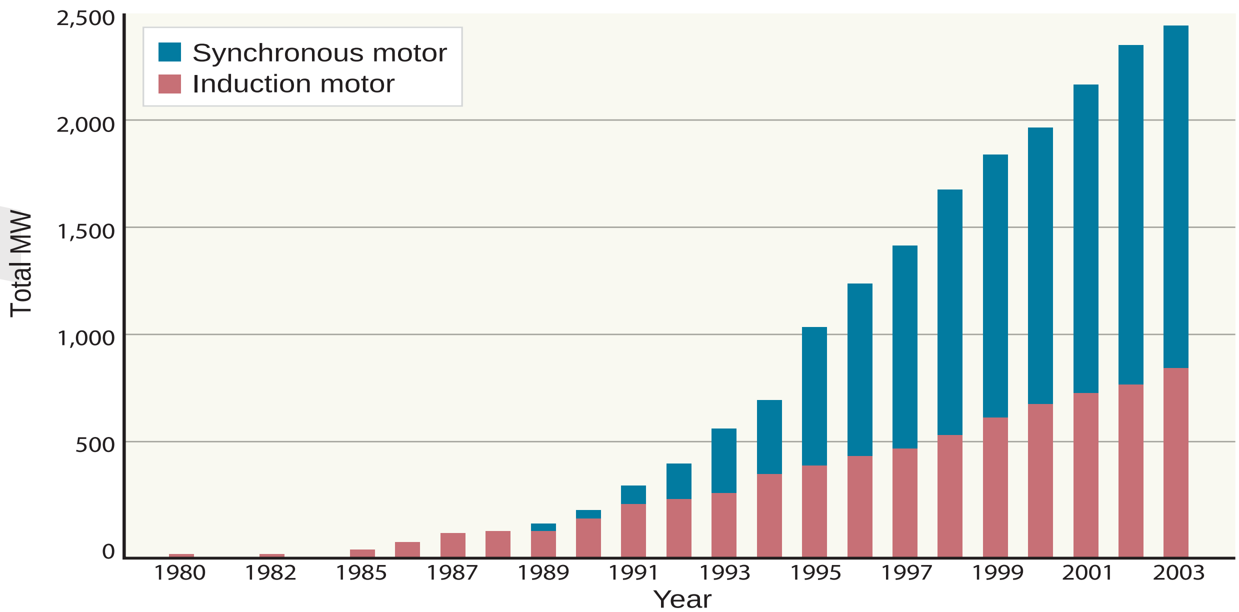
Introduction

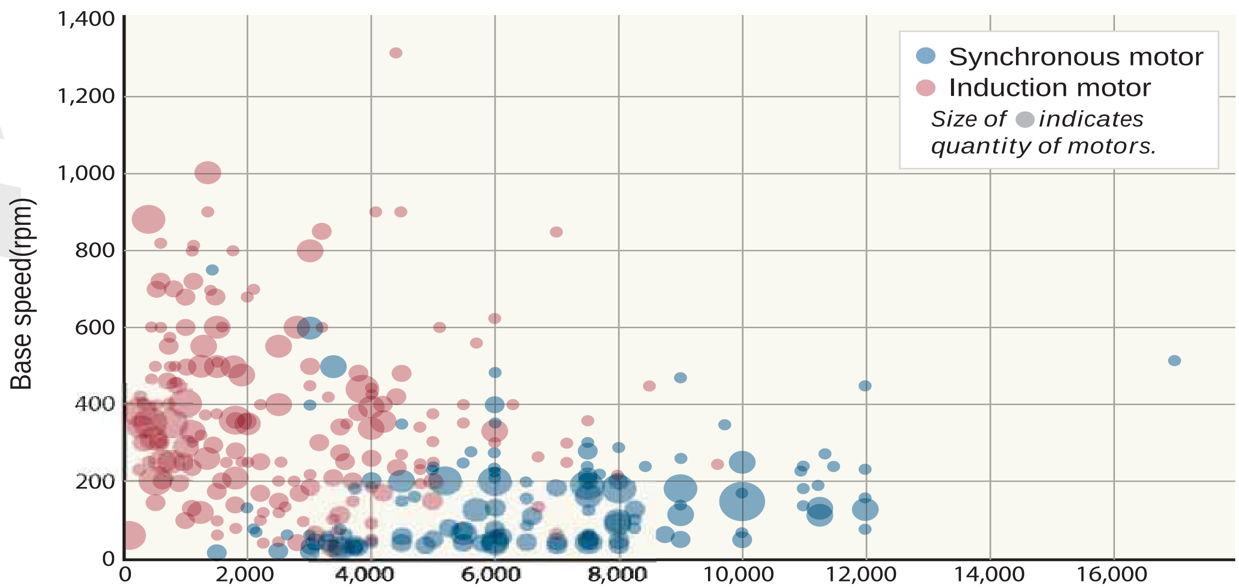
AC adjustable-speed motor drive systems have been established as the preferred technology for new rolling mill installations and extensive modernization projects.

