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Fused Deposition Modelling Machines -  
Technical Requirements for Safeguarding

(Draft for Approval)

Issued

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Issued by  
The National Bureau of Quality Supervision, Inspection and Quarantine  
People's Republic of China

## Preface

**Sections 5 to 7 in this standard are mandatory and the others are recommended.**

Please note that some contents in this standard may relate to particular patents. The issuing organisation of this standard is not liable to identify these patents.

Appendix A to this standard is an information appendix.

This standard was promulgated jointly by the Machinery Industry of China.

This standard is administrated by the National Standardisation Technical Committee for Special Machine Tools (SAC/TC161).

This standard was drafted by Qinghua University and the Suzhou Electrical Machine Tools Research Institute.

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# Fused Deposition Modelling Machines - Technical Requirements for Safeguarding

## 1 Scope

This standard defines the technical safety requirements for fused deposition modelling machines.

This standard applies to fused deposition modelling machines (FDM).

## 2 Standard Reference Documents

The clauses in the following documents become clauses of this standard after being referenced. In relation to dated reference documents, all later revision sheets (excluding corrections) and revised versions do not apply to this standard; however, the parties to the agreement are encouraged to study whether the latest versions of these documents are applicable. For undated reference documents, all the latest versions apply to this standard.

GB 2894 Safety Marking (GB 2894-2894, neq ISO 3864:1984)

GB 5226.1 Machinery Safety - Machine and Electrical Equipment - Part 1: General Technical Requirements (GB 5226.1-2002, IEC 60204-1:2000, IDT)

GB/T 14896.7-2004 Special Machine Tools - Glossary - Part 7: Rapid Prototyping Machines

GB/T 15706.1-1995 Machinery Safety - Basic Concept and General Design Rules - Part 1: Basic Glossary and Methodology (eqv ISO/TR 12100-1:1992)

GB/T 15706.2-1995 Machinery Safety - Basic Concept and General Design Rules - Part 2: Technical Principles and Specifications (eqv ISO /TR 12100-2:1992)

GB/T 16769-1997 Metal Cutting Machine Tools - Noise Sound Pressure Measuring Method

GB/T 18569.1-2001 Safety of Machinery – Reduction of Risks to Health from Hazardous Substances Emitted by Machinery – Part 1: Principles and Specifications for Machinery Manufacturers (eqv ISO 14123-1:1998)

GB/T 18569.2-2001 Safety of Machinery – Reduction of Risks to Health from Hazardous Substances Emitted by Machinery – Part 2: Methodology Leading Verification Procedures (eqv ISO 14123-2:1998)

## 3 Glossary and Definitions

The glossary and definitions defined by GB/T 14896.7-2004 and the following glossary and definitions apply to this standard.

### 3.1 Hazard

A source of potential damage or harm to health

Note: the term “hazard” is usually used with other terms to define the source and anticipate the nature of the damage or harm to health, such as electric shocks, extruding hazards, cutting hazards, poisonous hazards (see Section 4 for various hazards caused by machines).  
(GB/T 15706.1-1995, Definition of 3.5)

### 3.2 Risk

The combination of the probability and degree of potential damage or harm to health under a risk condition

(GB/T 15706.1-1995, Definition of 3.7)

### **3.3 Danger Zone**

A zone within or around the machine in which individuals' health could be put at risk or they could encounter harm

Note: the hazards covered by the risk of this definition can often exist during the commissioning of the machine tools (movement of hazardous parts, welding electric arc, etc), or occur accidentally (accidental starting).

(GB/T 15706.1-1995, Definition of 3.10)

### **3.4 Machining Area**

The area between the nozzle and the working platform in the forming room

### **3.5 Safeguarding**

The safety measures in the special technical methods whereby so-called safety protection devices (guarding devices and safety devices) are used to prevent people from encountering various hazards which cannot be avoided or limited by good design

(GB/T 15706.1-1995, Definition of 3.19)

### **3.6 Operator**

The staff member who installs, operates, adjusts, maintains, repairs or transports the machine tool

### **3.7 Guard**

Devices that use physical blocking protection methods, which could be structured as covers, hoods, screens, doors, enclosed protection devices, etc

Note 1: the guarding devices could operate when:

- used independently, only functional in a closed position
- used together with another device with or without an interlocking guarding lock; in this case the guarding device can provide the protection in any position

Note 2: "closed", of a fixed guarding device, refers to being kept in the intended position.

