



# 中华人民共和国国家标准

GB/T 19903.11—2008/ISO 14649-11:2004

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## 工业自动化系统与集成 物理设备控制 计算机数值控制器用的数据模型 第 11 部分：铣削用工艺数据

Industrial automation systems and integration—Physical device control—  
Data model for computerized numerical controllers—  
Part 11: Process data for milling

(ISO 14649-11:2004, IDT)

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## 前 言

GB/T 19903《工业自动化系统与集成 物理设备控制 计算机数值控制器用的数据模型》等同采用 ISO 14649。GB/T 19903 已经制定并计划制定的部分如下：

- 第 1 部分：概述和基本原理(ISO 14649-1)；
- 第 10 部分：通用工艺数据(ISO 14649-10)；
- 第 11 部分：铣削用工艺数据(ISO 14649-11)；
- 第 12 部分：车削用工艺数据(ISO 14649-12)；
- 第 111 部分：铣削刀具(ISO 14649-111)；
- 第 121 部分：车削刀具(ISO 14649-121)。

部分之间的空档留作标准的进一步补充制定之用。

本部分为 GB/T 19903 的第 11 部分。

本部分是首次制定的。本部分等同采用 ISO 14649-11:2004《工业自动化系统与集成 物理设备控制 计算机数值控制器用的数据模型 第 11 部分：铣削用工艺数据》(英文第二版)。

本部分等同翻译 ISO 14649-11:2004。

为便于使用，本部分作了如下编辑性修改：

- a) 删除了 ISO 14649-11:2004 的前言和引言；
- b) 删除了 ISO 14649-11:2004 第 2 章规范性引用文件中的引导语，用 GB/T 1.1—2000 中 6.2.3 规定的引导语代替；
- c) 无部分号的 ISO 14649 改为 GB/T 19903；
- d) 无部分号的 ISO 10303 改为 GB/T 16656；
- e) 索引部分按汉语拼音顺序排序，并保留了原英文索引。

在 ISO 14649-11:2004 中引用的其他国际标准，对于未被等同采用为我国标准的，在本部分中均被直接引用。

本部分的附录 A、附录 B、附录 C 为规范性附录；附录 D、附录 E 为资料性附录。

本部分由中国机械工业联合会提出。

本部分由全国工业自动化系统与集成标准化技术委员会归口。

本部分起草单位：北京发那科数控工程有限公司、华中科技大学、武汉华中数控股份有限公司。

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## 引 言

现代制造企业的生产设备常常分布在国内外,这些设备往往由不同的生产厂家提供。在加工制造过程中,需要在各工场和设备之间传输大量信息。当今,数字通信标准已解决了通过全球网络可靠地传输信息的技术问题。对于机械加工而言,通过 GB/T 16656(STEP 标准)可以使产品数据的描述标准化,这为机械制造企业在整个加工过程中采用标准化数据提供了可能。但是,妨碍实现标准化数据的原因是企业中使用的 CNC 机床采用的数据格式。目前大多数 CNC 机床仍采用 ISO 6983 规定的“G 和 M 代码”语言编程,数控程序通常是由 CAD/CAM 系统生成的。然而用 ISO 6983 编程存在一些不足:首先,所用语言针对的是刀具中心轨迹对机床轴的编程,而不是对零件加工工艺过程的编程;第二,该标准规定的程序语义在多数场合会产生歧义;第三,CNC 制造厂商往往会扩充编程语言,但这种扩充超出了 ISO 6983 规定的范围,不具有互换性。

GB/T 19903 是在 CAD/CAM 系统和 CNC 机床之间的一种新的数据传输模型,用来取代 ISO 6983。它利用工步(Workingstep)面向对象的原理,通过规定加工工艺过程(而不是刀具的运动)来克服 ISO 6983 存在的不足。工步相应于高层的加工特征及相关的工艺参数,CNC 系统将工步转换成轴运动和刀具操作。GB/T 19903 的一个主要优点是它利用来自 GB/T 16656 的数据模型。由于 GB/T 19903 提供了范围广泛的制造过程模型,因而,它也可以作为所有其他信息技术系统之间双向和多向数据交换的基础。

GB/T 19903 是一种面向对象的编程用的信息和语境保存方法,它代替数据变成简单的开关指令或直线和圆弧运动。由于它面向对象的特征,并描述工件的加工操作,而不是描述机床轴的运动,因而它能在不同的机床或控制器上运行。新的数据模型如在 NC 控制器上运用,它的兼容性将省去通过后置处理器的所有数据适配工作。如果在这种控制器中采用 ISO 6983 规定的 NC 程序,相应的解释程序应能并行处理不同类型的 NC 程序。

从使用 ISO 6983 编程到基于可移植的特征编程有一个渐进的过程。GB/T 19903 的早期使用者一定会支持手动或通过程序输入传统的“G 和 M 代码”数据,正如现代控制器既支持命令行界面又支持图形用户界面那样。随着开放式体系结构控制器的日益普及,这种做法会更加容易实现。

在整个生命周期内,在产品数据的领域里,GB/T 19903 与 GB/T 16656 是相互协调一致的。而在 GB/T 19903.1—2005 的图 1 中,表示 GB/T 19903、GB/T 16656 和 CNC 制造厂之间关于实现方法和软件开发标准的不同领域。

# 工业自动化系统与集成 物理设备控制

## 计算机数值控制器用的数据模型

### 第 11 部分:铣削用工艺数据

#### 1 范围

在 GB/T 19903 的本部分中详细说明了铣削工艺中的专用基本数据。这部分与 GB/T 19903.10 中所描述的通用加工数据模型一起,定义了铣削时计算机数值控制器和编程系统(例如 CAM 系统或车间级编程系统)的接口。它可用于各式机床的铣削操作,铣床、加工中心或带有自动刀具具有铣削功能的车床。本部分所定义的范围不包括车削、磨削或电火花加工等其他工艺,这些工艺会在 GB/T 19903 后面部分定义。

在 GB/T 19903 的本部分中 milling-schema 的主要内容是定义典型铣削和钻孔加工工艺专用数据类型。其中既有自由曲面铣削,也有棱形工件铣削(也称 2 轴半铣削)。模式中不包括几何类型、表示方法、加工特征、可用实例和通用工艺的基本类型。这些信息具体参见 GB/T 16656 和 GB/T 19903.10。加工数据的描述使用 GB/T 16656.11 定义的 EXPRESS 语言,数据编码使用 GB/T 16656.21 相关规定。

#### 2 规范性引用文件

下列文件中的条款通过 GB/T 19903 的本部分的引用而成为本部分的条款。凡是注日期的引用文件,其随后所有的修改单(不包括勘误的内容)或修订版均不适用于本部分,然而,鼓励根据本部分达成协议的各方研究是否可使用这些文件的最新版本。凡是不注日期的引用文件,其最新版本适用于本部分。

GB/T 16656.11 工业自动化系统与集成 产品数据的表达与交换 第 11 部分:描述方法: EXPRESS 语言参考手册(GB/T 16656.11—1996,eqv ISO/DIS 10303-11:1993)

GB/T 16656.21 工业自动化系统与集成 产品数据的表达与交换 第 21 部分:实现方法:交换结构的纯文本编码(GB/T 16656.21—1997,idt ISO 10303-21:1994)

#### 3 术语和定义

在本部分中使用下列术语和定义。

##### 3.1

##### **精加工 finishing**

铣削操作作用于切削工件。精加工常常在粗加工之后进行。精加工的目的是要达到表面质量的要求(相对于粗加工)。

##### 3.2

##### **粗加工 roughing**

铣削操作作用于切削工件。粗加工的目的是在短时间内去除大量材料,此时表面质量不是重要因素。粗加工之后通常是精加工(见 3.1)。

#### 4 通用工艺数据

##### 4.1 标题和引用(header and references)

下列清单给出标题和这种模式内所引用的实体表。

SCHEMA milling\_schema;

(\*

Version of April 30,2004

Author:ISO TC184/SC1/WG7

\*)

REFERENCE FROM support\_resource\_schema (\* ISO 10303-41e3\*)

(identifier,

label

);

REFERENCE FROM geometry\_schema (\* ISO 10303-42e3\*)

(bounded\_curve,

cartesian\_point,

direction

);

REFERENCE FROM measure\_schema (\* ISO 10303-41e3\*)

(length\_measure,

positive\_ratio\_measure,

time\_measure

);

REFERENCE FROM machining\_schema (\* ISO 14649-10\*)

(nc\_function,

machine\_functions,

machining\_operation,

machining\_tool,

material,

plane\_angle\_measure,

pressure\_measure,

property\_parameter,

rot\_direction,

rot\_speed\_measure,

speed\_measure,

technology,

toolpath\_list,

tool\_direction);

REFERENCE FROM milling\_machine\_tool\_schema (\* ISO 14649-111\*)

(

milling\_cutting\_tool);

## 4.2 专用加工操作(technology specific machining operations)

### 4.2.1 铣削 NC 功能(NC functions for milling)

铣削 NC 功能在接下来的条款中详细描述。这些功能是 GB/T 19903.10 定义 nc\_function 实体的子类。

#### 4.2.1.1 换托盘(exchange pallet)

这个功能用来实现换托盘。

```
ENTITY exchange_pallet (* m0* )
  SUBTYPE OF (nc_function);
END_ENTITY;
```

#### 4.2.1.2 检索托盘(index pallet)

这个功能把托盘置于由参数设定的指定位置。

```
ENTITY index_pallet (* m0* )
  SUBTYPE OF (nc_function);
  its_index:INTEGER;
END_ENTITY;
```

its\_index: 表示托盘目标位置的参数设定值。

#### 4.2.1.3 检索工作台(index table)

这个功能把回转工作台移动到参数设定的指定位置。

```
ENTITY index_table (* m0* )
  SUBTYPE OF (nc_function);
  its_index:INTEGER;
END_ENTITY;
```

its\_index: 表示工作台目标位置的参数设定值。

#### 4.2.1.4 装刀具(load tool)

这个功能是用来装刀具,刀具的选择与几何信息无关。

```
ENTITY load_tool (* m0* )
  SUBTYPE OF (nc_function);
  its_tool:machining_tool;
END_ENTITY;
  its_tool: 要装的刀具。
```

#### 4.2.1.5 卸刀具(unload tool)

这个功能用来卸刀具。

```
ENTITY unload_tool (* m0* )
  SUBTYPE OF (nc_function);
  its_tool:OPTIONAL machining_tool;
END_ENTITY;
```

its\_tool: 要换的刀具。为防止操作中同时使用一把以上刀具,必须分别设定其属性值。

### 4.2.2 铣削刀具方位(tool direction for milling)

这是用于自由曲面加工中的刀具状态的基本类型,是 GB/T 19903.10 定义的 tool\_direction 实体的子类。

```
ENTITY tool_direction_for_milling (* m0* )
  ABSTRACT SUPERTYPE OF (ONEOF(three_axes_tilted_tool,
  five_axes_var_tilt_yaw,five_axes_const_tilt_yaw))
```

```

SUBTYPE OF (tool_direction);
END_ENTITY;

```

#### 4.2.2.1 3轴倾斜刀具(three axes tilted tool)

在这个加工模式中,刀具是倾斜的,因此刀具方位与机床坐标系中的3个坐标轴都不平行。但是刀具倾角固定,并仍然是在3个线性轴上运动。和 five\_axes\_var\_tilt\_yaw 不同,3轴倾斜刀具方式中其倾角和偏转角是不变的。

```

ENTITY three_axes_tilted_tool (* m0*)
SUBTYPE OF (tool_direction_for_milling);
its_tool_direction: direction;
END_ENTITY;

```

its\_tool\_direction: 机床绝对坐标系定位中的刀具状态。

#### 4.2.2.2 可变倾角和偏转角的5轴加工(five axes with variable tilt and yaw angles)

加工时刀具5轴联动。在运动过程中,跟随刀具轨迹中的曲线不断调整刀具的状态。

```

ENTITY five_axes_var_tilt_yaw (* m1*)
SUBTYPE OF (tool_direction_for_milling);
END_ENTITY;

```

#### 4.2.2.3 固定倾角和偏转角的5轴加工(five axes with constant tilt and yaw angles)

这是可变倾角和偏转角5轴加工的特例。刀具在运动过程中倾角和偏转角在刀位点是不变的,其状态取决于刀具的接触点的法线和进给方向的切线组成的坐标系。倾角和偏转角设置为这个实体的属性。

注:如果给某条刀具路径指定一条详细的刀位状态曲线,那么这些值可能会被重设。

```

ENTITY five_axes_const_tilt_yaw (* m0*)
SUBTYPE OF (tool_direction_for_milling);
tilt_angle: plane_angle_measure;
yaw_angle: plane_angle_measure;
END_ENTITY;

```

tilt\_angle: 刀具在进给方向的倾斜角度,以刀具接触点上的曲面法线来计算。

yaw\_angle: 倾斜刀具绕曲面法线的偏转角度,以刀具接触点在进给方向的曲面切线来计算。

#### 4.2.3 铣削加工操作(milling machining operation)

GB/T 19903的本部分定义了所有操作的基本类型。这是 GB/T 19903.10 定义的 machining\_operation 实体的子类。例如当 its\_technology 中的 feedrate\_per\_tooth 被选中时,its\_tool 中的 number\_of\_effective\_teeth 会自动给出。

```

ENTITY milling_machining_operation (* m0*)
ABSTRACT SUPERTYPE OF (ONEOF(milling_type_operation,
drilling_type_operation))
SUBTYPE OF (machining_operation);
overcut_length: OPTIONAL length_measure;
WHERE
WR1: (EXISTS(SELF. its_technology. feedrate_per_tooth) AND
EXISTS(SELF. its_tool. number_of_effective_teeth))
OR (NOT (EXISTS(SELF. its_technology. feedrate_per_tooth)));
END_ENTITY;

```

overcut\_length: 位于特征中开放侧的间距。加工中不允许所有面都有材料作为边界,例如开槽。

在 Round-hole 场合,此属性只有在是通孔时是允许的。如果 drilling\_type\_operation 中为 cutting\_depth 指定了一个有冲突的值,overcut\_length 可以忽略。

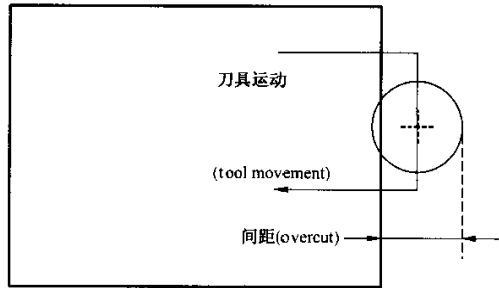


图 1 间距

#### 4.2.4 铣削工艺 (milling technology)

这个实体定义铣削操作的工艺参数。它是 GB/T 19903.10 定义的工艺实体的子类。在 4 个可选速度值中,两个必须通过 WHERE 规则指定。如果调用了 adaptive\_control 属性,其中一些或全部值可能被忽略。

```
ENTITY milling_technology (* m0 *)
  SUBTYPE OF (technology);
  cutspeed;                OPTIONAL speed_measure;
  spindle;                 OPTIONAL rot_speed_measure;
  feedrate_per_tooth;     OPTIONAL length_measure;
  synchronize_spindle_with_feed;  BOOLEAN;
  inhibit_feedrate_override;  BOOLEAN;
  inhibit_spindle_override;  BOOLEAN;
  its_adaptive_control;    OPTIONAL adaptive_control;
```

WHERE

```
WR1: (EXISTS(cutspeed) AND NOT EXISTS(spindle))
OR (EXISTS(spindle) AND NOT EXISTS(cutspeed))
OR (EXISTS(its_adaptive_control));
WR2: (EXISTS(SELF.feedrate) AND NOT
```

```
EXISTS(feedrate_per_tooth))
OR (EXISTS(feedrate_per_tooth) AND NOT EXISTS(SELF.feedrate))
OR (EXISTS(its_adaptive_control));
```

END\_ENTITY;

cutspeed;	刀具的切削速度,主轴速度转速转化为线速度。
spindle;	刀具转速。根据 rot_speed_measure 的定义,正值表示刀具转向为 C 轴数学上的正方向旋转,例如从刀架向工件方向看刀具逆时针运动是正向。 注:通常加工中需要刀具顺时针运动,此时 spindle 为负值。
feedrate_per_tooth;	每齿进给量。
synchronize_spindle_with_feed;	如果为真,切削速度和刀具进给同步。当切削速度提高或降低时,孔底部的螺距能保持恒定。
inhibit_feedrate_override;	如果为真,则不允许通过操作面板或者自适应控制系统重设

inhibit_spindle_override	进给倍率。 如果为真,则不允许通过操作面板或者自适应控制系统重设主轴转速倍率。
its_adaptive_control	用户自定义自适应控制策略。

4.2.4.1 自适应控制(adaptive control)

本实体定义了用户自适应控制策略。在后面章节中,自适应控制特定的算法和更多的参数将会在相应的子类中给出。

```
ENTITY adaptive_control; (* m1 *)
END_ENTITY;
```

4.2.5 铣削加工功能(milling machine functions)

本实体定义了机床在一个加工时间段的各种功能状态,像冷却液、排屑等。本实体是 GB/T 19903. 10中定义 machine\_functions 实体的子类。

```
ENTITY milling_machine_functions (* m0 *)
SUBTYPE OF (machine_functions);
coolant: BOOLEAN;
coolant_pressure: OPTIONAL pressure_measure;
mist: OPTIONAL BOOLEAN;
through_spindle_coolant: BOOLEAN;
through_pressure: OPTIONAL pressure_measure;
axis_clamping: LIST [0:?] OF identifier;
chip_removal: BOOLEAN;
oriented_spindle_stop: OPTIONAL direction;
its_process_model: OPTIONAL process_model_list;
other_functions: SET [0:?] OF property_parameter;
END_ENTITY;
```

coolant:	如果为真,冷却液开启。
coolant_pressure:	冷却系统压力,可选项,仅冷却液开启时有效。
mist:	如果为真,喷雾冷却开启。默认状态为假。仅冷却液开启时有效。
through_spindle_coolant:	如果为真,通过主轴的冷却液开启,默认状态为关闭。
through_pressure:	通过主轴的冷却液压力。 仅在 through_spindle_coolant 为真时有效。
axis_clamping:	指定被锁紧的轴,比如 X、Y、A。 注:此信息是否有效取决于机床操作面板和参数设定。
chip_removal:	如果为真,排屑功能开启。
oriented_spindle_stop:	如果指定,主轴在工步进行或结束时停机的情况下,主轴将会停止在相对于 C 轴机床零点设定的位置。
its_process_model:	工艺控制信息,可选项。
other_functions:	一般类型的其他功能列表,可选项。

4.2.5.1 工艺模型表(process model list)

对每一工步,可能会启动一个或更多的工艺模型。有许多用于工艺控制的模块,如减振、热补偿等。

```
ENTITY process_model_list; (* m1 *)
its_list: LIST [1:?] OF process_model;
```

END\_ENTITY;

its\_list: 当前工步的工艺模型表。

#### 4.2.5.1.1 工艺模型(process model)

使加工过程更安全、更精确的专用功能。(例如减少振动、热补偿……)