The AC adjustable-speed motor drive system provides metals mills with many advantages compared to traditional DC drive technology, including:

- Improved drive efficiency
- Robust motor construction
- Reduced motor maintenance
- High degree of controllability and responsiveness
- Greater operational flexibility, notably in terms of extreme rolling conditions, such as ultra-low speed rolling with minimal torque ripple, or high speed rolling associated with reels
- Ability to achieve very large drive power and/or wide field weakening range without "*M* factor"[1] limitations

1. *"M Factor" is the numerical representation of a limitation to the manufacture of a DC motor, M, whereby M = kW × (Top speed)2 / (Base speed)*





Introduction

TMEIC[2] installed its first AC adjustable-speed motor drive system for a rolling mill main stand in 1980; by January 2004 TMEIC had installed AC adjustable-speed motor drive systems on more than 700 main mill stands, coilers and reels, constituting more than 2,400 MW of installed main drive power.

2. TMEIC: includes equipment supplied by Toshiba Corporation and Mitsubishi Electric Corporation.

TMEIC has continued to develop and refine its AC adjustable-speed motor drive technology for rolling mill applications. As a result, TMEIC provides customers with an unparalleled choice of technology, including:

1. Proven AC drive solution for each type of rolling mill application, ranging from large torque, slow-speed roughing mills to the high-speed, wide tension range aluminum foil mills.
2. Synchronous or induction motor solutions, fed from either a voltage source inverter (such as IEGT, GCT or IGBT) or cycloconverter.

TMEIC offers an optimal drive solution for each specific rolling mill application, based on extensive manufacturing expertise, capability and application experience.

The AC motor is the fundamental component of an AC adjustable-speed drive system. TMEIC pioneered the adaptation and enhancement of conventional synchronous and induction machine technology to provide an AC motor with the necessary degree of robustness and responsiveness for rolling mill applications, where the load and speed undergo significant variations on a frequent and recurring basis.

To guarantee the integrity of each AC motor design as well as the highest standard of manufacturing, TMEIC incorporates a number of state-of-the-art analytical design tools, fabrication processes and verification tests into the manufacturing process. As a result, TMEIC AC motors for rolling mill applications have established a worldwide reputation for high reliability, robust construction and excellence of operational performance.

Main Features

The principal features of TMEIC AC Adjustable-speed motors are:

- **High Reliability**
  Resulting from extensive knowledge of mill applications, proven design technology and excellent manufacturing know-how combined with thorough quality control and comprehensive testing throughout the production cycle.

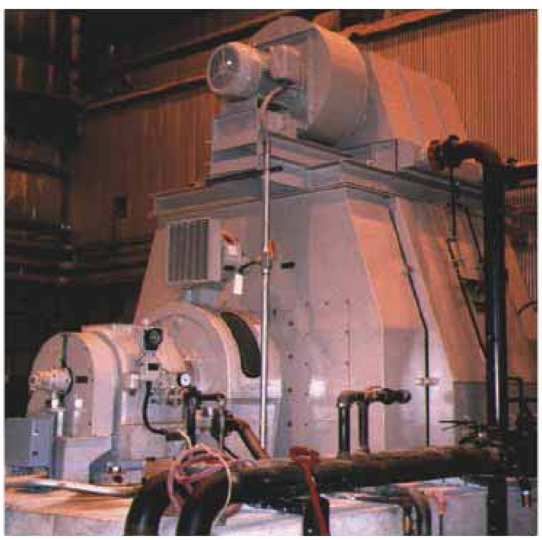
- **High Efficiency**
  Detailed analysis of the electromagnetic field patterns and ventilating airflows facilitates an optimized motor design with maximum cooling efficiency.

- **High Strength Insulation**
  Application of TMEIC vacuum-impregnated insulation (VPI) by means of an oversized, epoxy resin vacuum impregnation facility.