(GB/T 15706.1-1995, Definition of 3.22)

### **3.8 Safety Device**

An individual risk-eliminating or risk-reducing guard device or a device (but not a guarding device itself) used together with another guarding device

(GB/T 15706.1-1995, Definition of 3.23)

### **3.9 Forming Materials**

Deposited component forming materials injected from the nozzle under the extrusion

## **4 Schedule of Hazards**

See Appendix A (information appendix) for the hazardous factors of the machine tools.

## 5 Safety Protection Requirements and Measures

### 5.1 General Requirements (see 7.1 for the inspection)

5.1.1 The safety protection measures should be considered when defining the designed function, usage and lifespan of the machine tool. The machine tool must not give rise to any hazard or cause any harm to people during the specified manufacturing condition, installation, adjustment, maintenance, storage, transportation and operation.

5.1.2 The best efforts should be made to eliminate or reduce risk through the design, including using the measures below whether individually or in combination:

- select an appropriate design structure to avoid or reduce the risk;
- reduce the need for the operators to get into the danger zone, and restrict the danger encountered

5.1.3 For hazards which are unavoidable or confined by the design, the safety guarding devices should be used to protect the operators.

5.1.4 For the remaining hazards unprotected by the safety guarding devices or any hazards which are difficult to protect against, an effective method should be used to inform the operators, such as an explanation in the product operating manual, or a warning sign or label at the hazardous position, if necessary.

### 5.2 Mechanical Hazards and Safeguarding (see 7.2 for the inspection)

5.2.1 There must not be any cusped edge, sharp corner, sharp edge, etc that may hurt people on the reachable parts of the machine.

5.2.2 In normal working conditions, the machine tool or other parts should not accidentally fall over.

5.2.3 The reliable limit mechanism should be used on the parts of the machine tool that precipitate movement. Reliable dual electrical and mechanical limit devices should be installed on each moving axis to prevent the danger of sliding out.

5.2.4 The interlocked shield should be equipped in the working area of the machine tool. In the case of machine tools with an enclosed working area construction, the door of the forming room should be interlocked.

5.2.5 When the interlocked protection device is opened, the machine tool should stop or become impossible to start, and it must be impossible to start it before the protection device is closed. For example, when the door of the forming room is open, to avoid the impact hazard caused by the high-speed movement of the nozzle, it must be impossible to run the machine tool.

5.2.6 The nozzle's holding device should be safe and reliable so as to make sure that the nozzle will not fall off or be thrown off while moving at high speed.

5.2.7 In some dangerous zones, multiple different safety protection devices, such as high-temperature protection devices, and dual electrical and mechanical position-limiting devices for the machine tool's axes, should be used to avoid failures resulting from combined factors.

### 5.3 Safety and Safeguarding Devices (see 7.3 for the inspection)

5.3.1 The safety and safeguarding devices are installed for the mechanical and other dangers they are designed to protect against. These devices should:

- meet the required mechanical strength, rigidity and reliability requirements;
- entail no additional hazards (such as causing clipping and cutting injuries);
- be able to be fastened reliably.

5.3.2 Removable safeguarding devices should be easy to mount and remove and the weight should be less than 6 kg. The pushing force required to open the safeguarding device should not exceed 40 N.

### 5.4 Control System and Devices (see 7.4 for the inspection)

5.4.1 The control and operating system (Control System for short) for the moving parts of the machine tool should be reliable and no part should interfere with another part's functioning. The system should be capable of enduring the designed load, external impacts, breaking-off and damage to the control information carrier without leading to a hazardous situation.

5.4.2 The introduction of hazards from operating errors should be considered during the design of the control devices. The error tolerance of operations susceptible to error should be considered when designing the control device.

5.4.3 The machine tool should have a working status selection switch for each control function. Each switch position must only correspond to one control method or working status (such as automatic control or adjustment, testing). Other methods (such as control code) can also be used to select working status.

5.4.4 With each "Start" control device there should be a "Stop" control device near it. An emergency stop device should be mounted at each working station. The emergency stop device should be in line with the provisions of GB 5226.1.

5.4.5 The usual installation height for meters which need to be read frequently should be 0.7-1.7 m. The installation height for meters which do not need to be read frequently may be 0.3-2.5 m.

### 5.5 Electrical Hazards and Protection (see 7.5, 7.11 for the inspection)

5.5.1 The protection grade provided by the electric box (cabinet) should be in accordance with the provisions of GB 5226.1.

5.5.2 The machine tool should be earthed reliably. The ground resistance should be no less than 1 M $\Omega$  and meet the continuity requirement for the protection circuit.