ENTITY process\_model; (\* ml\*)

ini\_data\_file: label;

its\_type: label;

END\_ENTITY;

ini\_data\_file: 包含工艺模型初始化信息的文件名。

its\_type: 工艺模型的类型(例如减振,热补偿……)。

#### 4.2.6 铣削类型操作(milling type operation)

这是所有铣削操作的基本类型。它包括描述工艺和策略的所有必要的属性,是实体 milling\_machining\_operation 的子类。

通常,有两种类型的加工操作:粗加工和精加工。粗加工是用来从毛坯表面去除材料至包含多层精加工余量的特征底面或侧面。精加工是用来去除精加工的加工余量,完成最终的特征表面。如果有预留特征(如预留孔、预留槽),粗加工过程需要先执行一遍。特殊情况是在2轴半铣削策略中考虑 allow\_multiple\_passes 的属性。

ENTITY milling\_type\_operation (\* m0\*)

ABSTRACT SUPERTYPE OF (ONEOF(freeform\_operation, two5D\_milling\_operation))

SUBTYPE OF (milling\_machining\_operation);

approach: OPTIONAL approach\_retract\_strategy;

retract: OPTIONAL approach\_retract\_strategy;

END\_ENTITY;

approach: 起始切削的刀具趋近路径,可选项。如果像 allow\_multiple\_passes 指定的那样分层切削,这种策略会被用来从一层移动到下一层的开始位置。

默认情况下,由 NC 控制器决定趋近策略。如果切削的起始点与上一加工过程的终止点恰好重合,可能就不会有任何的趋近运动。如果给定 its\_toolpath,该属性被忽略。

retract: 在精加工最后一刀结束后的退刀策略,可选项。默认情况下由 NC 控制器决定退刀策略。如果切削的结束点与下一加工过程的起始点恰好重合,可能就不会有任何的退刀运动。如果给定 its\_toolpath,该属性被忽略。

##### 4.2.6.1 进退刀策略(approach retract strategy)

进退刀策略的基本类型。所有的进刀和退刀策略都相关于切削过程的起点或者终点而定义,不管其是否在 NC 控制器决定的加工过程中明显给出来。由此导致的进刀运动的起始点或者退刀运动的终止点定义为当前加工过程的起始点和终止点。进刀或退刀轨迹的进给速率就是相关的起始点或者终止点分别规定的切削进给速率。

ENTITY approach\_retract\_strategy (\* ml\*)

ABSTRACT SUPERTYPE OF (ONEOF(plunge\_strategy, air\_strategy, along\_path));

tool\_orientation: OPTIONAL direction;

END\_ENTITY;

tool\_orientation: 仅用于 5 轴加工机床。在进刀或者退刀运动中规定了刀具在起始或者终止时各自的刀具状态。

4.2.6.2 进刀策略(plunge strategy)

这是所有进刀包括切削材料时进刀运动的基本类型。槽加工操作是典型情况,在进刀至第一个切削层深度或者在切削层之间需要去除材料来生成进刀轨迹。

所有的进刀运动应在特征的边缘之内进行。在进刀过程中,当退刀平面有效时,所有的进刀运动才启动。在进刀过程中刀具的位置与切削起点位置一致时,进刀运动就结束。

```
ENTITY plunge_strategy (* ml * )
    ABSTRACT SUPERTYPE OF (ONEOF (plunge_toolaxis, plunge_ramp, plunge_helix,
    plunge_zigzag))
    SUBTYPE OF (approach_retract_strategy);
END_ENTITY;
```

4.2.6.2.1 沿刀具轴进刀(plunge tool axis)

沿刀具轴方向进刀。

注:如果铣刀不能切削进入指定层,必须使用另外的刀具进行进刀钻削操作。由于每一加工中只能使用一把刀具,这就需要对前述的 drilling\_type\_operation 进行定义。在这种情况下,对 milling\_type\_operation 就不应该给定进刀策略,刀具的 cut\_start\_point 设定必须与 milling\_type\_operation 和 drilling\_type\_operation 相一致。

```
ENTITY plunge_toolaxis (* ml * )
    SUBTYPE OF (plunge_strategy);
END_ENTITY;
```

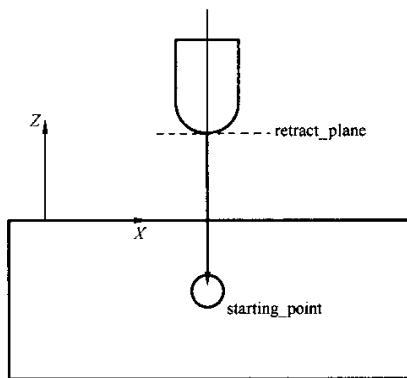
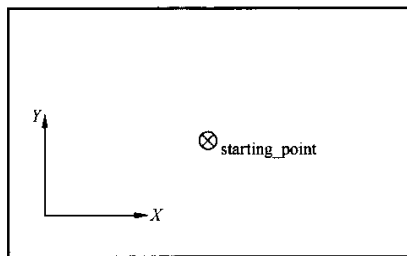


图 2 沿刀具轴进刀

## 4.2.6.2.2 斜向进刀(plunge ramp)

沿与特征表面成一定角度的线性刀具轨迹进刀。

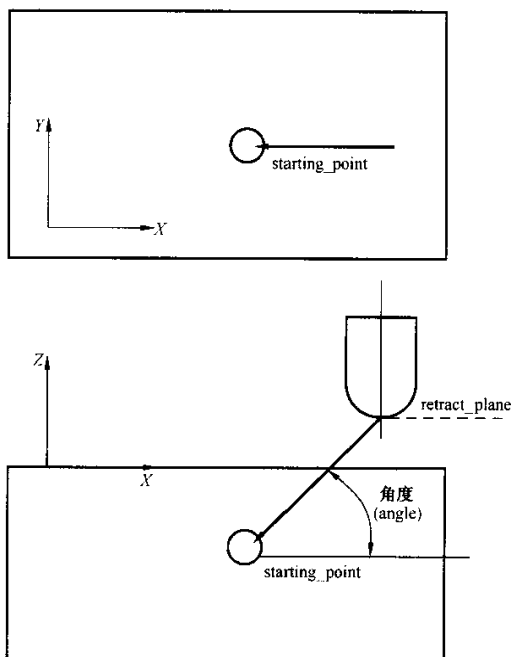


图3 斜向进刀

ENTITY plunge\_ramp (\* m1 \*)

SUBTYPE OF (plunge\_strategy);

angle: plane\_angle\_measure;

END\_ENTITY;

angle: 在趋近终点时刀具斜向运动相对于平面的角度。

注：起点和终点能够通过 4.2.6.2 中的相关规定进行计算。

## 4.2.6.2.3 螺旋线进刀(plunge helix)

沿螺旋线轨迹进刀。刀具轨迹通过指定螺旋线的半径和螺距来定义。当螺旋线的螺距为零就是沿圆周进刀。

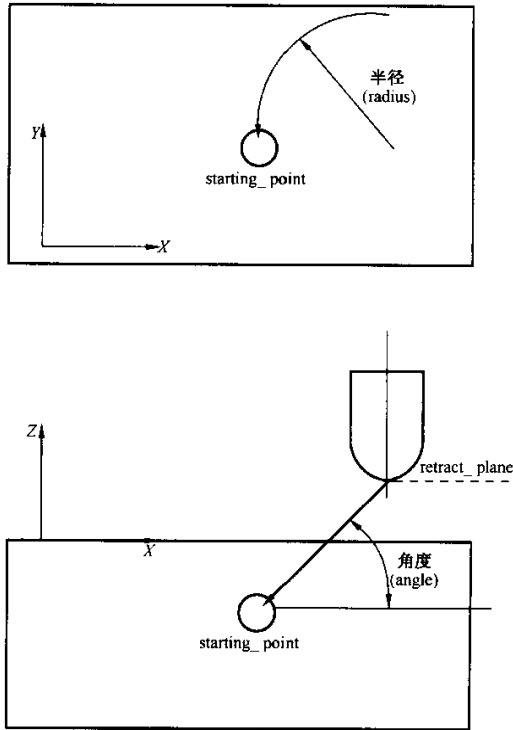


图 4 螺旋线进刀

```

ENTITY plunge_helix (* m1 * )
  SUBTYPE OF (plunge_strategy);
  radius: length_measure;
  angle: plane_angle_measure;
END_ENTITY;

```

radius: 螺旋线运动的半径。

angle: 在趋近终点时,刀具螺旋线运动相对于平面的角度。

注: 起点和终点可以通过 4.2.6.2 中的规定进行计算。

#### 4.2.6.2.4 锯齿形进刀(plunge zigzag)

锯齿形进刀运动。这和斜向进刀运动相似,除非碰到特征边界或如果刀具轨迹长度超过了指定的锯齿形的宽度,刀具才会改变方向。

```

ENTITY plunge_zigzag (* m1 * )
  SUBTYPE OF (plunge_strategy);
  angle: plane_angle_measure;
  width: length_measure;
END_ENTITY;

```

angle: 在趋近终点时,刀具锯齿形运动相对于平面的角度。

注: 起点和终点可以通过 4.2.6.2 中的相关规定进行计算。

width: 锯齿形轨迹垂直于下降方向的宽度。

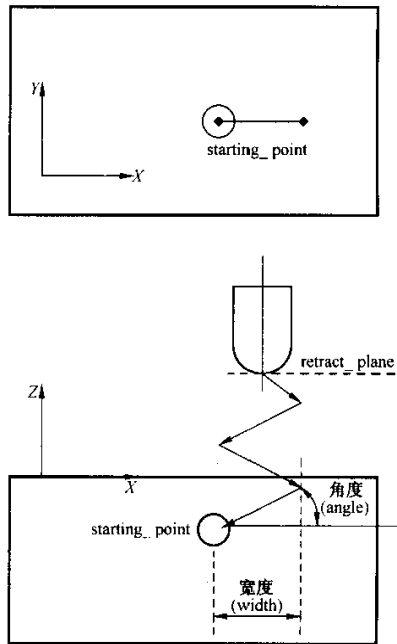


图 5 锯齿形进刀

#### 4.2.6.3 空切削策略(air strategy)

这是所有通过空间趋近或回退运动的基本类型。

和 plunge-strategy 不同的是这些运动都未限制在特征内部。所有这些运动都应该在由加工特征的法线和在起点或终点处切削轨迹的切线所定义的一平面内。如果起点和终点位于两个平面的交汇处,就像 bottom\_and\_side\_mill 的情形,平面的法线就被认为在这两条法线的中间。

注:对于侧铣的情形,例如对一个轮廓的铣削,运动将在机床坐标系的 XY 平面。

ENTITY air\_strategy (\* m1 \*)

ABSTRACT SUPERTYPE OF (ONEOF (ap\_retract\_angle, ap\_retract\_tangent))

SUBTYPE OF (approach\_retract\_strategy);

END\_ENTITY;

##### 4.2.6.3.1 进退刀角度(approach retract angle)

与面成某一角度朝向起点或离开终点运动。对于平面铣削,为了从工件外面直接开始切削材料,该值可设置为 0。

ENTITY ap\_retract\_angle (\* m1 \*)

SUBTYPE OF (air\_strategy);

angle: plane\_angle\_measure;

travel\_length: length\_measure;

END\_ENTITY;

angle: 分别代表在趋近或提升起点、终点处相对于平面的趋近或提升角。

travel\_length: 倾斜趋近的长度。当走完 travel\_length 之后,刀具将沿最短的路线运动到回退面,反之亦然。

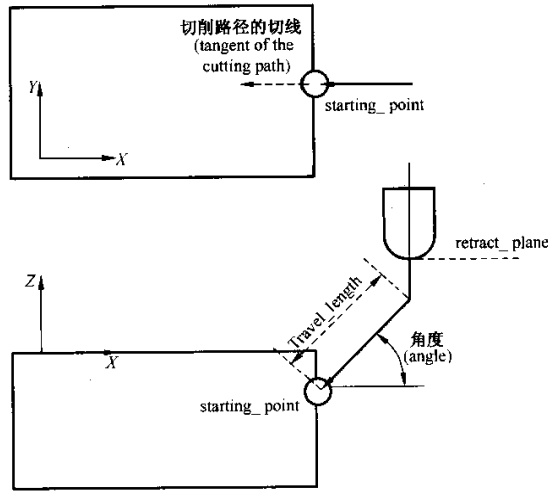


图 6 进退刀角度

4.2.6.3.2 进退刀切线 (approach retract tangent)

沿某弧线朝向起点或离开终点运动。它开始或终止于当前操作有效的退刀平面内。如果此运动指定的半径小于当前操作属性“retract\_plane”中指定的距退刀平面的距离，则剩余的轨迹将垂直于退刀平面线性运动直到退刀面。

```
ENTITY ap_retract_tangent (* m1 *)
  SUBTYPE OF (air_strategy);
  radius:length_measure;
END_ENTITY;
radius:进刀或退刀运动的半径。
```

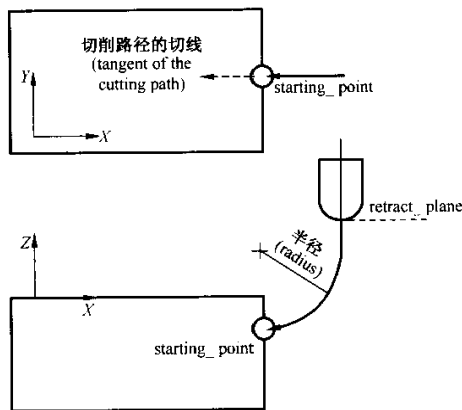


图 7 进退刀切线

4.2.6.4 沿轨迹进退刀 (along path)

在一般轨迹上趋近或提升运动。如刀具状态完全控制，它可用于趋近运动或有其他特殊用途。

```
ENTITY along_path (* m1 *)
  SUBTYPE OF (approach_retract_strategy);
```

```
path; toolpath_list;
END_ENTITY;
```

path: 对于趋近或提升运动的一般轨迹的说明。

注: 此轨迹是在一个特殊的坐标系中指定的。原点是切削操作的起点或终点, 坐标轴方位如同特征的局部坐标系。

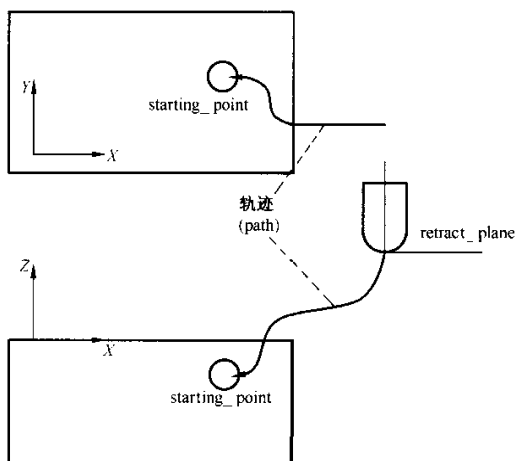


图 8 沿轨迹进退刀

#### 4.2.7 自由曲面操作 (freeform operation)

从铣削类型中派生, 属于自由曲面铣削类型操作。

注: 当前仅有某些高性能控制器在详尽指定刀具轨迹时能加工自由曲面。

```
ENTITY freeform_operation (* m0*)
```

```
    SUBTYPE OF (milling_type_operation);
```

```
    its_machining_strategy: OPTIONAL freeform_strategy;
```

```
END_ENTITY;
```

its\_machining\_strategy: 加工策略的描述。当父类加工的“its\_toolpath”属性被指定了, 则此策略仅为提示信息。

##### 4.2.7.1 自由曲面加工策略 (freeform strategy)

以下实体定义了用于铣削自由曲面的策略。如果使用这个实体, 则只能通过铣削策略和公差定义刀具轨迹。数控系统自身则必须从这些值中计算出相应刀具轨迹。

如果已经定义了刀具轨迹和自由曲面加工策略, 则属性“freeform\_strategy”仅作为提示信息。

```
ENTITY freeform_strategy (* m1*)
```

```
    ABSTRACT SUPERTYPE OF (ONEOF(uv_strategy, plane_cc_strategy, plane_cl_strategy,
    leading_line_strategy));
```

```
    pathmode: pathmode_type;
```

```
    cutmode: cutmode_type;
```

```
    its_milling_tolerances: tolerances;
```

```
    stepover: OPTIONAL length_measure;
```

```
END_ENTITY;
```

Pathmode: 进给方向。

cutmode: 行距方向。

its\_milling\_tolerances: 生成刀具轨迹时的公差值。  
 stepover: 两条相邻的刀具轨迹之间的距离。如果给出此项值,则忽略“its\_milling\_tolerances”计算出来的行距。

4.2.7.1.1 刀具轨迹类型(pathmode type)

铣削中的刀具轨迹类型。它可以是向前(或单向)铣削或锯齿形(或双向)铣削。

```
TYPE pathmode_type = ENUMERATION OF (
    forward,
    zigzag
);
END_TYPE;
```

4.2.7.1.2 切削类型(cutmode type)

铣削中的切削类型。它可以是逆铣或顺铣。在单向方式中,顺铣是指如果刀具逆时针旋转,行距运动沿着进给方向的左侧进行。在双向方式中,切削类型仅与第一次切削有关。

```
TYPE cutmode_type = ENUMERATION OF (
    climb,
    conventional
);
END_TYPE;
```

4.2.7.1.3 公差(tolerances)

公差与自由曲面加工相关。这并不是指一般意义上的制造公差,而是特指 NC 控制器对自由曲面加工生成刀具轨迹时所需要的两个参数。通过这些值,可以导出刀具轨迹之间的行距。

```
ENTITY tolerances; (* ml *)
    chordal_tolerance: length_measure;
    scallop_height: length_measure;
END_ENTITY;
```

chordal\_tolerance: 由曲线的线性近似法而引起的几何误差。

scallop\_height: 由于刀具半径(图 9 中“C”状)形成的凹槽的高度。

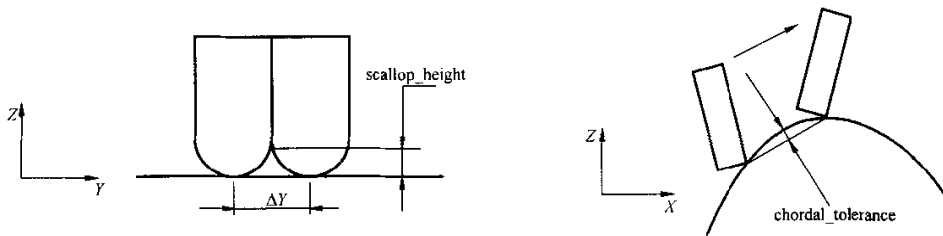


图 9 残余高度和弦高公差

4.2.7.1.4 UV 策略(UVstrategy)

铣削沿局部坐标系(U,V)的参数线铣削。

```
ENTITY uv_strategy (* ml *)
SUBTYPE OF (freeform_strategy);
    forward_direction: direction;
    sideward_direction: direction;
END_ENTITY;
```