- **High Mechanical Strength**
  Static and dynamic strength analysis of stator frame, rotor, shaft and bearing. Motor shafts of forged steel with high tensile strength for enduring rolling stresses.

For each specific rolling mill application, the most appropriate motor technology is selected by TMEIC resulting in an optimal drive solution, typically:

Synchronous motors



Salient pole type synchronous motors are applied for large power and/or heavy torque applications, for example hot strip mill roughing and finishing stands.

- Excellent torque characteristics
- High efficiency
- Unity power factor and ease of controllability.

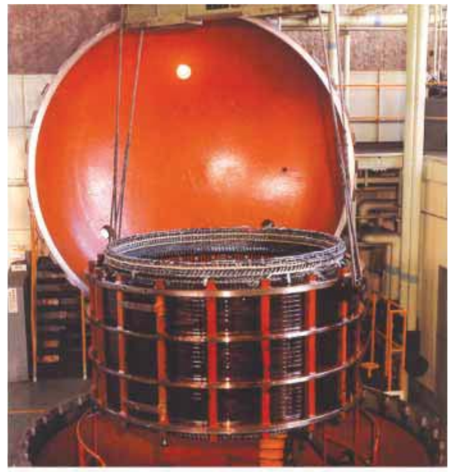
Induction motors

Induction motors are suitable for medium power applications and stands or reels where high speed or wide field weakening range is required.

- Extremely robust construction
- High flexibility
- Excellent torque characteristics, especially for ultra low speed rolling applications
- Constant power output throughout the field weakening range meeting NEMA MG1 and JEM 1157 specifications

Motor Construction

Stator assembly



Vacuum pressurized impregnation process

Stator

The stator is a fabricated, welded steel plate structure of high rigidity, strongly resistant to vibration with a very low resonance frequency. The stator core is constructed with high-grade silicon steel plates to minimize iron loss and provide maximum efficiency.

The stator core includes air ducts to ensure thorough cooling of both the core and the stator coils. The stator coils are formed with a double-layer coil. The coil ends are firmly fastened to each other and supported by a special securing method capable of withstanding the shock resulting from rapid change in mill load and/or exceptional circumstances such as short-circuit of the power distribution system. Thorough testing ensures the coil end can withstand the severe electromagnetic forces generated during mill operation or at the occurrence of a short-circuit.

The stator core and stator coils are integrated as a single assembly before undergoing the vacuum pressurized impregnation process in the VPI tank. This ensures the stator assembly is insulated to withstand:

1. Bending stresses that result from quick start/stop operation or short-circuit of the power distribution system
2. Repetitive thermal stresses and electrostatic pressure associated with frequent and rapid load fluctuations

TMEIC vacuum pressurized impregnated insulation is particularly resistant to water and chemical contamination. This method is ideal for motors operating in harsh rolling mill environments, where the atmosphere is pervaded by damaging water mist, rolling oil and emulsion.

The stator construction is designed to accommodate two alternative types of motor cooling depending upon the customer's preference or installation conditions:

1. Air draft cooling from installed air ducts, typically IC17 (up draft), IC27 (down draft), or, IC37 (up and down draft)
2. Water-air "top-hat" unit cooler according to IC86W. Typically, this solution is preferred as it is simpler to install and cost-effective

Construction

Rotor

Conventional rotor design and fabrication has been enhanced by TMEIC to ensure that adjustable-speed motors for rolling mill applications are equipped with a rotor assembly capable of withstanding frequently applied forces and stresses, such as:

- Mechanical impact forces and shock resulting from mill engagement of rolled material and spindle thrusts.
- Repeated electrical overloads associated with the normal duty cycle of the mill or load

The design of each rotor's tightening fixture was determined after a detailed strength analysis study based on conservative, “worst-case” criteria. Design integrity was verified through comprehensive factory tests.