5.5.3 The electrical device (including components) in the forming room of the machine tool should be equipped with heat-resistant electrical products (see the relevant provisions of GB 5226.1).

5.5.4 The other safety requirements for the electrical devices of machine tools should conform to the relevant provisions of GB 5226.1.

## 5.6 High Temperature Protection Requirements (see 7.6 and 7.12 for the inspection)

5.6.1 The nozzle heating system should have a reliable temperature control device which can adjust the nozzle temperature automatically. The nozzle and its heating system should have exterior heat insulation measures (such as installing protective covers made from heat insulation materials) to avoid the hazard of scalding.

5.6.2 The following measures should be taken for the machine tools in the heated forming room:

- use a reliable temperature control device to control the heater's temperature and prevent overheating;
- an indication should be given for the machine to start work when the temperature of the forming room reaches the defined level, and the machine should prompt the operator to confirm.

5.6.3 The door of the forming room should be interlocked with the nozzle's heating system; it must be impossible to open the door while the nozzle heating or the operation of the machine is in progress.

5.6.4 The nozzle's temperature for different materials and the temperature accuracy range of the forming room should be given in the operating manual.

## 5.7 Ventilation System Requirements (see 7.7 for the inspection)

The flow should meet the cooling requirements of the forming room installed with a ventilation system and the system should be interlocked with the forming room heater. When the forming room is being heated, the ventilation is cut off; when the ventilation is connected through, the forming room is not being heated.

## 5.8 Requirements in terms of Protection against Harmful Gases (see 7.13 for the inspection)

5.8.1 The principles specified in GB/T 18569.1-2001 should be followed and hazards to health caused by harmful substance emissions should be taken into account; measures for confining and discharging harmful gases should be given in the operating manual.

5.8.2 The test method for harmful substance concentrations should conform to the provisions of GB/T 18569.2-2001.

## 5.9 Noise (see 7.8 for the inspection)

5.9.1 The overall noise of the machine tool should not exceed 60dB (A). The measuring method for the noise sound pressure level should conform to the provisions of GB/T 16769-1997.

5.9.2 There should not be any squeaking or impact noise while the machine tool is running.

## 5.10 Lighting (see 7.9 for the inspection)

5.10.1 Lighting devices for the machine tool's safe functioning should be supplied or a connection interface should be provided for the lighting devices on the machine tool.

5.10.2 The electrical safety requirement for the machine tool's lighting devices should conform to the provisions of GB 5226.1.

## 6 Operating Information (see 7.10 for the inspection)

### 6.1 Signal and Warning Devices

The design and configuration of the signal and warning devices should be easy to inspect; there should be provisions for inspecting the warning devices in the operating manual.

### 6.2 Markings and Symbols

6.2.1 The machine tool should bear its own product marking (nameplate), including the following information:

- name of manufacturer;
- name of product;
- model of product;
- manufacturing date or factory leaving date;
- product serial number.

6.2.2 There should be markings at the oil filling and lubricating points on the machine tool and its accessories. The colour of the operating devices and components should be different from the main machine.

6.2.3 In areas susceptible to hazards (including the safety protection devices), there should be safety symbols or a painted colour to warn the operator to be aware of various hazards. The warning symbols should be in accordance with the provisions of GB 2894-1996.

6.2.4 The markings on the machine tool's electrical equipment should conform to the relevant provisions of GB 5226.1.

6.2.5 The markings on the machine tools should be made from anticorrosive materials and be well fastened. The information should be kept clear and easily visible.

### 6.3 Operating manual

#### 6.3.1 General

The description of safety requirements in the operating manual should remind the operator comprehensively, specifically and clearly of the hazards he/she could encounter, and there should be instructions for the safeguarding measures he/she should take against the hazards, together with instructions for the protection methods. See 6.3.2-6.3.7 for the safety content in the operating manual. The operating manual should be made from durable materials.

#### 6.3.2 Information on Transportation, Moving and Storage of the Machine Tool

- Conditions for the safe storage of the machine tool;
- The dimensions, mass and centre of gravity of the machine tool;
- An explanation of how to move the machine tool (such as the lifting point for hoist equipment);
- The requirements for safe packaging and an illustration of the packaging markings of the machine tool.

#### 6.3.3 Commissioning Information on Machine Tool Delivery



- The fastening requirements of the machine tool;
- The assembly and installation requirements, installation space requirement, etc;
- The power supply and its connection details, including the requirements regarding the earthing device;
- The permitted environmental conditions, such as the requirements in terms of temperature, humidity, vibration, etc.