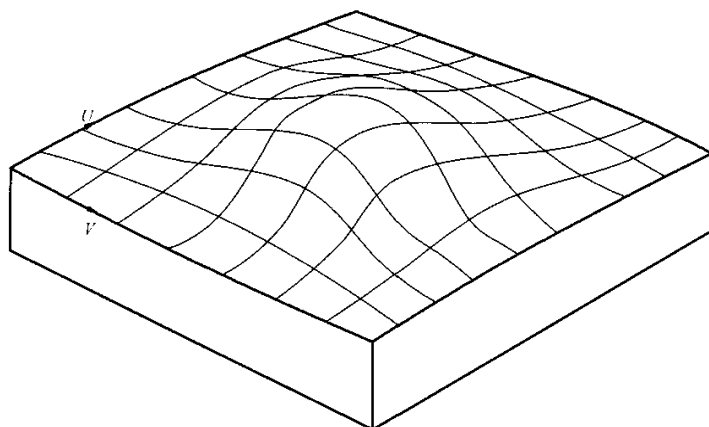


图 10 UV 策略

forward\_direction: 第一刀切削方向。

sideward\_direction: 第二刀偏移第一刀的方向。

#### 4.2.7.1.5 截平面刀具接触点策略(plane cutter contact strategy)

一组平行平面截取目标曲面,产生一系列交线。这些交线形成了刀具与加工表面的接触点轨迹。

ENTITY plane\_cc\_strategy (\* ml \*)

SUBTYPE OF (freeform\_strategy);

its\_plane\_normal: direction;

END\_ENTITY;

its\_plane\_normal: 与目标曲面相交的正交平面。

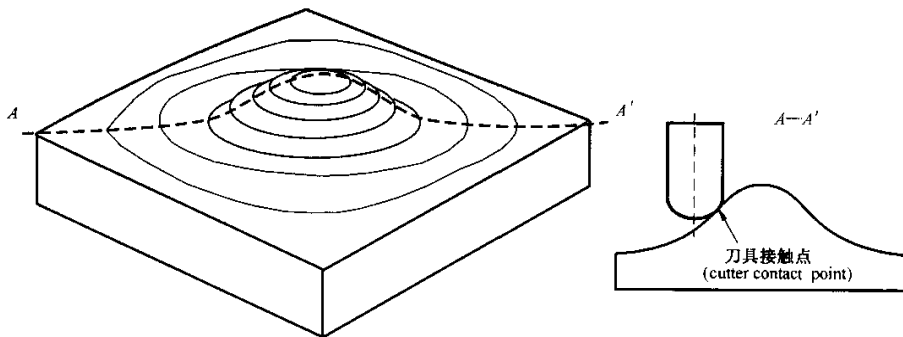


图 11 截平面刀具接触点策略

#### 4.2.7.1.6 截平面刀位策略(plane cutter location strategy)

截平面与目标曲面相截产生交线偏移了刀具半径大小。这样就产生了刀位轨迹。这种策略适用于球头刀和牛鼻刀。

ENTITY plane\_cl\_strategy (\* ml \*)

SUBTYPE OF (freeform\_strategy);

its\_plane\_normal: direction;

END\_ENTITY;

its\_plane\_normal: 与目标曲面相交的正交平面。

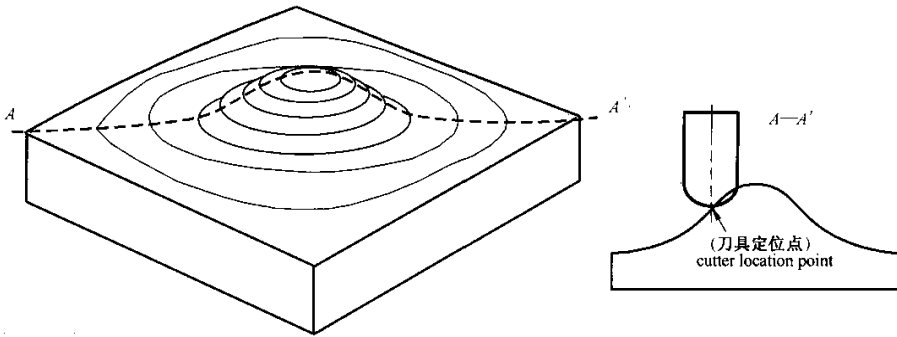


图 12 截平面刀位策略

#### 4.2.7.1.7 导动曲线策略(leading line strategy)

刀具轨迹是由沿局部坐标系 Z 轴向工件表面的投影曲线计算出来的。该曲线是作为属性给出的。

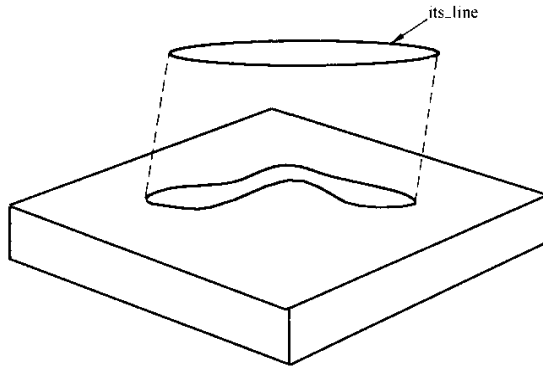


图 13 导动曲线策略

```
ENTITY leading_line_strategy (* ml *)
  SUBTYPE OF (freeform_strategy);
  its_line: bounded_curve;
END_ENTITY;
its_line: 用于计算刀具轨迹的曲线。
```

#### 4.2.8 2 轴半铣削操作(two5D milling operation)

这是从 milling\_type\_operation 中派生出的所有 2 轴半铣削加工的基本类型。

```
ENTITY two5D_milling_operation (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(plane_milling, side_milling,
  bottom_and_side_milling))
  SUBTYPE OF (milling_type_operation);
  its_machining_strategy: OPTIONAL two5D_milling_strategy;
END_ENTITY;
```

its\_machining\_strategy: 加工策略。当基本类型的 its\_toolpath 属性指定后,该策略仅为提示信息。

##### 4.2.8.1 2 轴半铣削策略(two5D milling strategy)

这是所有用于产生 2 轴半铣削刀具轨迹策略的基本类型。

```

ENTITY two5D_milling_strategy (* ml *)
  ABSTRACT SUPERTYPE OF (ONEOF (unidirectional,bidirectional,
  contour_parallel,bidirectional_contour,
  contour_bidirectional,
  contour_spiral,center_milling,explicit_strategy));
  overlap:OPTIONAL positive_ratio_measure;
  allow_multiple_passes:OPTIONAL BOOLEAN;
END_ENTITY;

```

overlap: 两相邻刀具轨迹之间的重叠区,一般用刀具直径百分比表示。

allow\_multiple\_passes: 可选项,用于粗铣加工工步。如果为真,多道标准粗铣加工,例如,考虑最大切削深度,多层材料将顺序去除。如果为假,这是单通道预制特征特殊铣加工,默认值为真。

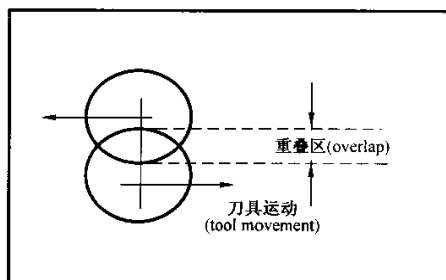


图 14 重叠区

#### 4.2.8.1.1 单向铣削(unidirectional milling)

铣削为线性方式。例如,从一侧运动到另一侧,然后抬刀,回到起点。这样,切削方式(逆铣或顺铣)不像在双向铣削方式那样会改变。切削行距方向自动从 feed\_direction 和 cutmode 中派生。

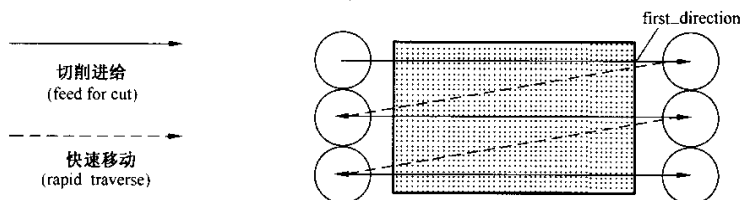


图 15 单向铣削

```

ENTITY unidirectional (* ml *)
  SUBTYPE OF (two5D_milling_strategy);
  feed_direction:OPTIONAL direction;
  cutmode:OPTIONAL cutmode_type;
END_ENTITY;

```

feed\_direction: 铣削加工的进给方向。如果给出了 cutmode 属性,cutmode 优先级高于本属性。

cutmode: 宜指定逆铣或顺铣。默认值为逆铣。

#### 4.2.8.1.2 双向铣削(bidirectional milling)

曲折形铣削。例如,从一侧运动到另一侧,然后返回。为进一步描述该铣削策略,也许会指定曲折铣削的两个方向。切削模式(顺铣或逆铣)是交替的。

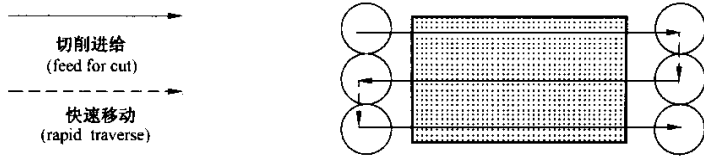


图 16 双向铣削

ENTITY bidirectional (\* ml \*)

SUBTYPE OF (two5D\_milling\_strategy);  
 feed\_direction: OPTIONAL direction;  
 stepover\_direction: OPTIONAL left\_or\_right;  
 its\_stroke\_connection\_strategy: OPTIONAL  
 stroke\_connection\_strategy;

END\_ENTITY;

feed\_direction: 铣削加工中第一个刀具轨迹的进给方向。  
 stepover\_direction: 曲折形加工中的刀具轨迹行距方向。  
 its\_stroke\_connection\_strategy: 指定行程之间的刀具行为。

4.2.8.1.3 左向或右向(left or right)

指定相对于进给方向的行距方向。

TYPE left\_or\_right = ENUMERATION OF (left, right);  
 END\_TYPE;

4.2.8.1.4 行程连接策略(stroke connection strategy)

描述双向铣削加工中刀具状态的枚举程序。

TYPE stroke\_connection\_strategy = ENUMERATION OF  
 (straghtline, lift\_shift\_plunge, degouge, loop\_back);  
 END\_TYPE;

4.2.8.1.5 沿轮廓铣削(contour parallel milling)

沿特征轮廓的几条轨迹铣削。典型应用为槽铣削。刀具行距方向(outside-in 或 inside-out)自动从 rotation\_direction 和 cutmode 中派生。

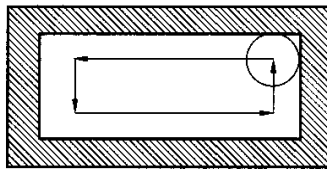


图 17 沿轮廓铣削

ENTITY contour\_parallel (\* ml \*)

SUBTYPE OF (two5D\_milling\_strategy);  
 rotation\_direction: OPTIONAL rot\_direction;  
 cutmode: OPTIONAL cutmode\_type;

END\_ENTITY;

rotation\_direction: 从特征顶部看螺旋线方向(顺时针或逆时针)。默认值为逆时针方向。如果给定了 cutmode 属性, cutmode 属性优先级高于本属性。  
 cutmode: 宜指定顺铣或逆铣。默认值为逆铣。cutmode 与侧铣加工中的轮廓相关, 例如型腔和可能的凸台的外轮廓。

## 4.2.8.1.6 先双向后轮廓铣削(bidirectional and contour milling)

首先使用双向方式轮廓铣削,最后一轮沿特征轮廓轨迹铣削。

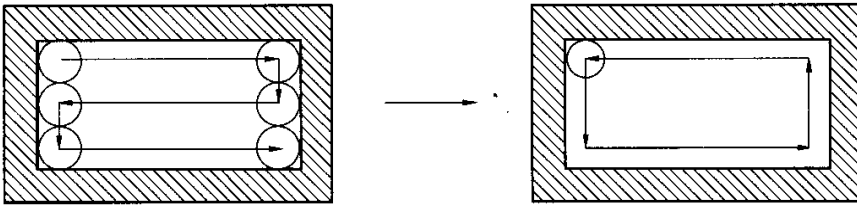


图 18 先双向后轮廓铣削

ENTITY bidirectional\_contour (\* m1\* )

SUBTYPE OF (two5D\_milling\_strategy);  
 feed\_direction: OPTIONAL direction;  
 stepover\_direction: OPTIONAL left\_or\_right;  
 rotation\_direction: OPTIONAL rot\_direction;  
 spiral\_cutmode: OPTIONAL cutmode\_type;

END\_ENTITY;

feed\_direction: 铣削加工第一条轨迹的进给方向。如果给出了 first\_cutmode 属性, first\_cutmode 优先级高于本属性。

stepover\_direction: 曲折形加工中行距方向。

rotation\_direction: 从加工特征的顶部看最后一刀的螺旋线方向(顺时针或逆时针),默认值为逆时针方向。如果给出了 spiral\_cutmode 属性,该属性优先级高于 rotation\_direction。

spiral\_cutmode: 宜指定最后一刀中使用逆铣或顺铣。默认值为逆铣。刀具方式与侧铣加工中的轮廓相关,例如型腔和可能的凸台的外轮廓。

## 4.2.8.1.7 先轮廓后双向铣削(contour and bidirectional milling)

首先沿平行轮廓的轨迹铣削轮廓,然后双向铣削剩下的中心区域。

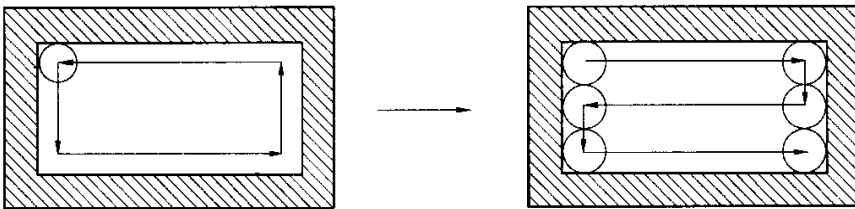


图 19 先轮廓后双向铣削

ENTITY contour\_bidirectional (\* m1\* )

SUBTYPE OF (two5D\_milling\_strategy);  
 feed\_direction: OPTIONAL direction;  
 stepover\_direction: OPTIONAL left\_or\_right;  
 rotation\_direction: OPTIONAL rot\_direction;  
 spiral\_cutmode: OPTIONAL cutmode\_type;

END\_ENTITY;

feed\_direction: 铣削加工第一条轨迹的进给方向。如果给出了 first\_cutmode 属性, first\_cutmode 优先级高于本属性。

stepover\_direction: 曲折形加工中行距方向。

rotation\_direction: 从加工特征的顶部看最后一刀的螺旋线方向(顺时针或逆时针), 默认值为逆时针。如果给出了 spiral\_cutmode 属性, spiral\_cutmode 优先级高于本属性。

spiral\_cutmode: 宜指定最后一刀中使用逆铣或顺铣。默认值为逆铣。切削方式与侧铣加工中的轮廓相关, 例如型腔的外轮廓和可能的凸台。

#### 4.2.8.1.8 轮廓螺旋铣(contour spiral milling)

轮廓螺旋铣与沿轮廓铣相似, 但与沿轮廓铣削加工不同的是, 轮廓螺旋铣的铣削路径完全是螺旋形的, 不是具有垂直运动的同心圆路径。刀具行距方向(outside-in 或 inside-out)是自动从 rotation\_direction 和 cutmode 中派生出来的。

```
ENTITY contour_spiral (* ml *)
  SUBTYPE OF (two5D_milling_strategy);
  rotation_direction; OPTIONAL rot_direction;
  cutmode; OPTIONAL cutmode_type;
```

END\_ENTITY;

rotation\_direction: 从特征顶部看螺旋线方向(顺时针或逆时针)。默认值为逆时针。如果给定了 cutmode 属性, cutmode 属性优先级高于本属性。

cutmode: 宜指定是逆铣或顺铣。默认值为逆铣, 切削方式与侧铣轮廓的壁相关。例如型腔的外轮廓和可能的凸台。

#### 4.2.8.1.9 中心铣削(center milling)

本实体描述了沿特征中心的铣削策略。它应用在例如沿槽中心的铣削。

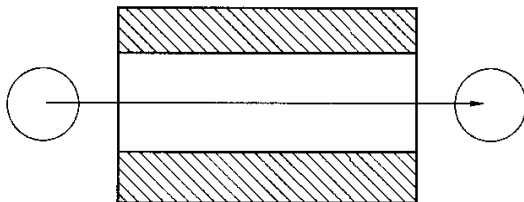


图 20 中心铣削

```
ENTITY center_milling (* ml *)
  SUBTYPE OF (two5D_milling_strategy);
  END_ENTITY;
```

#### 4.2.8.1.10 显式策略(explicit strategy)

当不能使用上述描述 2 轴半加工的各种加工策略, 必须指定显式策略。在这种情况下, 需要清楚地给出实体工步的 its\_toolpath 属性。

```
ENTITY explicit_strategy (* ml *)
  SUBTYPE OF (two5D_milling_strategy);
  END_ENTITY;
```

#### 4.2.9 平面铣削(plane milling)

本实体用于描述平面铣削。这是粗加工和精加工的父类。

```

ENTITY plane_milling (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(plane_rough_milling,plane_finish_milling))
  SUBTYPE OF (two5D_milling_operation);
  axial_cutting_depth;OPTIONAL length_measure;
  allowance_bottom;OPTIONAL length_measure;

```

END\_ENTITY;

axial\_cutting\_depth: 刀轴方向的切削深度。用于指定比特征深度所要求去除的材料量小的最大切削深度,这将导致分层加工。如果省略,按选择的切削深度加工。

allowance\_bottom: 由相关加工特征定义的平面表面顶部某层材料的余量。

#### 4.2.9.1 平面粗铣(plane rough milling)

粗加工铣削。除了 allowance\_bottom 外,使用给定的刀具去除在加工特征内的所有材料。

```

ENTITY plane_rough_milling (* m0 *)
  SUBTYPE OF (plane_milling);
WHERE
  WR1; EXISTS(SELF, allowance_bottom) AND
  (SELF. allowance_bottom >= 0.0);

```

END\_ENTITY;

#### 4.2.9.2 平面精铣(plane finish milling)

精加工铣削。使用适当的策略保证给定的公差,在加工特征内的所有材料将被去除。如果给定了 allowance\_bottom,应使用其他特殊操作譬如磨削来除去余下的材料。

```

ENTITY plane_finish_milling (* m0 *)
  SUBTYPE OF (plane_milling);

```

END\_ENTITY;

#### 4.2.10 侧铣(side milling)

本实体用于描述侧铣加工,即材料从刀具侧面去除。

```

ENTITY side_milling (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(side_rough_milling,side_finish_milling))
  SUBTYPE OF (two5D_milling_operation);
  axial_cutting_depth;OPTIONAL length_measure;
  radial_cutting_depth;OPTIONAL length_measure;
  allowance_side;OPTIONAL length_measure;