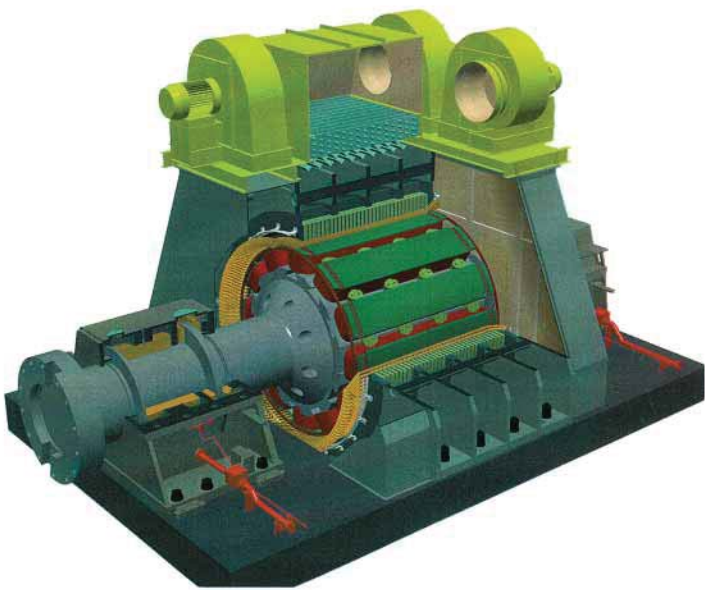
For synchronous motors, each rotor tightening fixture is secured to a predetermined torque in order to prevent loosening of constituent parts during heavy impact loads in the rolling mill and/or frequent reversing operations. Such preventative measures are particularly pertinent for heavy duty reversing mills. The integrity of each rotor fixture and the validity of each torque setting has been field-proven in TMEIC’s extensive installations.

Motor

A number of specific design considerations were made for synchronous and induction machines, including:

Synchronous motors

- A high-strength fixing brace between the rotor coil of each salient-pole to secure its position under all rolling conditions including frequent reversing operations.
- A coil-end connection capable of withstanding expansion and contraction movements of the rotor coil in the direction of the motor shaft.



Induction motors

- The construction of the cage-type rotor bar and end ring were adapted to increase the intrinsic strength and maintain rigidity under all rolling conditions, particularly for frequent repetitions of acceleration and deceleration.
- Reinforcing end rings reduce rotor bar stress in high speed applications.

Specifications

Standard Specification

Applicable Standard

Synchronous motor: JEC-2130 (2000)
Induction motor: JEC-2137 (2000)
Rotating electrical machines: IEC 60034

- Overload withstand strength confirms to JEM 1157 (2002) equivalent to NEMA MG1

Type and Form

Motor type

- Synchronous motor with salient laminated poles
- Squirrel cage rotor induction motor

Motor Construction

- Top forward, twin drive
  - Twin drive motors are arranged in top forward configuration.
  - Each motor has a single rotor, with a coupling between the motor and the mechanical equipment.
- Single drive, horizontally mounted
- Single drive, vertically mounted

Protection method

- Totally enclosed water to air cooling type: IP 44 (IP 54 as option)

Cooling method

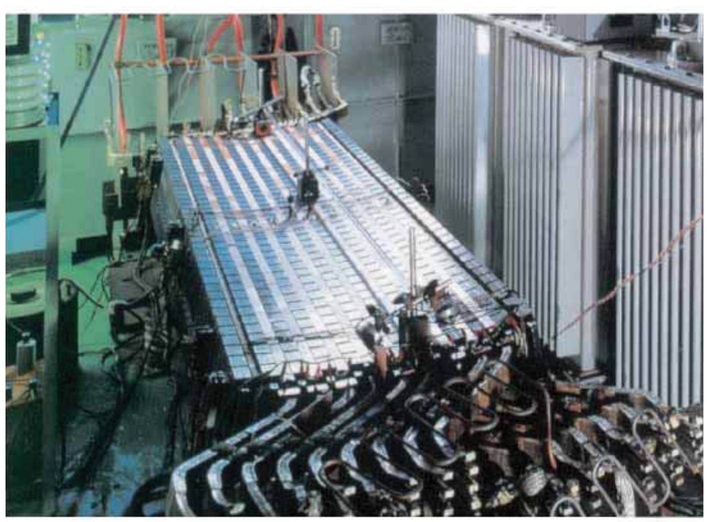
- Top mount cooling system (TEWAC, IC86W)
- Totally enclosed water to air cooling type
- Heat exchanger: Fin tube exchanger. Material: copper

Remarks

- Collector part of synchronous motor is independently cooled by a separate cooling fan (IP12).