#### 6.3.4 Information on the Machine Tool Itself

- Data on the noise generated by the machine tool;
- Explanations and diagrams of the safety functions.

#### 6.3.5 Machine Tool Operating Information

- pre-work preparation and inspection;
- explanations of the safety warnings and safety protection, safety markings before and during operation;
- the operating procedure, method, noteworthy items, operations susceptible to error and safety measures to be taken when starting up and running the machine;
- hazardous situations that could occur during operation;
- monitoring and recording of the safety situation during operation.

#### 6.3.6 Information on Maintenance of the Machine Tool

The technical safety requirements for maintenance personnel carrying out maintenance should be supplied.

#### 6.3.7 Harmful Gas Release Information

There should be installation and operating instructions for the accessories relating to the release of harmful gases.

### 7 Inspection Regarding Safety Protection Requirements

The safety protection of the machine tool can be inspected by checking and testing. The checking can be done by visual observation, manual tests, measuring, etc. The testing needs to follow certain methods with the test instruments to get the related specified data and draw quantitative and qualitative conclusions (the testing can include the inspection content).

#### 7.1 General Inspection (see 5.1 for the safety protection requirement)

After the safety evaluation, designed safety analysis, etc, check if the machine tool meets the designed safety requirement and if the safety measures are adequate.

#### 7.2 Inspection of Mechanical Hazards and Safeguarding (see 5.2 for the safety protection requirement)

7.2.1 Check whether the touchable areas on the machine tool are smooth, if there are any cusped edges, sharp corners, burrs, etc.

7.2.2 Check whether the machine tool and other parts are fastened well.

7.2.3 Check whether the reliable limit mechanism is used on the parts of the machine tool that precipitate movement; besides the electrical limiting device, check whether the reliable mechanical limit device is also installed on each moving axis.

7.2.4 Check whether the interlocked shield is installed in the working area of the machine tool and if the interlocking door is installed for the forming room.

7.2.5 Check whether the interlocking safety protection device is effective and reliable. Carry out 3 repeat tests to test its interlocking function in line with the design requirement.

7.2.6 Check whether the nozzle holding device is reliable.

7.2.7 Check whether multiple safety protection measures are taken in highly hazardous zones.

### **7.3 Inspection of Safety Protection Devices** (see 5.3 for the safety protection requirement)

7.3.1 Check whether the setting of the safety protection devices is adequate, whether their rigidity, strength, and installation capabilities meet the requirements, and whether there is any additional hazard.

7.3.2 Check whether the weight of the removable safeguarding devices exceeds 6 kg, and whether the pushing force required to open the safeguarding device exceeds 40 N.

### **7.4 Inspection of Control Systems and Devices** (see 5.4 for the safety protection requirement)

7.4.1 Check whether the control system is reliable and that no part of it interferes with any other part. Check whether the control information carrier breaking off would lead to any hazard.

7.4.2 Check whether there is an error-tolerant design for operations susceptible to error. Check whether there is any measure to prevent accidental starting.

7.4.3 Check that one position of the working status selection switch corresponds to only one control method or working status.

7.4.4 Check whether the settings of the “Start”, “Stop” and emergency stop devices are adequate and correct.

7.4.5 Check whether the installation heights of the instrument meters, etc meet the requirements.

### **7.5 Inspection of Electrical Safety** (see 5.5 for the safety protection requirement)

7.5.1 Check whether the protection grade of the electric box (cabinet) meets the requirements.

7.5.2 Check whether the electrical equipment in the forming room is a product that meets the requirements in terms of extra heat resistance.

7.5.3 Check whether the other electrical equipment of the machine tool meets the relevant provisions of GB 5226.1.

### **7.6 Inspection of High Temperature Protection** (see 5.6 for the safety protection requirement)

7.6.1 Check whether the temperature control device of the nozzle heating system is reliable.

7.6.2 Check whether there are any heat insulation safety measures for the nozzle and its heating parts.

7.6.3 Check whether there is any reliable temperature control device for the forming room.

7.6.4 Check whether the door of the forming room is interlocked with the nozzle heating system.

#### 7.7 **Inspection of Ventilation System** (see 5.7 for the safety protection requirement)

Check whether there is any ventilation system for the forming room, whether its flow meets the design requirement and whether it is interlocked with the heater.