```

END\_ENTITY;

axial\_cutting\_depth: 刀轴方向的切削深度。参见平面铣削。

radial\_cutting\_depth: 垂直于刀轴的切削深度。该参数用于限制切削深度。如果 radial\_cutting\_depth 小于加工特征要求去除的材料宽度,将需多次加工操作。

allowance\_side: 由相关加工特征定义的侧面某层材料余量。

#### 4.2.10.1 粗侧铣(side rough milling)

粗加工侧铣。除了 allowance\_side 外,用给定的刀具去除在加工特征内的所有材料。

```

ENTITY side_rough_milling (* m0 *)
  SUBTYPE OF (side_milling);
WHERE
  WR1; EXISTS(SELF, allowance_side) AND (SELF. allowance_side >= 0.0);

```

END\_ENTITY;

#### 4.2.10.2 精侧铣(side finish milling)

精加工侧铣。使用适当的策略保证给定的公差,在加工特征内的所有材料将被去除。如果给出了 allowance\_side,应使用其他特殊加工,如磨削来去除余下的材料。

```
ENTITY side_finish_milling (* m0*)
  SUBTYPE OF (side_milling);
END_ENTITY;
```

#### 4.2.11 底面与侧面铣削(bottom and side milling)

实体描述了底面与侧面组合的铣削过程。

```
ENTITY bottom_and_side_milling (* m0*)
  ABSTRACT SUPERTYPE OF (ONEOF(bottom_and_side_rough_milling, bottom_and_
  side_finish_milling))
  SUBTYPE OF (two5D_milling_operation);
  axial_cutting_depth; OPTIONAL length_measure;
  radial_cutting_depth; OPTIONAL length_measure;
  allowance_side; OPTIONAL length_measure;
  allowance_bottom; OPTIONAL length_measure;
END_ENTITY
```

axial\_cutting\_depth: 刀具方向的切削深度。参见平面铣削。

radial\_cutting\_depth: 用于侧铣,垂直于刀具的切削深度。参见侧铣。

allowance\_side: 由相关加工特征定义的侧面某层材料余量。

allowance\_bottom: 由相关加工特征定义的平面表面某层材料余量。

##### 4.2.11.1 底面与侧面粗铣(bottom and side rough milling)

底面与侧面组合粗铣工步。除了 allowance\_side 和 allowance\_bottom 外,使用给定的刀具去除在加工特征内的所有材料。

```
ENTITY bottom_and_side_rough_milling (* m0*)
  SUBTYPE OF (bottom_and_side_milling);
WHERE
  WR1; EXISTS(SELF. allowance_side) AND (SELF. allowance_side >= 0.0);
  WR2; EXISTS(SELF. allowance_bottom) AND
  (SELF. allowance_bottom >= 0.0);
END_ENTITY;
```

##### 4.2.11.2 底面与侧面精铣(bottom and side finish milling)

底面与侧面组合精铣工步。使用适当的加工策略保证给定的公差,去除在加工特征内的所有材料。如果给出了 allowance\_side 和 allowance\_bottom,应使用其他特殊加工,如磨削来去除余下的材料。

```
ENTITY bottom_and_side_finish_milling (* m0*)
  SUBTYPE OF (bottom_and_side_milling);
END_ENTITY;
```

#### 4.2.12 钻削类型操作(drilling type operation)

这是与钻孔、绞孔、沉孔等相关的所有操作的基本类型。它是 milling\_machining\_operation 实体的子类,这里也包含了切削螺纹。基本类型提供了所有描述钻类加工工艺和策略的必要属性。对于预钻孔,在完成钻孔前,先通过指定比特征小的钻孔深度(或合适的刀具)进行预钻孔。通过指定已去除材料的 previous\_diameter 属性进行后继钻孔加工。

起始点从继承属性 retract\_plane 和 cut\_start\_point 中给定,如果省略 cut\_start\_point,隐含特征的

中心将会替代它。从那里开始刀具将沿局部坐标系 Z 轴钻削进给。使用先前描述的策略,对通孔将使用继承属性 `overcut_length`, 刀具将钻到相关特征的深度。对预钻孔加工, `cutting_depth` 属性可以用于减小比孔深小的切削深度。退刀时, 刀具将以钻孔进给速度或从 `drilling_type_strategy` 中指定的 `feed_on_retract` 速度(如果给定的话)回到退刀面。

注: 在这些加工中所有几何信息都是在隐含特征的局部坐标系中给出。

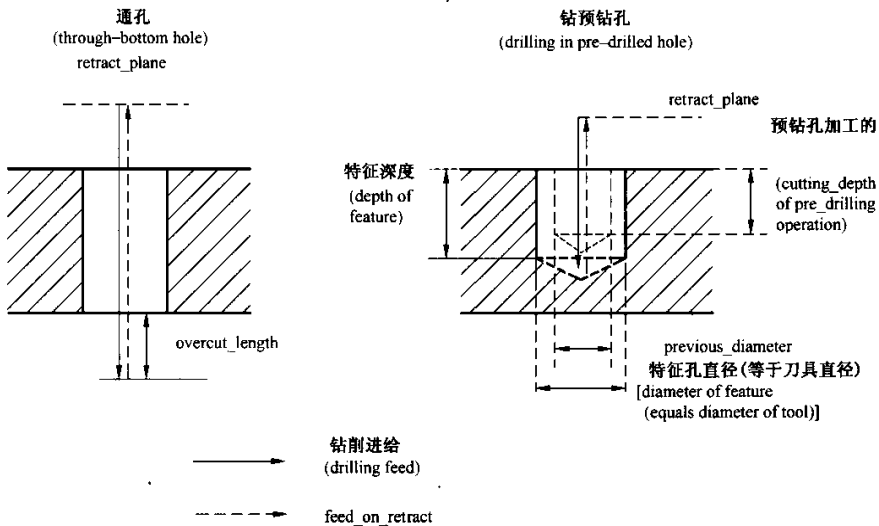


图 21 钻削类型操作

ENTITY `drilling_type_operation` (\* m0\* )

ABSTRACT SUPERTYPE OF (ONEOF(`drilling_operation`,  
`boring_operation`,  
`back_boring`, `tapping`, `thread_drilling`))  
SUBTYPE OF (`milling_machining_operation`);  
`cutting_depth`: OPTIONAL `length_measure`;  
`previous_diameter`: OPTIONAL `length_measure`;  
`dwelt_time_bottom`: OPTIONAL `time_measure`;  
`feed_on_retract`: OPTIONAL `positive_ratio_measure`;  
`its_machining_strategy`: OPTIONAL `drilling_type_strategy`;  
END\_ENTITY;

`cutting_depth`: 加工中的切削深度, 该深度与孔的深度不同。如果 `cutting_depth` 超出了孔特征的边界, NC 控制器将不会检测该项。如果省略了该项, 将钻至特征的全部深度。中心孔加工时, `cutting_depth` 是从切削尖端的最低点到孔的最高点测量距离。在其他情况下, 从刀具圆柱体部分的起点来测量(或锥形刀具钻削中的锥体部分)。

`previous_diameter`: 如果在预钻孔或预制孔上操作, 若给定, 这个值规定已存在的孔的直径。于是它描述了刀具去除的材料量, 它仅仅用于提供相关信息。

`dwelt_time_bottom`: 在孔底部可能的暂停时间。

`feed_on_retract`: 钻孔进给速度与用于退刀到 `retract_plane` 的速度的比率, 如果没有指定, 使用钻孔进给速度。

`its_machining_strategy`: 加工策略。如果父类的 `its_toolpath` 属性指定后, 该策略仅为提示信息。

注：钻削加工不仅仅用于孔类，还用于其他特征类型。例如，插式钻孔加工可用于槽加工。但是，在与刀具相关的情况下，如果特征的整个深度都被钻削，特征的底部也许会被损坏（参见图 21）。为了避免这种情况，每次可以指定较小的 cutting\_depth。并且，这对于非旋转特征用它来明确指定继承属性 cut\_start\_point 也是可取的。

4.2.12.1 钻削类型策略(drilling type strategy)

这是钻削专用策略的详细说明。对于钻削，主要涉及刀具运动的切削速度和进给速度。

```
ENTITY drilling_type_strategy; (* m0 *)
    reduced_cut_at_start; OPTIONAL positive_ratio_measure;
    reduced_feed_at_start; OPTIONAL positive_ratio_measure;
    depth_of_start; OPTIONAL length_measure;
    reduced_cut_at_end; OPTIONAL positive_ratio_measure;
    reduced_feed_at_end; OPTIONAL positive_ratio_measure;
    depth_of_end; OPTIONAL length_measure;
WHERE
    WR1: EXISTS(depth_of_start) OR NOT (EXISTS(reduced_cut_at_start)
    OR EXISTS(reduced_feed_at_start));
    WR2: EXISTS(depth_of_end) OR NOT (EXISTS(reduced_cut_at_end)
    OR EXISTS(reduced_feed_at_end));
```

END\_ENTITY;

- reduced\_cut\_at\_start: 在切削开始时以编程指定值的百分比来降低切削速度。
- reduced\_feed\_at\_start: 在切削开始时以编程指定值的百分比来降低进给速度。
- depth\_of\_start: 在开始处深度减少值有效。
- reduced\_cut\_at\_end: 在切削结束时以编程指定值的百分比来降低切削速度。
- reduced\_feed\_at\_end: 在切削结束时以编程指定值的百分比来降低进给速度。
- depth\_of\_end: 在结束处深度减少值有效。

4.2.13 钻削操作(drilling operation)

与钻削、中心钻削、沉孔钻削和分步钻削有关的钻削操作的基本类型。

```
ENTITY drilling_operation (* m0 *)
    ABSTRACT SUPERTYPE OF (ONEOF(drilling, center_drilling, counter_sinking,
    multistep_drilling))
    SUBTYPE OF (drilling_type_operation);
END_ENTITY;
```

4.2.13.1 钻削(drilling)

普通孔钻削工步。

```
ENTITY drilling (* m0 *)
    SUBTYPE OF (drilling_operation);
END_ENTITY;
```

4.2.13.2 中心钻削(center drilling)

中心孔钻削工步。

```
ENTITY center_drilling (* m0 *)
    SUBTYPE OF (drilling_operation);
END_ENTITY;
```

4.2.13.3 沉头孔钻削(counter sinking)

沉头孔钻削工步。

```
ENTITY counter_sinking (* m0 *)
  SUBTYPE OF (drilling_operation);
END_ENTITY;
```

#### 4.2.13.4 分步钻削(multistep drilling)

深孔分步钻削工步。

```
ENTITY multistep_drilling (* m0 *)
  SUBTYPE OF (drilling_operation);
  retract_distance: length_measure;
  first_depth: length_measure;
  depth_of_step: length_measure;
  dwell_time_step: OPTIONAL time_measure;
END_ENTITY;
```

retract\_distance: 如果 retract\_distance 为正值, 刀具在各工步间回退到该值高度来排屑。如果为 0 或负值, 刀具在各工步间退刀到退刀平面来清除孔屑。

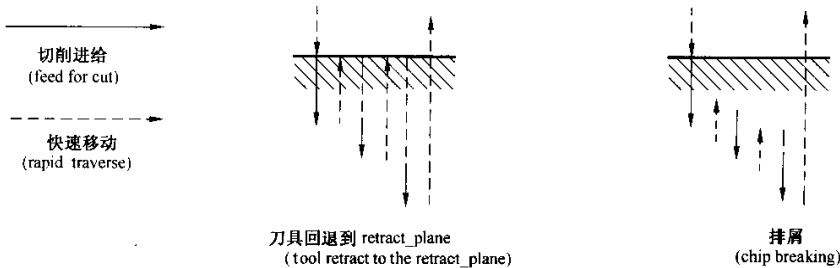


图 22 分步钻削

first\_depth: 第一步深度。  
 depth\_of\_step: 每步深度(重复直到到达孔的深度)。  
 dwell\_time\_step: 各步间的暂停时间。

注: 如果需要更复杂的钻削加工(例如对特殊刀具), 这可以通过工步的 its\_toolpath 属性中明确的刀具轨迹定义来指定。

#### 4.2.14 镗削操作(boring operation)

与镗孔和绞孔相关的镗削操作的基本类型。宜给定在底部的主轴方位。

```
ENTITY boring_operation (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(boring, reaming))
  SUBTYPE OF (drilling_type_operation);
  spindle_stop_at_bottom: BOOLEAN;
  depth_of_testcut: OPTIONAL length_measure;
  waiting_position: OPTIONAL cartesian_point;
END_ENTITY;
```

spindle\_stop\_at\_bottom: 主轴在孔底部可能停止。如果在工步中指定了 oriented\_spindle\_stop 属性, 将引起主轴定向停止。

depth\_of\_testcut: 测量孔试切后的深度。

waiting\_position: 刀具等待位置, 例如, 测量时。刀具沿刀轴移出孔外直到到达 waiting\_position 平面, 然后它自己运动到等待位置。

4.2.14.1 镗孔(boring)

镗孔工步。

```
ENTITY boring (* m0 *)
    SUBTYPE OF (boring_operation);
END_ENTITY;
```

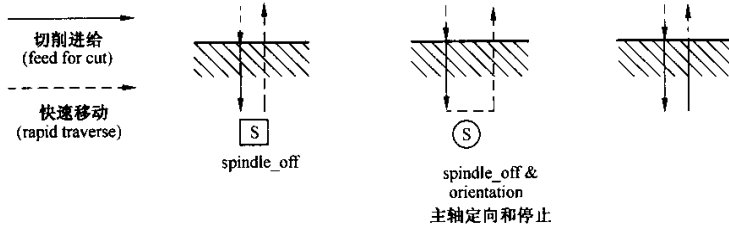


图 23 镗孔

4.2.14.2 绞孔(reaming)

绞孔工步。

```
ENTITY reaming (* m0 *)
    SUBTYPE OF (boring_operation);
END_ENTITY;
```

4.2.15 背镗(back boring)

背镗工步。背镗用于加工通孔的背面。当刀具定位到起始点后，主轴停止在由 milling\_cutting\_tool 的属性 direction\_of\_spindle\_orientation 所指定的位置上。为了快速穿过孔，刀具移动到与 direction\_of\_spindle\_orientation 相反的位置。在孔的底部，刀具返回到移动值大小的切削位置，主轴开始旋转。在特殊刀具中切削刃可以隐藏到刀具体里，在穿过孔和反向后，主轴停下来。Its\_machining\_funcions 的 oriented\_spindle\_stop 属性是需要的，该属性将使可伸缩的背镗孔刀具必须定向主轴停止。

```
ENTITY back_boring (* m0 *)
    SUBTYPE OF (drilling_type_operation);
WHERE
    WR1: EXISTS(SELF, its_machine_functions, oriented_spindle_stop);
END_ENTITY;
```

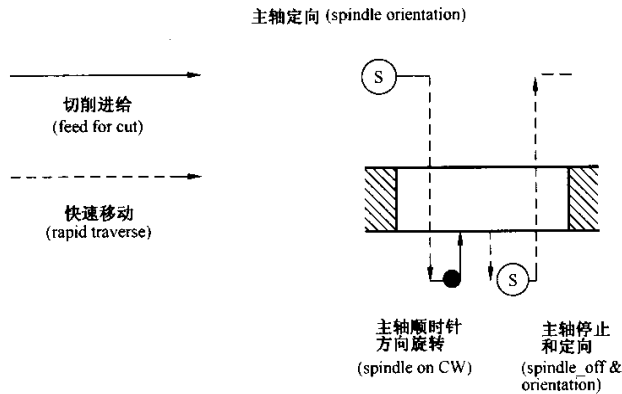


图 24 背退镗孔

注：如果需要更复杂的镗孔加工(例如，对于特殊刀具)，这可以通过在工步的 its\_toolpath 属性中明确的刀具轨迹定义来指定。

#### 4.2.16 攻丝(tapping)

攻丝工步。这要使用能转动和沿刀轴移动的特殊刀具来完成。

ENTITY tapping (\* m0\*)

SUBTYPE OF (drilling\_type\_operation);

compensation\_chuck; BOOLEAN;

END\_ENTITY;

compensation\_chuck: 如果为真,补偿夹具应用于攻丝孔。

#### 4.2.17 螺纹钻削(thread drilling)

孔螺纹钻削工步。这包含刀具的螺旋运动。有时候也称为“thrilling”,作为“螺纹钻削”的简称。前进运动中可有螺旋运动,也可以没有。每转进给量是通过孔的螺纹来计算的。螺旋运动的螺距与螺纹的螺距相关。进给速率是刀尖与螺旋轨迹材料之间的相对速度。

ENTITY thread\_drilling (\* m0\*)

SUBTYPE OF (drilling\_type\_operation);

helical\_movement\_on\_forward; BOOLEAN;

END\_ENTITY;

helical\_movement\_on\_forward: 指定前进运动中是否需要螺旋运动。

#### 4.3 模式结束(end schema)

END\_SCHEMA; (\* milling\_schema\*)

### 5 一致性要求(conformance requirements)

GB/T 19903 的本部分一致性包括满足本部分规定的要求,满足实现支持的方法要求,满足相关标准化的参考文献的要求。

关于实现方法要求请见附录 C。

GB/T 19903 的本部分提供了一系列被实现支持的选项。这些选项将被一致性的 6 个类型来支持。这些一致性类型描述如下:

- 一致性类型 1——c0m0;曲线集合最小集和加工数据最小集。
- 一致性类型 2——c0m0m1;类型 1 加上加工数据全集,特别是加工特征。
- 一致性类型 3——s0c0m0m1;类型 2 加上曲面几何最小集。
- 一致性类型 4——s0slc0clm0m1;类型 3 加上曲面几何全集。
- 一致性类型 5——t0t1s0c0m0m1;类型 3 加上拓扑信息。
- 一致性类型 6——t0t1s0slc0clm0m1;类型 4 加上拓扑信息。

为了便于实现各种类型集(m0/m1,c0/cl,s0/sl,t0/t1)标识符可在附录 A 中 EXPRESS 列表中查询每个数据集的成员。在 GB/T 19903 的本部分定义的实体属于 m0 或 m1 之一,在下面描述中,一致性类型 3,4,5,6 的列表与一致性类型 2 中的列表一样。

#### 5.1 一致性类型 1 实体(conformance class 1 entities)

GB/T 19903 的本部分一致性 1(m0)的实现将支持以下实体和相关的结构:

back\_boring

boring

boring\_operation

bottom\_and\_side\_finish\_milling

bottom\_and\_side\_milling

bottom\_and\_side\_rough\_milling

center\_drilling

counter\_sinking  
drilling  
drilling\_operation  
drilling\_type\_operation  
drilling\_type\_strategy  
exchange\_pallet  
five\_axes\_const\_tilt\_yaw  
freeform\_operation  
index\_pallet  
index\_table  
load\_tool  
milling\_machine\_functions  
milling\_machining\_operation  
milling\_technology  
milling\_type\_operation  
multistep\_drilling  
plane\_finish\_milling  
plane\_milling  
plane\_rough\_milling  
reaming  
side\_finish\_milling  
side\_milling  
side\_rough\_milling  
tapping  
thread\_drilling  
three\_axes\_tilted\_tool  
tool\_direction\_for\_milling  
two5D\_milling\_operation  
unload\_tool