Insulation Class

Insulation class: Class F
Temperature rise: Class B or F



Evaluation for coil insulation at test laboratory

Overload Class

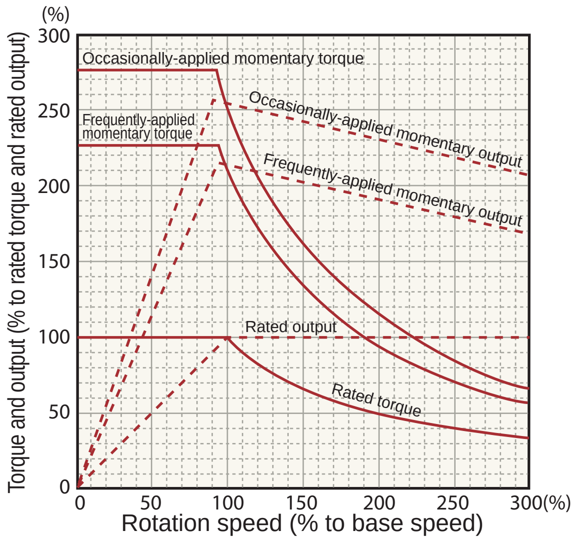
Motors are classified as class 1 or 2 according to the overload capacity specified in JEM 1157 (2002), NEMA MG 1-23 (1998) compatible, unless otherwise specified.

Class 1 motor

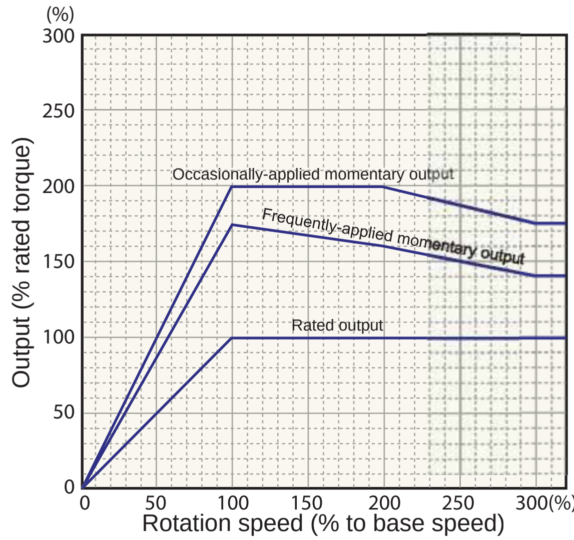
- A motor that accelerates/decelerates in a short time (approx. 2 to 3 seconds), and is frequently run in forward and reverse
- A motor where sudden fluctuations in load may be applied, requiring a large short-time overload capacity
- Example: Motors used for blooming, hot roughing rolling, plate rolling, large section steel rolling and steel pipe rolling, etc.

Class 2 motor

- A motor that accelerates/decelerates in a relatively long time (approx. 10 to
- 20 sec) and either intermittently or never runs in forward and reverse.
- This motor has both long and short overload capability.
- As a long-time overload, 115% - continuous, and 125% - 2 hours can be applicable as options.
- Example: Motors used for continuous hot strip mills, cold tandem mills, cold reversing mills, bar steel and rod steel rolling, etc.



Overload of class 1 motor



Overload of class 2 motor

Mechanical Strength

1. Torsional vibration: the allowable shaft torque value generated by torsional vibration is double the value of the frequency applied momentary torque.
2. Vibration conveyed from foundation: the allowable value of vibration conveyed from the foundation is 1G

Installation Site, Ambient and Cooling Water Temperature

1. Altitude: (a) standard: at or below 1,000 m (3,280 ft.) above sea level
   (b) option: 1,000-3,000 m (3,280 - 9,842 ft.) above sea level
2. Ambient temperature: (a) standard: 40° C or less
   (b) option: 41° C or higher
3. Cooling water temperature: (a) standard: equal or less than 32° C
   (b) option: 32° C or higher

Temperature Rise Limit

The temperature rise of each motor part must not exceed the temperature rise limit value shown below. Motors were tested by equivalent temperature method. The values given on the table below are applicable for air-cooling with an ambient temperature of 40° C maximum at or below an altitude 1,000 m (3,280 ft.) above sea level.