#### 7.8 **Inspection of Noise** (see 5.9 for the safety protection requirement)

Check whether the noise level is  $\leq 60$ dB (A), and whether there is any squeaking or impact noise.

#### 7.9 **Inspection of Lighting** (see 5.10 for the safety protection requirement)

7.9.1 Check whether the machine tool is provided with the required lighting devices and the related interface.

7.9.2 Check whether the electrical safety of the machine tool's lighting devices meets the relevant standard regulations.

#### 7.10 **Inspection of Operating Information** (see Section 6 for the safety protection requirement)

7.10.1 Check whether the signals, warning devices, markings and symbols on the machine tool are correct and complete.

7.10.2 Check whether the markings and symbols are properly attached and clearly visible.

7.10.3 Check whether there are any details of the hazards, protection measures and environmental requirements of the machine tool.

7.10.4 Check whether the operating manual is made from a durable material.

7.10.5 Check whether the nozzle temperature for different forming materials and the forming room's temperature range are given in the operating manual.

#### 7.11 **Electrical Safety Test Inspection** (see 5.5 for the safety protection requirement)

The following tests should be carried out on the machine tool according to the provisions of GB 5226.1:

- a) a test of the continuity of the protective earthing circuit  
The continuity of the protective earthing circuit should be tested according to the relevant provisions of GB 5226.1.
- b) an insulation resistance test  
The insulation resistance test should be carried out according to the relevant provisions of GB 5226.1.

c) the withstand voltage test

The withstand voltage test should be carried out according to the relevant provisions of GB 5226.1.

## 7.12 Heating System Control Test (see 5.5 for the safety protection requirement)

### 7.12.1 Nozzle Heating System Temperature Control Test

- a) Select the nozzle temperature range as the nozzle's upper and lower limit settings according to the instructions in the operating manual;
- b) Adjust the temperature control device to set the nozzle's temperature between the lower and upper limits; the temperature control device should be able to control the heating system automatically to make the nozzle's temperature increase or decrease within the specified time;
- c) Repeat the test three times to demonstrate that the temperature control is correct and reliable.

### 7.12.2 Forming Room Heater Temperature Control Test

- a) Select the nozzle temperature range as the nozzle's upper and lower limit settings according to the instructions in the operating manual;
- b) Adjust the temperature control device to set the forming room's temperature between the lower and upper limits; the temperature control device should be able to control the heating system automatically to make the nozzle's temperature increase or decrease within the specified time;
- c) Repeat the test three times to demonstrate that the temperature control is correct and reliable.

## 7.13 Inspection of Harmful Gas Protection (see 5.8 for the safety protection requirement)

The test should be carried out according to GB/T 18569.1-2001 and GB/T 18569.2-2001.

## Appendix A

(Information Appendix)

### Schedule of Hazards Relevant to This Standard

This schedule has been drawn up based on the current situation of fused deposition modelling machines and in accordance with the principles of GB/T 15706.1 and 15706.2-1995.

**Table A.1 Schedule of Hazards**

Hazard		Corresponding clause in this standard
1	Mechanical hazard	5.2
1.1	Hazard of an injury caused by a cusped edge, sharp corner or sharp edge	5.2.1
1.2	Hazard of the machine tool or its accessories falling over	5.2.2
1.3	Hazard of sliding off	5.2.3
1.4	Impact hazard	5.2.5
1.5	Hazard of the nozzle falling off or being thrown off	5.2.6
2	High temperature hazard	5.6
2.1	Scalding hazard	5.6.1, 5.6.3
2.2	Fire hazard	5.6.2, 5.6.4
3	Electrical hazard	5.5
3.1	Electrical equipment hazard	5.5.3, 5.5.4
4	Hazard of ignoring ergonomics	5.4, 5.10
4.1	Hazard from operating error	5.4.2
4.2	Wrong control status setting	5.4.4
4.3	Inadequate working area lighting	5.10
5	Hazard from power supply failure, mechanical part damage, etc	5.2, 5.4
5.1	A control component or liquid being accidentally thrown off	5.2.6
5.2	Breaking-off of the control information carrier, failure of control system	5.4.1
6	Hazard from an incorrect safety measure or incorrect setting	5.2, 5.3, 5.4, 6
6.1	Hazard from unreliable interlocking of a safety protection device	5.2.7
6.2	Various related safety devices	5.3
6.3	Various safeguarding devices	5.3
6.4	Start and stop devices	5.4.4
6.5	Safety signals and devices	6.1
6.6	Various information or alarm devices	6.1, 6.2, 6.3