## 5.2 一致性类型 2 实体(conformance class 2 entities)

GB/T 19903 的本部分一致性 2(m1)的实现将支持以下实体和相关的结构:

adaptive\_control  
air\_strategy  
along\_path  
ap\_retract\_angle  
ap\_retract\_tangent  
approach\_retract\_strategy  
back\_boring  
bidirectional  
bidirectional\_contour  
boring  
boring\_operation  
bottom\_and\_side\_finish\_milling

bottom\_and\_side\_milling  
bottom\_and\_side\_rough\_milling  
center\_drilling  
center\_milling  
contour\_bidirectional  
contour\_parallel  
contour\_spiral  
counter\_sinking  
drilling  
drilling\_operation  
drilling\_type\_operation  
drilling\_type\_strategy  
exchange\_pallet  
explicit\_strategy  
five\_axes\_const\_tilt\_yaw  
five\_axes\_var\_tilt\_yaw  
freeform\_operation  
freeform\_strategy  
index\_pallet  
index\_table  
leading\_line\_strategy  
load\_tool  
milling\_machine\_functions  
milling\_machining\_operation  
milling\_technology  
milling\_type\_operation  
multistep\_drilling  
plane\_cc\_strategy  
plane\_cl\_strategy  
plane\_finish\_milling  
plane\_milling  
plane\_rough\_milling  
plunge\_helix  
plunge\_ramp  
plunge\_strategy  
plunge\_toolaxis  
plunge\_zigzag  
process\_model  
process\_model\_list  
reaming  
side\_finish\_milling  
side\_milling  
side\_rough\_milling

bottom\_and\_side\_milling  
bottom\_and\_side\_rough\_milling  
center\_drilling  
center\_milling  
contour\_bidirectional  
contour\_parallel  
contour\_spiral  
counter\_sinking  
drilling  
drilling\_operation  
drilling\_type\_operation  
drilling\_type\_strategy  
exchange\_pallet  
explicit\_strategy  
five\_axes\_const\_tilt\_yaw  
five\_axes\_var\_tilt\_yaw  
freeform\_operation  
freeform\_strategy  
index\_pallet  
index\_table  
leading\_line\_strategy  
load\_tool  
milling\_machine\_functions  
milling\_machining\_operation  
milling\_technology  
milling\_type\_operation  
multistep\_drilling  
plane\_cc\_strategy  
plane\_cl\_strategy  
plane\_finish\_milling  
plane\_milling  
plane\_rough\_milling  
plunge\_helix  
plunge\_ramp  
plunge\_strategy  
plunge\_toolaxis  
plunge\_zigzag  
process\_model  
process\_model\_list  
reaming  
side\_finish\_milling  
side\_milling  
side\_rough\_milling

tapping  
thread\_drilling  
three\_axes\_tilted\_tool  
tolerances  
tool\_direction\_for\_milling  
two5D\_milling\_operation  
two5D\_milling\_strategy  
unidirectional  
unload\_tool  
uv\_strategy

附 录 A  
(规范性附录)  
**EXPRESS 列表**

下列 EXPRESS 就是在第 4 章中给出的整个模式。当在短形式和扩展列表中存在任何差异时,必须使用扩展列表的相关内容。双字符标志用于一个实体表示该实体应属于一致性类型(见第 5 章)。

SCHEMA milling\_schema;

( \*

Version of April 30,2004

Author:ISO TC184/SC1/WG7

\* )

REFERENCE FROM support\_resource\_schema (\* ISO 10303-41e3\* )

(identifier,

label

);

REFERENCE FROM geometry\_schema (\* ISO 10303-42e3\* )

( bounded\_curve,

cartesian\_point,

direction

);

REFERENCE FROM measure\_schema (\* ISO 10303-41e3\* )

( length\_measure,

positive\_ratio\_measure,

time\_measure

);

REFERENCE FROM machining\_schema (\* ISO 14649-10\* )

( nc\_function,

machine\_functions,

machining\_operation,

machining\_tool,

material,

plane\_angle\_measure,

pressure\_measure,

property\_parameter,

rot\_direction,

rot\_speed\_measure,

speed\_measure,

technology,

toolpath\_list,

tool\_direction);

REFERENCE FROM milling\_machine\_tool\_schema (\* ISO 14649-111\* )

(milling\_cutting\_tool);

```

(* ***** *)
(* ***** *)
(* Types defined in process data for milling ISO 14649-11 *)
(* ***** *)
(* ***** *)
(* ***** *)
(* NC functions for milling *)
(* ***** *)
ENTITY exchange_pallet (* m0 *)
SUBTYPE OF (nc_function);
END_ENTITY;
ENTITY index_pallet (* m0 *)
SUBTYPE OF (nc_function);
its_index: INTEGER;
END_ENTITY;
ENTITY index_table (* m0 *)
SUBTYPE OF (nc_function);
its_index: INTEGER;
END_ENTITY;
ENTITY load_tool (* m0 *)
SUBTYPE OF (nc_function);
its_tool: machining_tool;
END_ENTITY;
ENTITY unload_tool (* m0 *)
SUBTYPE OF (nc_function);
its_tool: OPTIONAL machining_tool;
END_ENTITY;
(* ***** *)
(* Technology-specific Tool direction select *)
(* ***** *)
ENTITY tool_direction_for_milling (* m0 *)
ABSTRACT SUPERTYPE OF (ONEOF(three_axes_tilted_tool, five_axes_var_tilt_yaw,
five_axes_const_tilt_yaw))
SUBTYPE OF (tool_direction);
END_ENTITY;
ENTITY three_axes_tilted_tool (* m0 *)
SUBTYPE OF (tool_direction_for_milling);
its_tool_direction: direction;
END_ENTITY;
ENTITY five_axes_var_tilt_yaw (* m1 *)
SUBTYPE OF (tool_direction_for_milling);
END_ENTITY;
ENTITY five_axes_const_tilt_yaw (* m0 *)

```

```

SUBTYPE OF (tool_direction_for_milling);
tilt_angle: plane_angle_measure;
yaw_angle: plane_angle_measure;
END_ENTITY;
( * ..... *)
( * Base class for technology specific operation and strategy * )
( * ..... *)
ENTITY milling_machining_operation ( * m0 * )
ABSTRACT SUPERTYPE OF (ONEOF(milling_type_operation,
drilling_type_operation))
SUBTYPE OF (machining_operation);
overcut_length: OPTIONAL length_measure;
WHERE
WR1: (EXISTS(SELF. its_technology. feedrate_per_tooth) AND
      EXISTS(SELF. its_tool. number_of_effective_teeth))
      OR (NOT (EXISTS(SELF. its_technology. feedrate_per_tooth)));
END_ENTITY;
( * ..... *)
( * Milling technology * )
( * ..... *)
ENTITY milling_technology ( * m0 * )
SUBTYPE OF (technology);
cutspeed: OPTIONAL speed_measure;
spindle: OPTIONAL rot_speed_measure;
feedrate_per_tooth: OPTIONAL length_measure;
synchronize_spindle_with_feed: BOOLEAN;
inhibit_feedrate_override: BOOLEAN;
inhibit_spindle_override: BOOLEAN;
its_adaptive_control: OPTIONAL adaptive_control;
WHERE
WR1: (EXISTS(cutspeed) AND NOT EXISTS(spindle))
      OR (EXISTS(spindle) AND NOT EXISTS(cutspeed))
      OR (EXISTS(its_adaptive_control));
WR2: (EXISTS(SELF. feedrate) AND NOT EXISTS(feedrate_per_tooth))
      OR (EXISTS(feedrate_per_tooth) AND NOT EXISTS(SELF. feedrate))
      OR (EXISTS(its_adaptive_control));
END_ENTITY;
ENTITY adaptive_control; ( * m1 * )
END_ENTITY;
( * ..... *)
( * Milling machine functions * )
( * ..... *)
ENTITY milling_machine_functions ( * m0 * )

```

```

SUBTYPE OF (machine_functions);
coolant;BOOLEAN;
coolant_pressure;OPTIONAL pressure_measure;
mist;OPTIONAL BOOLEAN;
through_spindle_coolant;BOOLEAN;
through_pressure;OPTIONAL pressure_measure;
axis_clamping;LIST [0:?] OF identifier;
chip_removal;BOOLEAN;
oriented_spindle_stop;OPTIONAL direction;
its_process_model;OPTIONAL process_model_list;
other_functions;SET [0:?] OF property_parameter;
END_ENTITY;
ENTITY process_model_list; (* m1 *)
    its_list;LIST [1:?] OF process_model;
END_ENTITY;
ENTITY process_model; (* m1 *)
    ini_data_file;label;
    its_type;label;
END_ENTITY;
(* Milling type operation *)
(* ***** *)
ENTITY milling_type_operation (* m0 *)
    ABSTRACT SUPERTYPE OF (ONEOF(freeform_operation,two5D_milling_operation))
    SUBTYPE OF (milling_machining_operation);
    approach;OPTIONAL approach_retract_strategy;
    retract;OPTIONAL approach_retract_strategy;
END_ENTITY;
(* ***** *)
(* approach retract strategy *)
(* ***** *)
ENTITY approach_retract_strategy (* m1 *)
    ABSTRACT SUPERTYPE OF (ONEOF(plunge_strategy,air_strategy,along_path));
    tool_orientation;OPTIONAL direction;
END_ENTITY;
ENTITY plunge_strategy (* m1 *)
    ABSTRACT SUPERTYPE OF (ONEOF(plunge_toolaxis,plunge_ramp,plunge_helix,plunge_
zigzag))
    SUBTYPE OF (approach_retract_strategy);
END_ENTITY;
ENTITY plunge_toolaxis (* m1 *)
    SUBTYPE OF (plunge_strategy);
END_ENTITY;

```

```

ENTITY plunge_ramp (* m1 * )
    SUBTYPE OF (plunge_strategy);
    angle:plane_angle_measure;
END_ENTITY;
ENTITY plunge_helix (* m1 * )
    SUBTYPE OF (plunge_strategy);
    radius:length_measure;
    angle:plane_angle_measure;
END_ENTITY;
ENTITY plunge_zigzag (* m1 * )
    SUBTYPE OF (plunge_strategy);
    angle:plane_angle_measure;
    width:length_measure;
END_ENTITY;
ENTITY air_strategy (* m1 * )
    ABSTRACT SUPERTYPE OF (ONEOF (ap_retract_angle,ap_retract_tangent))
    SUBTYPE OF (approach_retract_strategy);
END_ENTITY;
ENTITY ap_retract_angle (* m1 * )
    SUBTYPE OF (air_strategy);
    angle:plane_angle_measure;
    travel_length:length_measure;
END_ENTITY;
ENTITY ap_retract_tangent (* m1 * )
    SUBTYPE OF (air_strategy);
    radius:length_measure;
END_ENTITY;
ENTITY along_path (* m1 * )
    SUBTYPE OF (approach_retract_strategy);
    path:toolpath_list;
END_ENTITY;
(* ***** *)
(* Freeform operation *)
(* ***** *)
ENTITY freeform_operation (* m0 * )
    SUBTYPE OF (milling_type_operation);
    its_machining_strategy:OPTIONAL freeform_strategy;
END_ENTITY;
(* ***** *)
(* Freeform strategy *)
(* ***** *)
ENTITY freeform_strategy (* m1 * )
    ABSTRACT SUPERTYPE OF (ONEOF (uv_strategy,plane_cc_strategy,

```

```

    plane_cl_strategy,leading_line_strategy));
    pathmode:pathmode_type;
    cutmode:cutmode_type;
    its_milling_tolerances:tolerances;
    stepover:OPTIONAL length_measure;
END_ENTITY;
TYPE pathmode_type = ENUMERATION OF (
    forward,
    zigzag
);
END_TYPE;
TYPE cutmode_type = ENUMERATION OF (
    climb,
    conventional
);
END_TYPE;
ENTITY tolerances; (* ml *)
    chordal_tolerance:length_measure;
    scallop_height:length_measure;
END_ENTITY;
ENTITY uv_strategy (* ml *)
    SUBTYPE OF (freeform_strategy);
    forward_direction:direction;
    sideward_direction:direction;
END_ENTITY;
ENTITY plane_cc_strategy (* ml *)
    SUBTYPE OF (freeform_strategy);
    its_plane_normal:direction;
END_ENTITY;
ENTITY plane_cl_strategy (* ml *)
    SUBTYPE OF (freeform_strategy);
    its_plane_normal:direction;
END_ENTITY;
ENTITY leading_line_strategy (* ml *)
    SUBTYPE OF (freeform_strategy);
    its_line:bounded_curve;
END_ENTITY;
(* ***** *)
(* two5D_milling operation *)
(* ***** *)
ENTITY two5D_milling_operation (* m0 *)
    ABSTRACT SUPERTYPE OF (ONEOF(plane_milling,side_milling,bottom_and_side_milling))
    SUBTYPE OF (milling_type_operation);

```

```

    its_machining_strategy:OPTIONAL two5D_milling_strategy;
END_ENTITY;
(* ***** *)
(* two5D_milling_strategy *)
(* ***** *)
ENTITY two5D_milling_strategy (* m1 *)
    ABSTRACT SUPERTYPE OF ( ONEOF ( unidirectional, bidirectional, contour _ parallel,
    bidirectional_contour, contour_bidirectional, contour_spiral, center_milling, explicit_strategy));
    overlap:OPTIONAL positive_ratio_measure;
    allow_multiple_passes:OPTIONAL BOOLEAN;
END_ENTITY;
ENTITY unidirectional (* m1 *)
    SUBTYPE OF (two5D_milling_strategy);
    feed_direction:OPTIONAL direction;
    cutmode:OPTIONAL cutmode_type;
END_ENTITY;
ENTITY bidirectional (* m1 *)
    SUBTYPE OF (two5D_milling_strategy);
    feed_direction:OPTIONAL direction;
    stepover_direction:OPTIONAL left_or_right;
    its_stroke_connection_strategy:OPTIONALs troke_connection_strategy;
END_ENTITY;
TYPE left_or_right = ENUMERATION OF (left,right);
END_TYPE;
TYPE stroke_connection_strategy = ENUMERATION OF
    (straghtline, lift_shift_plunge, degouge, loop_back);
END_TYPE;
ENTITY contour_parallel (* m1 *)
    SUBTYPE OF (two5D_milling_strategy);
    rotation_direction:OPTIONAL rot_direction;
    cutmode:OPTIONAL cutmode_type;
END_ENTITY;
ENTITY bidirectional_contour (* m1 *)
    SUBTYPE OF (two5D_milling_strategy);
    feed_direction:OPTIONAL direction;
    stepover_direction:OPTIONAL left_or_right;
    rotation_direction:OPTIONAL rot_direction;
    spiral_cutmode:OPTIONAL cutmode_type;
END_ENTITY;
ENTITY contour_bidirectional (* m1 *)
    SUBTYPE OF (two5D_milling_strategy);
    feed_direction:OPTIONAL direction;
    stepover_direction:OPTIONAL left_or_right;

```

```

rotation_direction; OPTIONAL rot_direction;
spiral_cutmode; OPTIONAL cutmode_type;
END_ENTITY;
ENTITY contour_spiral (* m1 *)
  SUBTYPE OF (two5D_milling_strategy);
  rotation_direction; OPTIONAL rot_direction;
  cutmode; OPTIONAL cutmode_type;
END_ENTITY;
ENTITY center_milling (* m1 *)
  SUBTYPE OF (two5D_milling_strategy);
END_ENTITY;
ENTITY explicit_strategy (* m1 *)
  SUBTYPE OF (two5D_milling_strategy);
END_ENTITY;
(* ***** *)
(* plane_milling, side_milling, bottom_and_side_milling *)
(* ***** *)
ENTITY plane_milling (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(plane_rough_milling, plane_finish_milling))
  SUBTYPE OF (two5D_milling_operation);
  axial_cutting_depth; OPTIONAL length_measure;
  allowance_bottom; OPTIONAL length_measure;
END_ENTITY;
ENTITY plane_rough_milling (* m0 *)
  SUBTYPE OF (plane_milling);
WHERE
  WR1; EXISTS(SELF. allowance_bottom) AND (SELF. allowance_bottom >= 0.0);
END_ENTITY;
ENTITY plane_finish_milling (* m0 *)
  SUBTYPE OF (plane_milling);
END_ENTITY;
ENTITY side_milling (* m0 *)
  ABSTRACT SUPERTYPE OF (ONEOF(side_rough_milling, side_finish_milling))
  SUBTYPE OF (two5D_milling_operation);
  axial_cutting_depth; OPTIONAL length_measure;
  radial_cutting_depth; OPTIONAL length_measure;
  allowance_side; OPTIONAL length_measure;
END_ENTITY;
ENTITY side_rough_milling (* m0 *)
  SUBTYPE OF (side_milling);
WHERE
  WR1; EXISTS(SELF. allowance_side) AND (SELF. allowance_side >= 0.0);
END_ENTITY;

```

ENTITY side\_finish\_milling (\* m0 \*)

SUBTYPE OF (side\_milling);

END\_ENTITY;

ENTITY bottom\_and\_side\_milling (\* m0 \*)

ABSTRACT SUPERTYPE OF (ONEOF (bottom\_and\_side\_rough\_milling, bottom\_and\_side\_finish\_milling))

SUBTYPE OF (two5D\_milling\_operation);

axial\_cutting\_depth; OPTIONAL length\_measure;

radial\_cutting\_depth; OPTIONAL length\_measure;

allowance\_side; OPTIONAL length\_measure;

allowance\_bottom; OPTIONAL length\_measure;

END\_ENTITY;

ENTITY bottom\_and\_side\_rough\_milling (\* m0 \*)

SUBTYPE OF (bottom\_and\_side\_milling);

WHERE

WR1; EXISTS(SELF.allowance\_side) AND (SELF.allowance\_side >= 0.0);

WR2; EXISTS(SELF.allowance\_bottom) AND (SELF.allowance\_bottom >= 0.0);

END\_ENTITY;

ENTITY bottom\_and\_side\_finish\_milling (\* m0 \*)

SUBTYPE OF (bottom\_and\_side\_milling);

END\_ENTITY;

(\* \*\*\*\*\* \*)

(\* Drilling type operation \*)

(\* \*\*\*\*\* \*)

ENTITY drilling\_type\_operation (\* m0 \*)

ABSTRACT SUPERTYPE OF (ONEOF (drilling\_operation, boring\_operation, back\_boring, tapping, thread\_drilling))

SUBTYPE OF (milling\_machining\_operation);

cutting\_depth; OPTIONAL length\_measure;

previous\_diameter; OPTIONAL length\_measure;

dwell\_time\_bottom; OPTIONAL time\_measure;

feed\_on\_retract; OPTIONAL positive\_ratio\_measure;

its\_machining\_strategy; OPTIONAL drilling\_type\_strategy;

END\_ENTITY;

(\* \*\*\*\*\* \*)

(\* Drilling type strategy \*)

(\* \*\*\*\*\* \*)