Temperature rise limit (Unit K)

Motor part	Measurement Method	F class insulation 100% continuous output	B class insulation 100% continuous output
AC winding machines outputs of 5,000 kW or more	Embedded temperature method (ETD)	105	85
	Resistance method (R)	100	80
AC winding machines outputs above 200 kW, but less than 5,000 kW	Embedded temperature method (ETD)	110	90
	Resistance method (R)	105	80
Field winding[3]	Resistance method (R)	110	90
Core brushes, brush holders	Temperature that does not affect the machine and does not damage nearby insulation		

Remarks: Based on JEC-2137, JEC-2130, IEC 60034-1

3: Single layer windings with exposed bare or varnish metal surfaces

Bearings

Main motor bearings

Pedestal type

- Twin drive motor thrust bearings withstand the thrust force from each mechanical spindle shaft
- A single drive motor does not have thrust bearings. End play of the machine and coupling shall be less than that of the motor
- Thrust bearings can be applied for a single drive motor as an option

Bracket type

- Sleeve bearing without thrust bearing is standard
- Thrust bearings are an option

Motor Coupling

Twin drive motors

- Flange coupling method should be applied (Flange forged shaft)
- Template of key shall be sent to TMEIC

Single motors

- Customer shall provide a rough-bored half coupling; TMEIC will finish and fit the coupling.

Main Motor Test Procedures

Factory tests are performed in accordance with JEC-2130 and JEC-2137. Test results are provided for inspection.

Synchronous motor test items

Applied Standard: JEC 2130

No.	Inspection Items	First unit	Other units
1	Visual and dimensional inspection	Yes	Yes
2	Measurement of winding resistance	Yes	Yes
3	Open-circuit saturation test	Yes	—
4	Measurement of friction and windage loss and core loss	Yes	—
5	Inspection of voltage balance	Yes	—
6	Inspection of phase sequence	Yes	Yes
7	Short-circuit saturation test	Yes	—
8	Measurement of load loss	Yes	—
9	Inspection of current balance	Yes	—
10	Determination of short-circuit ratio	Yes	—
11	Determination of direct-axis synchronous reactance	Yes	—
12	Calculation of conventional efficiency	Yes	—
13	Temperature rise test (superposition method)	Yes	—
14	Measurement of vibration at no load condition	Yes	—
15	Measurement of insulation resistance	Yes	Yes
16	Dielectric test	Yes	Yes

Note: for large synchronous motors with pedestal type bearings only the first unit is completely assembled at the factory prior to shipment.

Induction motor test items

Applied Standard: JEC 2137

No.	Inspection Items	First unit	Other units
1	Visual and dimensional inspection	Yes	Yes
2	Measurement of winding resistance	Yes	Yes
3	Rotation direction check	Yes	Yes
4	No load test	Yes	Yes
5	Locked rotor test	Yes	—
6	Calculation of characteristics (equivalent circuit calculation method)	Yes	—
7	Temperature rise test (superposition method)	Yes	—
8	Measurement of vibration at no load condition	Yes	Yes
9	Measurement of insulation resistance	Yes	Yes
10	Dielectric test	Yes	Yes

Standard Paint

Paint	Description	Remarks
Pre-treatment	Shot blast	—
Base coat	Epoxy resin primer	1 coat 0.025 mm thick
Final coat	Alkyd resin enamel	1 coat 0.025 mm thick
Finish color	Munsel 2.5 PB 6/2	—

Specifications

Accessories

Standard Accessories

1. Stator winding
   6 - Resistance temperature detectors, Pt100 Ω at 0°C, (three points are for spare)
   1 - Space heater (anti-condensation heater)

2. Bearing
   1 - Dial thermometer with one alarm contact, for each sleeve bearing
   1 - Earth brushes (shaft current preventive device) on drive end pedestals

3. Water-to-air-heat exchanger for totally enclosed water-to-air-cooling type
   1 - Heat exchanger
   1 set - Cooling fan with motor
   1 - Resistance temperature detector, Pt100Ω at 0°C, for air inlet temperature
   1 - Resistance temperature detector, Pt100Ω at 0°C, for air outlet temperature
   1 - Water leakage detection relay

4. Speed detector
   1 - Speed sensor, Resolver

Optional Accessories

1. Bearing
   1 - Resistance temperature detector, Pt100Ω at 0°C

2. Foundation
   1 set - Sole plates or base plate
   1 set - Anchor plates
   1 set - Anchor bolts

3. Air cooling unit
   1 - Cooling water flow relay
   1 - Cooling water thermometer

4. Installation
   1 - Lifting beam and/or extension shaft required to install/remove the motor stators and rotors (for all Main Motor Common use)

Note: Embedded parts to be provided by the customer according to TMEIC drawings.

TMEIC

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