ENTITY drilling\_type\_strategy; (\* m0 \*)

reduced\_cut\_at\_start; OPTIONAL positive\_ratio\_measure;

reduced\_feed\_at\_start; OPTIONAL positive\_ratio\_measure;

depth\_of\_start; OPTIONAL length\_measure;

reduced\_cut\_at\_end; OPTIONAL positive\_ratio\_measure;

reduced\_feed\_at\_end:OPTIONAL positive\_ratio\_measure;  
depth\_of\_end:OPTIONAL length\_measure;

WHERE

WR1:EXISTS(depth\_of\_start) OR NOT (EXISTS(reduced\_cut\_at\_start)  
OR EXISTS(reduced\_feed\_at\_start));

WR2:EXISTS(depth\_of\_end) OR NOT (EXISTS(reduced\_cut\_at\_end)  
OR EXISTS(reduced\_feed\_at\_end));

END\_ENTITY;

(\* \*\*\*\*\* \*)

(\* Drilling operation \*)

(\* \*\*\*\*\* \*)

ENTITY drilling\_operation (\* m0 \*)

ABSTRACT SUPERTYPE OF (ONEOF (drilling, center\_drilling, counter\_sinking, multistep\_drilling))

SUBTYPE OF (drilling\_type\_operation);

END\_ENTITY;

ENTITY drilling (\* m0 \*)

SUBTYPE OF (drilling\_operation);

END\_ENTITY;

ENTITY center\_drilling (\* m0 \*)

SUBTYPE OF (drilling\_operation);

END\_ENTITY;

ENTITY counter\_sinking (\* m0 \*)

SUBTYPE OF (drilling\_operation);

END\_ENTITY;

ENTITY multistep\_drilling (\* m0 \*)

SUBTYPE OF (drilling\_operation);

retract\_distance:length\_measure;

first\_depth:length\_measure;

depth\_of\_step:length\_measure;

dwelt\_time\_step:OPTIONAL time\_measure;

END\_ENTITY;

(\* \*\*\*\*\* \*)

(\* Boring operation \*)

(\* \*\*\*\*\* \*)

ENTITY boring\_operation (\* m0 \*)

ABSTRACT SUPERTYPE OF (ONEOF(boring,reaming))

SUBTYPE OF (drilling\_type\_operation);

spindle\_stop\_at\_bottom:BOOLEAN;

depth\_of\_testcut:OPTIONAL length\_measure;

waiting\_position:OPTIONAL cartesian\_point;

END\_ENTITY;

ENTITY boring (\* m0 \*)

```
    SUBTYPE OF (boring_operation);
END_ENTITY;
ENTITY reaming (* m0 *)
    SUBTYPE OF (boring_operation);
END_ENTITY;
ENTITY back_boring (* m0 *)
    SUBTYPE OF (drilling_type_operation);
WHERE
    WR1; EXISTS(SELF. its_machine_functions. oriented_spindle_stop);
END_ENTITY;
ENTITY tapping (* m0 *)
    SUBTYPE OF (drilling_type_operation);
    compensation_chuck; BOOLEAN;
END_ENTITY;
ENTITY thread_drilling (* m0 *)
    SUBTYPE OF (drilling_type_operation);
    helical_movement_on_forward; BOOLEAN;
END_ENTITY;
END_SCHEMA; (* milling_schema *)
```

附录 B  
(规范性附录)  
实体短名

表 B.1

实 体 名	短 名
ADAPTIVE_CONTROL	ADPCNT
AIR_STRATEGY	ARSTR
ALONG_PATH	ALNPTH
AP_RETRACT_ANGLE	APRTAN
AP_RETRACT_TANGENT	APRTTN
APPROACH_RETRACT_STRATEGY	APRTST
BACK_BORING	BCKBRN
BIDIRECTIONAL	BDRCTN
BIDIRECTIONAL_CONTOUR	BDRCNT
BORING	BORING
BORING_OPERATION	BRNOPR
BOTTOM_AND_SIDE_FINISH_MILLING	BASFM
BOTTOM_AND_SIDE_MILLING	BASM
BOTTOM_AND_SIDE_ROUGH_MILLING	BASRM
CENTER_DRILLING	CNTDRL
CENTER_MILLING	CNTMLL
CONTOUR_BIDIRECTIONAL	CNTBDR
CONTOUR_PARALLEL	CNTPRL
CONTOUR_SPIRAL	CNTSPR
COUNTER_SINKING	CNTSNK
DRILLING	DRLLNG
DRILLING_OPERATION	DRLOPR
DRILLING_TYPE_OPERATION	DRTYOP
DRILLING_TYPE_STRATEGY	DRTYST
EXCHANGE_PALLET	EXGPLL
EXPLICIT_STRATEGY	EXPSTR
FIVE_AXES_CONST_TILT_YAW	FACTY
FIVE_AXES_VAR_TILT_YAW	FAVTY
FREEFORM_OPERATION	FRFOPR
FREEFORM_STRATEGY	FRFSTR
INDEX_PALLET	INDPLL

表 B.1 (续)

实 体 名	短 名
INDEX_TABLE	INDTBL
LEADING_LINE_STRATEGY	LDLNST
LOAD_TOOL	LDTL
MILLING_MACHINE_FUNCTIONS	MLMCFN
MILLING_MACHINING_OPERATION	MLMCOP
MILLING_TECHNOLOGY	MLLTCH
MILLING_TYPE_OPERATION	MLTYOP
MULTISTEP_DRILLING	MLTDRL
PLANE_CC_STRATEGY	PLCCST
PLANE_CL_STRATEGY	PLCLST
PLANE_FINISH_MILLING	PLFNML
PLANE_MILLING	PLNMLL
PLANE_ROUGH_MILLING	PLRGML
PLUNGE_HELIX	PLNHLX
PLUNGE_RAMP	PLNRMP
PLUNGE_STRATEGY	PLNSTR
PLUNGE_TOOLAXIS	PLNTLX
PLUNGE_ZIGZAG	PLNZGZ
PROCESS_MODEL	PRCMDL
PROCESS_MODEL_LIST	PRMDLS
REAMING	RMNG
SIDE_FINISH_MILLING	SDFNML
SIDE_MILLING	SDMLL
SIDE_ROUGH_MILLING	SDRGML
TAPPING	TPPNG
THREAD_DRILLING	THRDRL
THREE_AXES_TILTED_TOOL	TATT
TOLERANCES	TLRNCS
TOOL_DIRECTION_FOR_MILLING	TDFM
TWO5D_MILLING_OPERATION	TWMLOP
TWO5D_MILLING_STRATEGY	TWMLST
UNIDIRECTIONAL	UNDRCT
UNLOAD_TOOL	UNLTL
UV_STRATEGY	UVSTR

**附 录 C**  
**(规范性附录)**  
**实现方法的具体要求**

实现方法定义了 GB/T 19903 本部分需要的交换类型。GB/T 19903 本部分的一致性应使用可交换结构来实现。该文件格式应根据语法和在 GB/T 16656.21 中定义的 EXPRESS 语言映射,以及本部分附录 A 中定义的带注释的清单来编。交换结构的标题应该使用 GB/T 19903 本部分中的模式名称“milling\_schema”来标识。

附录 D  
(资料性附录)  
EXPRESS-G 图

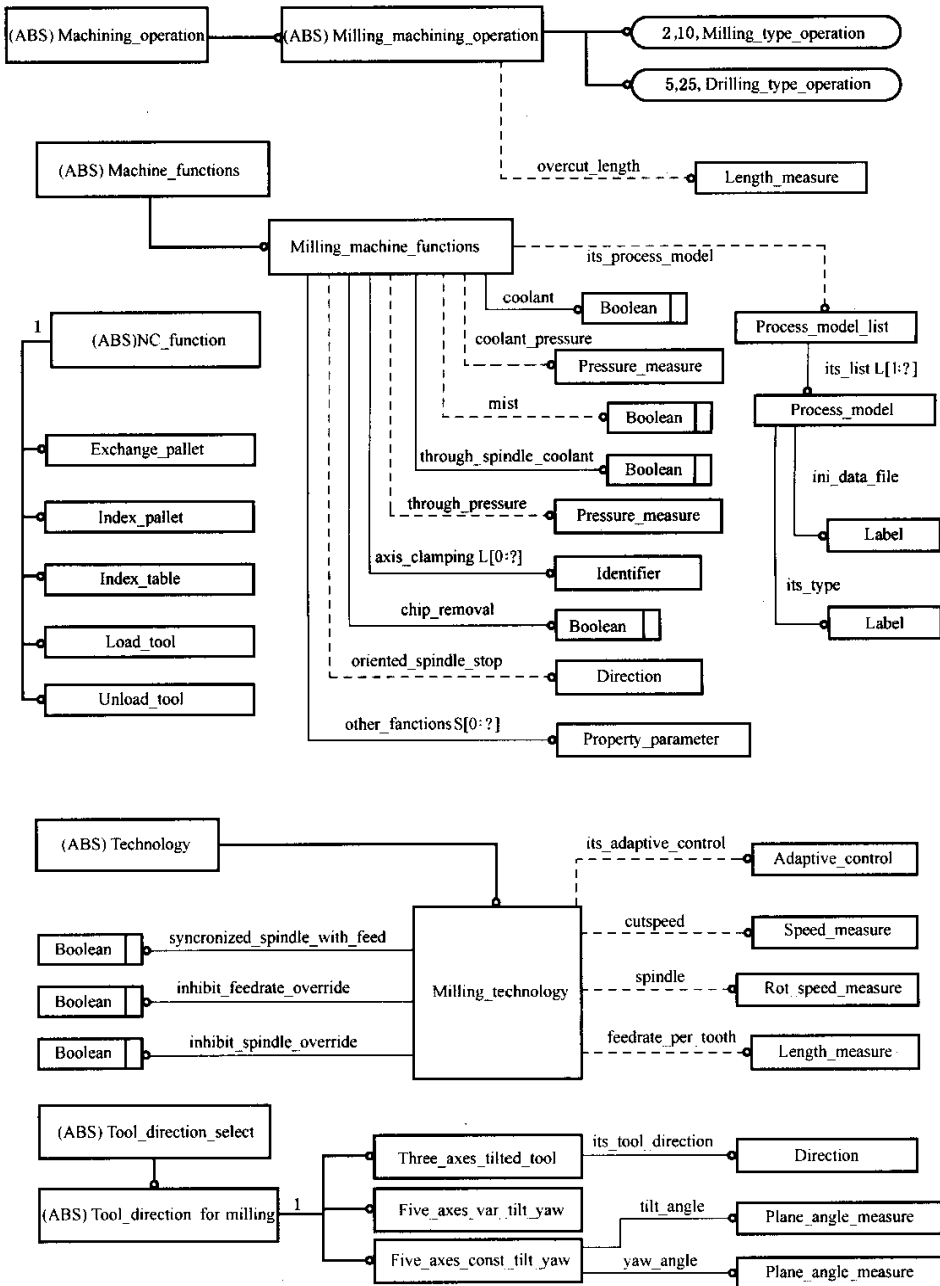


图 D. 1

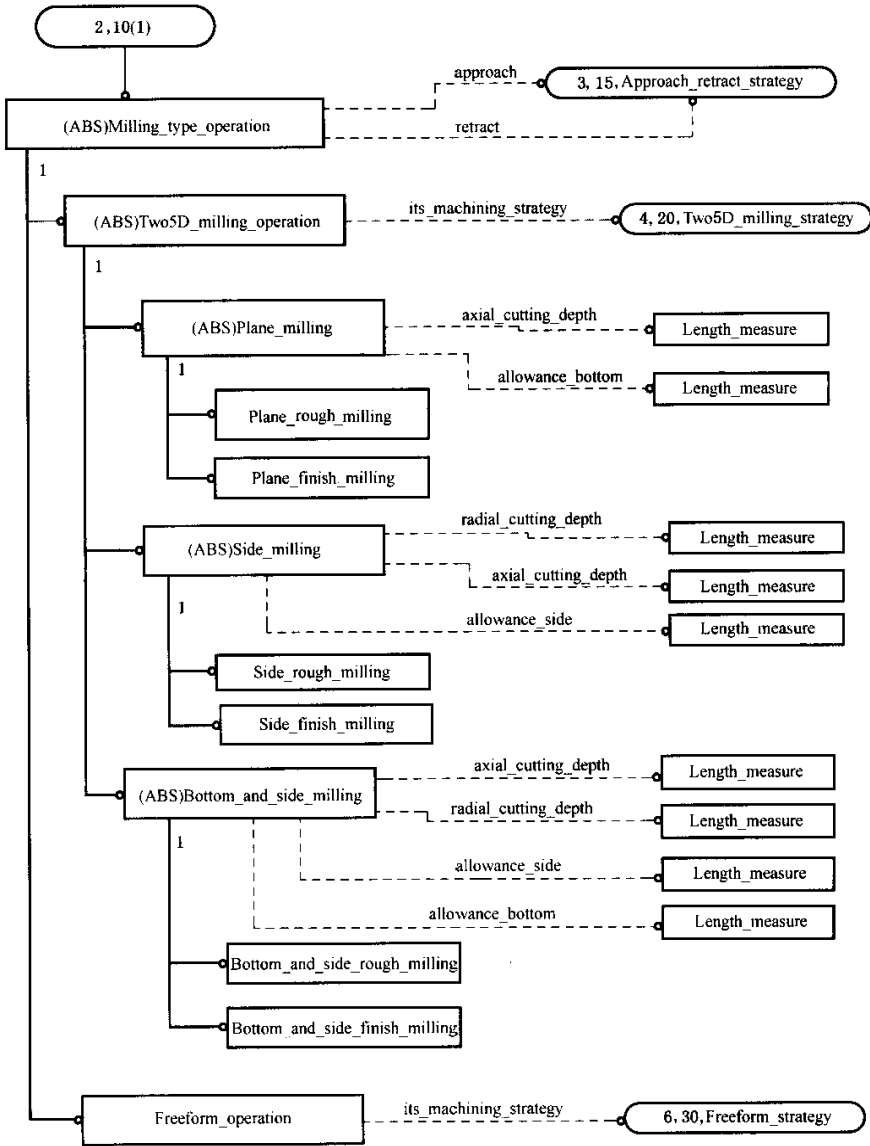


图 D. 2

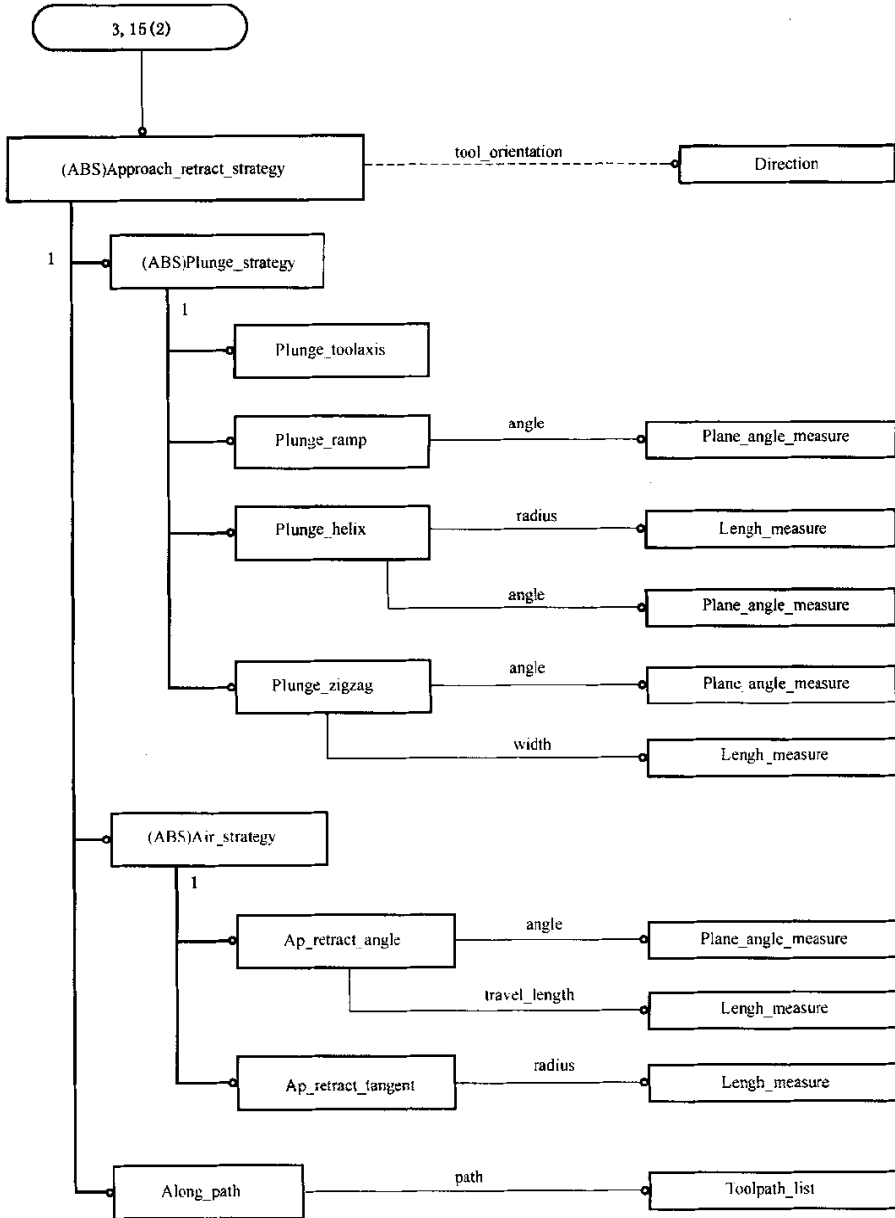


图 D.3

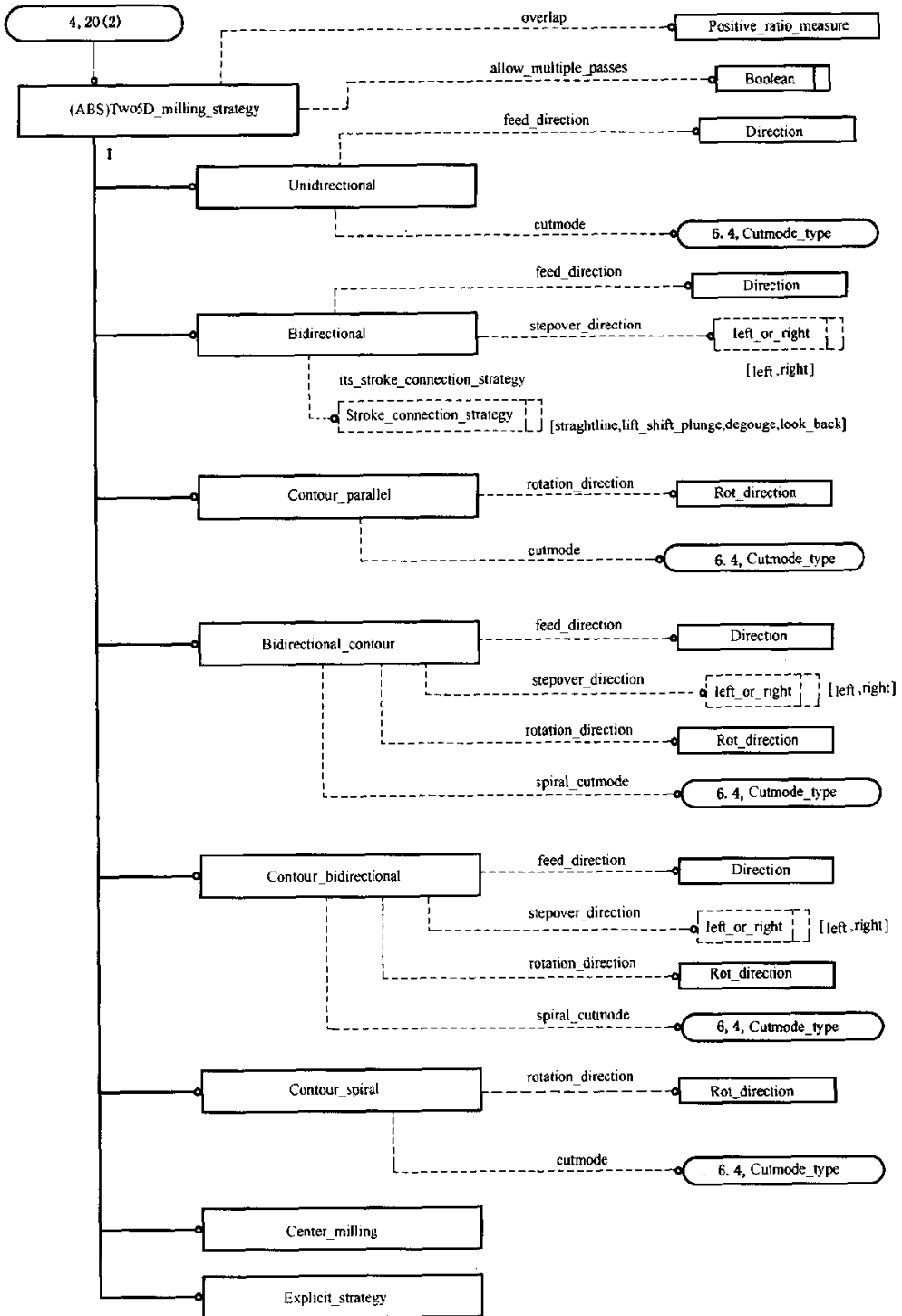


图 D. 4

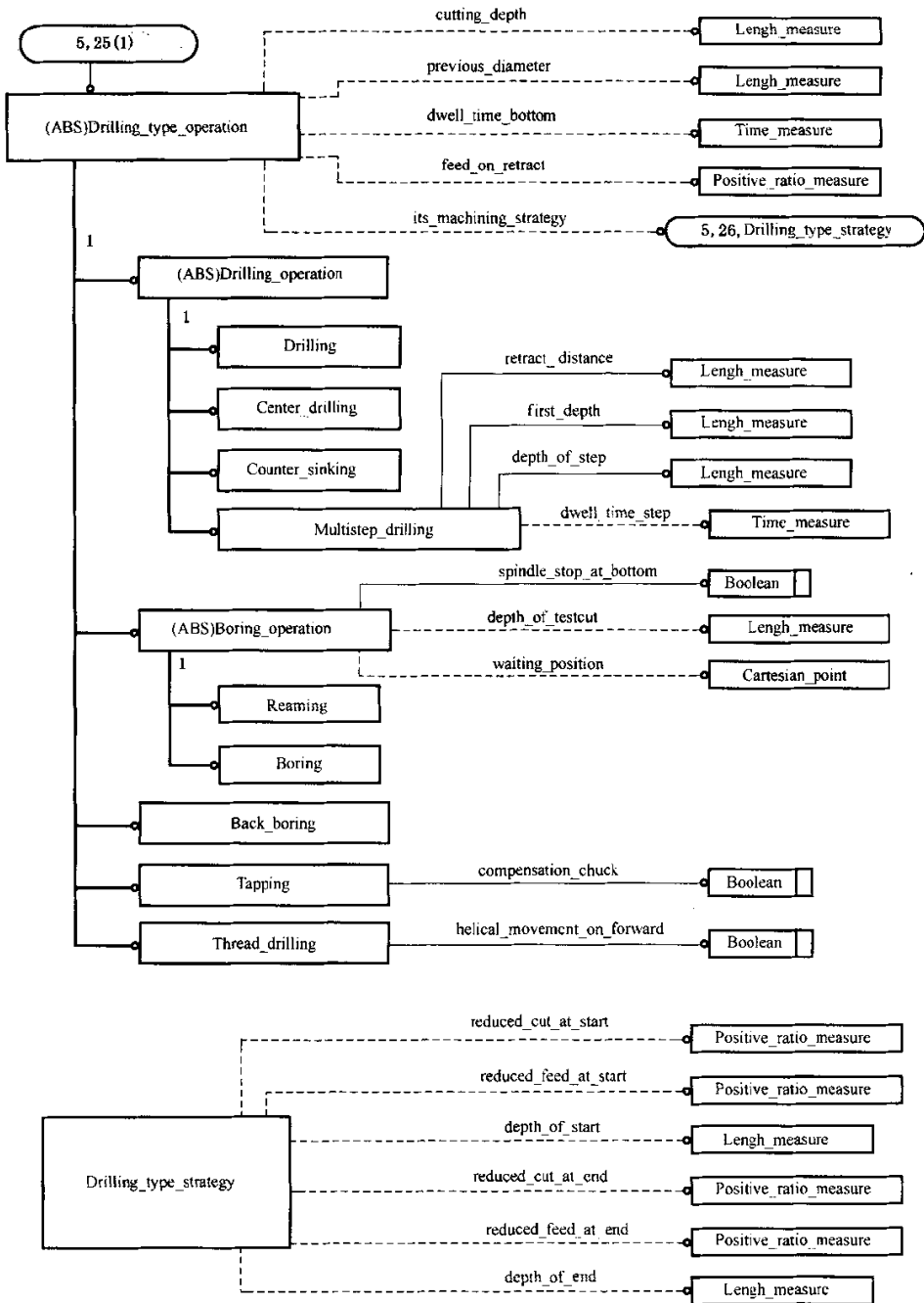


图 D.5

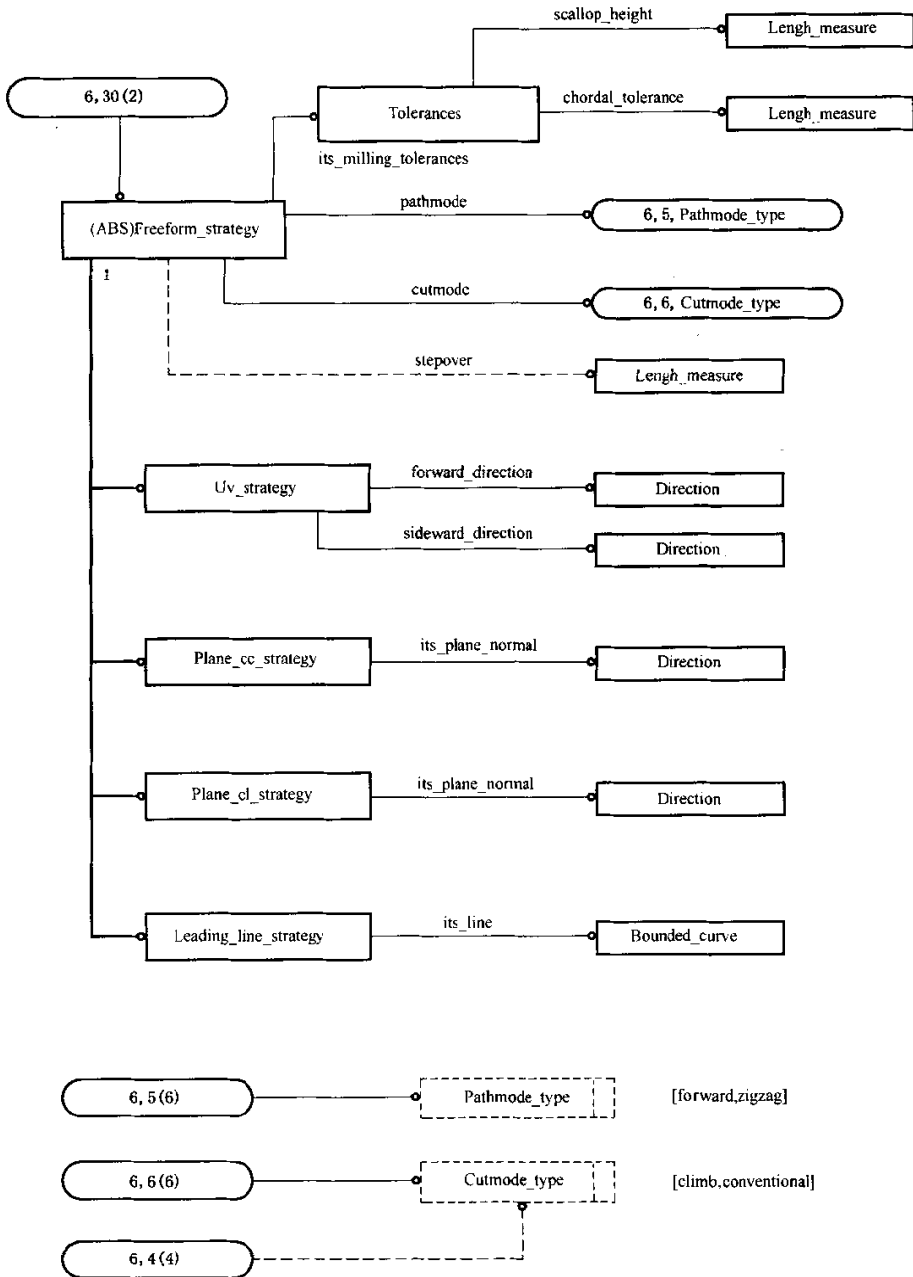


图 D. 6

附录 E  
(资料性附录)  
样本 NC 程序

## E.1 示例 1

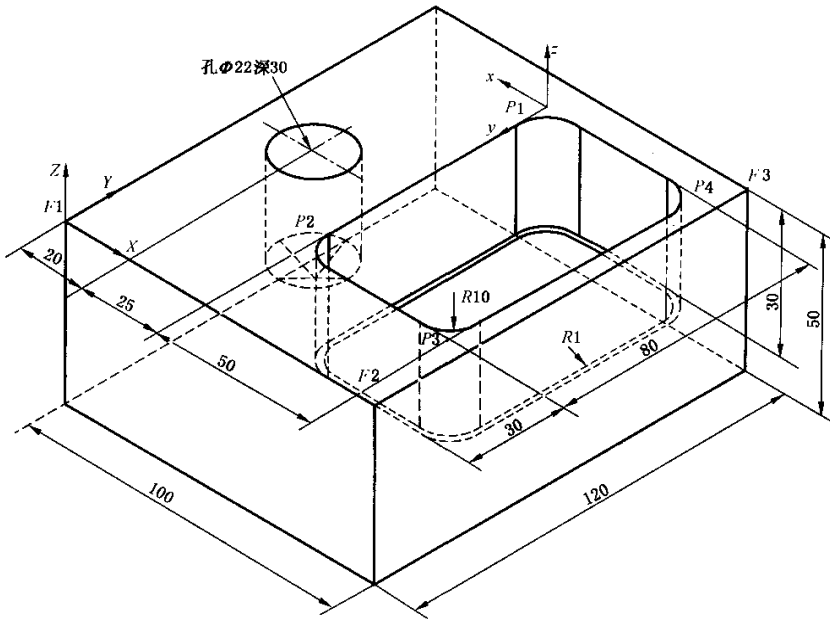


图 E.1 示例 1 的工件

```

ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('EXAMPLE 1'),'1');
FILE_NAME('EXAMPLE1.STP','2004-5-4T15-32-8','(AUTHOR)','( )','WZL
ISO 10303-PART21 PARSER
PACKAGE(' ',' ');
FILE_SCHEMA((( ' MACHINING _ SCHEMA', ' MILLING _ SCHEMA', ' MILLING _ TOOL _
SCHEMA')));
ENDSEC;
DATA;
# 1 = CARTESIAN _ POINT ( ' SECPLANE1; LOCATION ', (0.0000000000, 0.0000000000,
30.0000000000));
# 2 = DIRECTION( ' AXIS ', (0.0000000000, 0.0000000000, 1.0000000000));
# 3 = DIRECTION( ' REF_DIRECTION ', (1.0000000000, 0.0000000000, 0.0000000000));
# 4 = AXIS2_PLACEMENT_3D( ' PLANE1 ', # 1, # 2, # 3);
# 5 = ELEMENTARY_SURFACE( ' SECURITY PLANE ', # 4);

```

```

#6=PROPERTY_PARAMETER('E=200000N/M2');
#7=MATERIAL('ST-50','STEEL',( #6));
#8=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
#9=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
#10=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
#11=AXIS2_PLACEMENT_3D('', #8, #9, #10);
#12=BLOCK('BOUNDING STOCK', #11,100.0000000000,100.0000000000,100.0000000000);
#13=WORKPIECE('STOCK', #7,s,s,s, #12,());
#14 = CARTESIAN _ POINT (' CLAMPING _ POSITION1', (0.0000000000, 20.0000000000,
25.0000000000));
#15 = CARTESIAN _ POINT (' CLAMPING _ POSITION2', (100.0000000000, 20.0000000000,
25.0000000000));
#16 = CARTESIAN _ POINT (' CLAMPING _ POSITION3', (0.0000000000, 100.0000000000,
25.0000000000));
#17 = CARTESIAN _ POINT (' CLAMPING _ POSITION4', (100.0000000000, 100.0000000000,
25.0000000000));
#18 = WORKPIECE('SIMPLE WORKPIECE', #7,0.0100000000, #13,s,s,( #14, #15, #16,
#17));
#19=CUTTING_COMPONENT(80.0000000000,s,s,s);
#20 = ENDMILL (' MILL 20MM', ( #19, #19, #19, #19), 80.0000000000, 20.0000000000,
30.0000000000, .RIGHT. ,.F.,4,0.0500000000,s);
#21=MILLING_TECHNOLOGY(0.0400000000,.TCP.,s,12.0000000000,s,.F.,.F.,.F.,s);
#22=MILLING_MACHINE_FUNCTIONS(.T.,s,s,.F.,s,(),.T.,s,s,());
#23=PLUNGE_RAMP(s,45.0000000000);
#24=PLUNGE_RAMP(s,45.0000000000);
#25 = DIRECTION (' STRATEGY PLANAR FACE1: 1. DIRECTION', (0.0000000000,
1.0000000000,0.0000000000));
#26=BIDIRECTIONAL(5.0000000000,.T., #25,.LEFT.,s);
#27=PLANE_FINISH_MILLING(s,s,'FINISH PLANAR FACE1',10.0000000000,s, #20, #21,
#22,5.0000000000, #23, #24, #26,2.5000000000,s);
#28 = CARTESIAN _ POINT (' PLANAR FACE1: LOCATION ', (0.0000000000, 0.0000000000,
5.0000000000));
#29=DIRECTION(' AXIS ',(0.0000000000,0.0000000000,1.0000000000));
#30=DIRECTION(' REF_DIRECTION',(1.0000000000,0.0000000000,0.0000000000));
#31=AXIS2_PLACEMENT_3D('PLANAR FACE1', #28, #29, #30);
#32 = CARTESIAN _ POINT (' PLANAR FACE1: DEPTH ', (0.0000000000, 0.0000000000,
-5.0000000000));
#33=DIRECTION(' AXIS ',(0.0000000000,0.0000000000,1.0000000000));
#34=DIRECTION(' REF_DIRECTION',(1.0000000000,0.0000000000,0.0000000000));
#35=AXIS2_PLACEMENT_3D('PLANAR FACE1', #32, #33, #34);
#36=ELEMENTARY_SURFACE('PLANAR FACE1-DEPTH PLANE', #35);
#37=PLUS_MINUS_VALUE(0.3000000000,0.3000000000,3);
#38=TOLERANCED_LENGTH_MEASURE(120.0000000000, #37);

```

```

# 39 = DIRECTION (' COURSE OF TRAVEL DIRECTION', (0. 0000000000, 1. 0000000000,
0. 0000000000));
# 40=LINEAR_PATH(s, # 38, # 39);
# 41=NUMERIC_PARAMETER('PROFILE LENGTH', 100. 0000000000, 'MM');
# 42=LINEAR_PROFILE(s, # 41);
# 43=PLANAR_FACE('PLANAR FACE1', # 18, (# 27), # 31, # 36, # 40, # 42, s, ());
# 44=MACHINING_WORKINGSTEP('WS FINISH PLANAR FACE1', # 5, # 43, # 27, s);
# 45 = DRILLING _ CUTTING _ TOOL (' DRILL 20MM', ( ), 90. 0000000000, 20. 0000000000,
70. 0000000000, . RIGHT. , . F. , 120. 0000000000);
# 46=MILLING_TECHNOLOGY(0. 0300000000, . TCP. , s, 16. 0000000000, s, . F. , . F. , . F. , s);
# 47 = DRILLING _ TYPE _ STRATEGY ( 75. 0000000000, 50. 0000000000, 2. 0000000000,
50. 0000000000, 75. 0000000000, 8. 0000000000);
# 48 = DRILLING (s, s, ' DRILL HOLE1', 10. 0000000000, s, # 45, # 46, # 22, s, 30. 0000000000,
0. 0000000000, 0. 0000000000, s, # 47);
# 49 = REAMING _ CUTTING _ TOOL (' REAMER 22MM', ( # 19, # 19, # 19, # 19 ),
100. 0000000000, 22. 0000000000, 60. 0000000000, . RIGHT. , . F. , s);
# 50=MILLING_TECHNOLOGY(0. 0300000000, . TCP. , s, 18. 0000000000, s, . F. , . F. , . F. , s);
# 51=DRILLING_TYPE_STRATEGY(s, s, s, s, s);
# 52 = REAMING (s, s, ' REAM HOLE1', 10. 0000000000, s, # 49, # 50, # 22, s, 30. 0000000000,
20. 0000000000, 1. 0000000000, s, # 51, . T. , 5. 0000000000, s);
# 53 = CARTESIAN _ POINT (' HOLE1; LOCATION ', ( 20. 0000000000, 60. 0000000000,
0. 0000000000));
# 54=DIRECTION(' AXIS ', (0. 0000000000, 0. 0000000000, 1. 0000000000));
# 55=AXIS2_PLACEMENT_3D('HOLE1', # 53, # 54, s);
# 56=CARTESIAN_POINT('HOLE1;DEPTH ', (0. 0000000000, 0. 0000000000, -30. 0000000000));
# 57=DIRECTION(' AXIS ', (0. 0000000000, 0. 0000000000, 1. 0000000000));
# 58=DIRECTION(' REF_DIRECTION', (1. 0000000000, 0. 0000000000, 0. 0000000000));
# 59=AXIS2_PLACEMENT_3D('HOLE1', # 56, # 57, # 58);
# 60=ELEMENTARY_SURFACE('DEPTH SURFACE FOR ROUND HOLE1', # 59);
# 61=TOLERANCED_LENGTH_MEASURE(22. 0000000000, # 37);
# 62=THROUGH_BOTTOM_CONDITION();
# 63=ROUND_HOLE('HOLE1 D=22MM', # 18, (# 48, # 52), # 55, # 60, # 61, s, # 62);
# 64=MACHINING_WORKINGSTEP('WS DRILL HOLE1', # 5, # 63, # 48, s);
# 65=MACHINING_WORKINGSTEP('WS REAM HOLE1', # 5, # 63, # 52, s);
# 66=MILLING_TECHNOLOGY(s, . TCP. , s, 20. 0000000000, s, . F. , . F. , . F. , s);
# 67=CONTOUR_BIDIRECTIONAL(s, s, s, s, s);
# 68=BOTTOM_AND_SIDE_ROUGH_MILLING(s, s, 'ROUGH
POCKET1', 15. 0000000000, s, # 20, # 66, # 22, s, s, s, # 67, 2. 5000000000, 5. 0000000000,
1. 0000000000, 0. 5000000000);
# 69=MILLING_TECHNOLOGY(s, . TCP. , s, 20. 0000000000, s, . F. , . F. , . F. , s);
# 70=CONTOUR_PARALLEL(5. 0000000000, . T. , . CW. , . CONVENTIONAL. );
# 71=BOTTOM_AND_SIDE_FINISH_MILLING(s, s, 'FINISH
POCKET1', 15. 0000000000, s, # 20, # 69, # 22, s, s, s, # 70, 2. 0000000000, 10. 0000000000, s, s);

```

```

# 72 = CARTESIAN_POINT ('POCKET1: LOCATION ', (45.0000000000, 110.0000000000,
0.0000000000));
# 73 = DIRECTION ('AXIS ', (0.0000000000, 0.0000000000, 1.0000000000));
# 74 = DIRECTION ('REF_DIRECTION ', (-1.0000000000, 0.0000000000, 0.0000000000));
# 75 = AXIS2_PLACEMENT_3D ('POCKET1', # 72, # 73, # 74);
# 76 = CARTESIAN_POINT ('POCKET1: DEPTH ', (0.0000000000, 0.0000000000,
-30.0000000000));
# 77 = DIRECTION ('AXIS ', (0.0000000000, 0.0000000000, 1.0000000000));
# 78 = DIRECTION ('REF_DIRECTION ', (1.0000000000, 0.0000000000, 0.0000000000));
# 79 = AXIS2_PLACEMENT_3D ('POCKET1', # 76, # 77, # 78);
# 80 = ELEMENTARY_SURFACE ('DEPTH SURFACE FOR POCKET1', # 79);
# 81 = PLANAR_POCKET_BOTTOM_CONDITION ();
# 82 = PLUS_MINUS_VALUE (0.1000000000, 0.1000000000, 3);
# 83 = TOLERANCED_LENGTH_MEASURE (1.0000000000, # 82);
# 84 = PLUS_MINUS_VALUE (0.1000000000, 0.1000000000, 3);
# 85 = TOLERANCED_LENGTH_MEASURE (10.0000000000, # 84);
# 86 = CARTESIAN_POINT ('P1', (0.0000000000, 0.0000000000, 0.0000000000));
# 87 = CARTESIAN_POINT ('P2', (0.0000000000, 80.0000000000, 0.0000000000));
# 88 = CARTESIAN_POINT ('P3', (-50.0000000000, 80.0000000000, 0.0000000000));
# 89 = CARTESIAN_POINT ('P4', (-50.0000000000, 0.0000000000, 0.0000000000));
# 90 = POLYLINE ('CONTOUR OF POCKET1', (# 86, # 87, # 88, # 89, # 86));
# 91 = GENERAL_CLOSED_PROFILE (s, # 90);
# 92 = CLOSED_POCKET ('POCKET1', # 18, (# 68, # 71), # 75, # 80, (), s, # 81, # 83, # 85,
# 91);
# 93 = MACHINING_WORKINGSTEP ('WS ROUGH POCKET1', # 5, # 92, # 68, s);
# 94 = MACHINING_WORKINGSTEP ('WS FINISH POCKET1', # 5, # 92, # 71, s);
# 95 = CARTESIAN_POINT ('SETUP1: LOCATION ', (150.0000000000, 90.0000000000,
40.0000000000));
# 96 = DIRECTION ('AXIS ', (0.0000000000, 0.0000000000, 1.0000000000));
# 97 = DIRECTION ('REF_DIRECTION ', (1.0000000000, 0.0000000000, 0.0000000000));
# 98 = AXIS2_PLACEMENT_3D ('SETUP1', # 95, # 96, # 97);
# 99 = CARTESIAN_POINT ('WORKPIECE1: LOCATION ', (0.0000000000, 0.0000000000,
0.0000000000));
# 100 = DIRECTION ('AXIS ', (0.0000000000, 0.0000000000, 1.0000000000));
# 101 = DIRECTION ('REF_DIRECTION ', (1.0000000000, 0.0000000000, 0.0000000000));
# 102 = AXIS2_PLACEMENT_3D ('WORKPIECE', # 99, # 100, # 101);
# 103 = NC_VARIABLE ('', 0.0000000000);
# 104 = NC_VARIABLE ('', 0.0000000000);
# 105 = OFFSET_VECTOR ((# 103, # 103, # 103), (# 104, # 104, # 104));
# 106 = WORKPIECE_SETUP (# 18, # 102, # 105, s, ());
# 107 = SETUP ('SETUP1', # 98, # 5, (# 106));
# 108 = WORKPLAN ('MAIN WORKPLAN', (# 44, # 64, # 65, # 93, # 94), s, # 107, s);
# 109 = PROJECT ('EXECUTE EXAMPLE1', # 108, (# 18), s, s, s);

```

ENDSEC;  
 END-ISO-10303-21;  
 E.2 示例 2

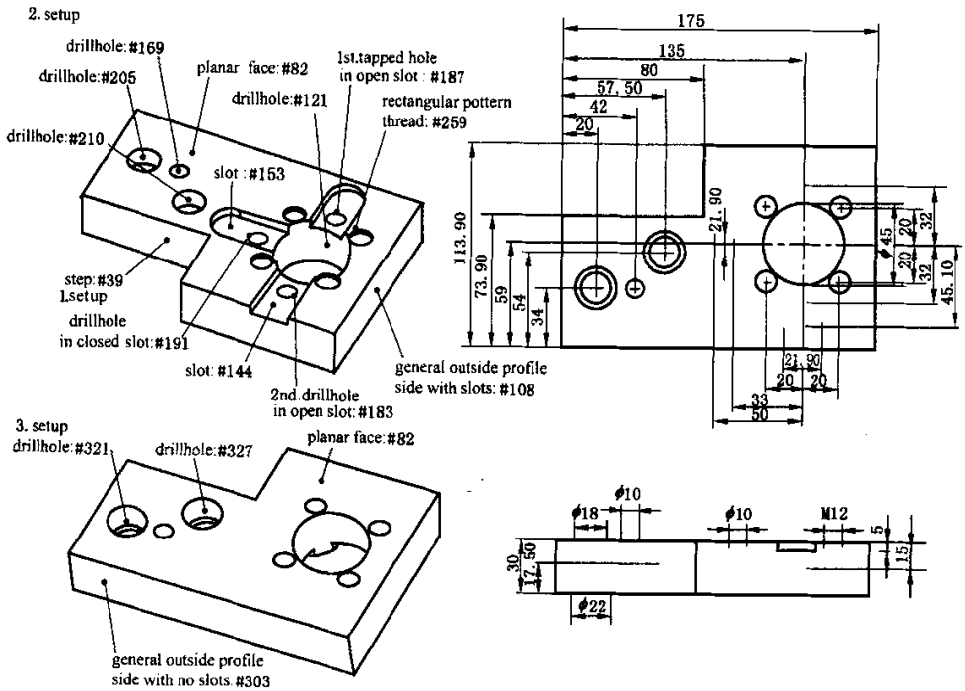


图 E.2 示例 2 的工件

```

ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('EXAMPLE 2'), '1');
FILE_NAME('EXAMPLE1. STP', '2004-5-4T16-32-8', ('AUTHOR'), (''), 'WZL
ISO 10303-PART21 PARSER
PACKAGE', '', '');
FILE_SCHEMA((( 'MACHINING_SCHEMA', 'MILLING_SCHEMA',
MILLING_TOOL_SCHEMA)));
ENDSEC;
DATA;
#1=CARTESIAN_POINT('LOCATION', (0.000000000, 0.000000000, 35.000000000));
#2=DIRECTION('AXIS', (0.000000000, 0.000000000, 1.000000000));
#3=DIRECTION('REF-DIR', (1.000000000, 0.000000000, 0.000000000));
#4=AXIS2_PLACEMENT_3D('', #1, #2, #3);
#5=PLANE('SECPLANE OF PLANAR FACE:STEP', #4);
#6=PROPERTY_PARAMETER('');
#7=MATERIAL('', '', (#6));
    
```

```

#8=CARTESIAN_POINT('',(-2.5000000000,-2.5000000000,-2.5000000000));
#9=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
#10=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
#11=AXIS2_PLACEMENT_3D('',#8,#9,#10);
#12=BLOCK('BOUNDING BOX OF STOCK',#11,180.0000000000,118.9000000000,
35.0000000000);
#13=WORKPIECE('STOCK',#7,s,s,s,#12,());
#14=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
#15=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
#16=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
#17=AXIS2_PLACEMENT_3D('',#14,#15,#16);
#18=BLOCK('BOUNDING BOX OF FINAL PART',#17,175.0000000000,113.9000000000,
30.0000000000);
#19=WORKPIECE('FINISHED PART',#7,0.0010000000,#13,s,#18,());
#20=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
#21=MILLING_TECHNOLOGY(s,.CCP.,s,100.0000000000,0.1000000000,s,s,s,s);
#22=CUTTING_COMPONENT(123.0000000000,s,987.0000000000,#21);
#23=ENDMILL('ENDMILL 40MM',( #22, #22, #22, #22),123.0000000000,40.0000000000,
60.0000000000,.RIGHT.,.F.,4,0.2000000000,0.0000000000);
#24=MILLING_MACHINE_FUNCTIONS(.F.,s,.F.,.F.,s,(),.F.,s,s,());
#25=BOTTOM_AND_SIDE_FINISH_MILLING(s,s,'OPERATION FOR FINISH MILLING OF
A STEP',10.0000000000,#20,#23,#21,#24,4.0000000000,s,s,s,8.0000000000,5.0000000000,
0.0000000000,0.0000000000);
#26=CARTESIAN_POINT('LOCATION',(0.0000000000,0.0000000000,0.0000000000));
#27=DIRECTION('AXIS',(0.0000000000,-1.0000000000,0.0000000000));
#28=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
#29=AXIS2_PLACEMENT_3D('PLACEMENT OF THE STEP RELATIVE TO THE
WORKPIECE',#26,#27,#28);
#30=CARTESIAN_POINT('LOCATION',(0.0000000000,0.0000000000,-40.0000000000));
#31=DIRECTION('AXIS',(0.0000000000,0.0000000000,1.0000000000));
#32=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
#33=AXIS2_PLACEMENT_3D('',#30,#31,#32);
#34=ELEMENTARY_SURFACE('DEPTH OF STEP',#33);
#35=PLUS_MINUS_VALUE(80.1000000000,79.9000000000,2);
#36=TOLERANCED_LENGTH_MEASURE(80.0000000000,#35);
#37=DIRECTION('DIRECTION OF OPEN BOUNDARY OF STEP',(1.0000000000,
0.0000000000,0.0000000000));
#38=LINEAR_PATH(s,#36,#37);
#39=STEP('STEP',#19,(#25),#29,#34,#38,s,());
#40=MACHINING_WORKINGSTEP('WORKINGSTEP TO MACHINE THE STEP',#5,#39,
#25,s);
#41=CARTESIAN_POINT('',(-60.0000000000,80.0000000000,250.0000000000));
#42=DIRECTION('Z 0 0 -1',(0.0000000000,0.0000000000,-1.0000000000));

```

```

# 43=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 44=AXIS2_PLACEMENT_3D('',# 41,# 42,# 43);
# 45=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
# 46=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
# 47=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 48=AXIS2_PLACEMENT_3D('',# 45,# 46,# 47);
# 49=NC_VARIABLE('',0.0000000000);
# 50=NC_VARIABLE('',0.0000000000);
# 51=OFFSET_VECTOR((# 49,# 49,# 49),(# 50,# 50,# 50));
# 52=WORKPIECE_SETUP(# 19,# 48,# 51,s,());
# 53=SETUP('SETUP FOR MACHINING STEP',# 44,s,(# 52));
# 54=WORKPLAN('WORKPLAN FOR FIRST SETUP - STEP',(# 40),s,# 53,s);
# 55=CARTESIAN_POINT('',(0.0000000000,0.0000000000,30.0000000000));
# 56=DIRECTION('Z-DIRECTION 0 0 +1',(0.0000000000,0.0000000000,1.0000000000));
# 57=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 58=AXIS2_PLACEMENT_3D('',# 55,# 56,# 57);
# 59=PLANE('SECURITY PLANE',# 58);
# 60=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
# 61=MILLING_TECHNOLOGY(s,.CCP.,s,100.0000000000,0.1000000000,.F.,.F.,.F.,s);
# 62=CUTTING_COMPONENT(160.0000000000,s,900.0000000000,# 61);
# 63=FACEMILL('FACEMILL 60MM',(# 62,# 62,# 62,# 62,# 62,# 62,# 62,# 62),
160.0000000000,60.0000000000,8.0000000000,.RIGHT.,.F.,8,0.2000000000,s);
# 64=MILLING_MACHINE_FUNCTIONS(.T.,s,s,s,(),.T.,s,s,());
# 65=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 66=BIDIRECTIONAL(0.5000000000,s,# 65,s,s);
# 67=PLANE_FINISH_MILLING(s,s,'PLANE FINISH MILLING
OPERATION',10.0000000000,# 60,# 63,# 61,# 64,10.0000000000,s,s,# 66,5.0000000000,
0.0000000000);
# 68=CARTESIAN_POINT('',(0.0000000000,0.0000000000,35.0000000000));
# 69=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
# 70=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 71=AXIS2_PLACEMENT_3D('',# 68,# 69,# 70);
# 72=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-5.0000000000));
# 73=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
# 74=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 75=AXIS2_PLACEMENT_3D('',# 72,# 73,# 74);
# 76=PLANE('',# 75);
# 77=PLUS_MINUS_VALUE(175.1000000000,174.9000000000,2);
# 78=TOLERANCED_LENGTH_MEASURE(175.0000000000,# 77);
# 79=PLUS_MINUS_VALUE(115.1000000000,114.9000000000,2);
# 80=TOLERANCED_LENGTH_MEASURE(115.0000000000,# 79);
# 81=RECTANGULAR_CLOSED_PROFILE(s,# 78,# 80);
# 82=PLANAR_FACE('PLANAR FACE AT THE SIDE WITH SLOTS',# 19,(# 67),# 71,# 76,

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s,s,#81,());
#83=MACHINING_WORKINGSTEP('MILL PLANAR FACE',#59,#82,#67,s);
#84=MILLING_TECHNOLOGY(s,.CCP.,s,100.0000000000,0.1000000000,.F.,F.,F.,s);
#85=CUTTING_COMPONENT(179.0000000000,s,987.0000000000,#84);
#86=ENDMILL('ENDMILL 20MM',( #85, #85, #85, #85),179.0000000000,20.0000000000,
45.0000000000,.RIGHT.,F.,4,0.2000000000,0.0000000000);
#87=MILLING_MACHINE_FUNCTIONS(F.,s,s,s,s,(),.F.,s,s,());
#88=UNIDIRECTIONAL(0.5000000000,s,s,s);
#89=BOTTOM_AND_SIDE_FINISH_MILLING(s,s,'OPERATION FOR FINISH MILLING OF
OUTSIDE PROFILES',10.0000000000,s,#86,#84,#87,10.0000000000,s,s,#88,5.0000000000,
10.0000000000,0.0000000000,0.0000000000);
#90=CARTESIAN_POINT('',(0.0000000000,0.0000000000,30.0000000000));
#91=DIRECTION('',(0.0000000000,0.0000000000,1.0000000000));
#92=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
#93=AXIS2_PLACEMENT_3D('PLACEMENT OF THE GENERAL OUTSIDE PROFILE
RELATIVE TO THE WORKPIECE',#90,#91,#92);
#94=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-30.0000000000));
#95=DIRECTION('Z-DIRECTION 0 0 1',(0.0000000000,0.0000000000,1.0000000000));
#96=DIRECTION('X-DIRECTION 1 0 0',(1.0000000000,0.0000000000,0.0000000000));
#97=AXIS2_PLACEMENT_3D('',#94,#95,#96);
#98=PLANE('DEPTH OF GENERAL OUTSIDE PROFILE - SIDE WITH SLOTS',#97);
#99=CARTESIAN_POINT('',(0.0000000000,113.9000000000,0.0000000000));
#100=CARTESIAN_POINT('',(0.0000000000,40.0000000000,0.0000000000));
#101=CARTESIAN_POINT('',(80.0000000000,40.0000000000,0.0000000000));
#102=CARTESIAN_POINT('',(80.0000000000,0.0000000000,0.0000000000));
#103=CARTESIAN_POINT('',(175.0000000000,0.0000000000,0.0000000000));
#104=CARTESIAN_POINT('',(175.0000000000,113.9000000000,0.0000000000));
#105=CARTESIAN_POINT('',(0.0000000000,113.9000000000,0.0000000000));
#106=POLYLINE('',(#99,#100,#101,#102,#103,#104,#105));
#107=GENERAL_CLOSED_PROFILE(s,#106);
#108=GENERAL_OUTSIDE_PROFILE('GENERAL OUTSIDE PROFILE ON SIDE WITH
SLOTS',#19,(#89),#93,#98,s,#107);
#109=MACHINING_WORKINGSTEP('GENERAL OUTSIDE PROFILE - SIDE WITH SLOTS',
#59,#108,#89,s);
#110=CARTESIAN_POINT('',(0.0000000000,0.0000000000,5.0000000000));
#111=UNIDIRECTIONAL(0.5000000000,s,s,s);
#112=BOTTOM_AND_SIDE_FINISH_MILLING(s,s,'CIRCULAR MILLING
OPERATION',10.0000000000,#110,#86,#84,#87,1.0000000000,s,s,#111,5.0000000000,
10.0000000000,0.0000000000,0.0000000000);
#113=CARTESIAN_POINT('',(135.0000000000,54.9000000000,30.0000000000));
#114=AXIS2_PLACEMENT_3D('PLACEMENT OF THE 40MM DRILLHOLE RELATIVE TO
THE WORKPIECE',#113,#91,#92);
#115=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-30.0000000000));

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#116=AXIS2_PLACEMENT_3D('', #115, #56, #57);
#117=PLANE('DEPTH OF THE 40MM DRILLHOLE', #116);
#118=PLUS_MINUS_VALUE(45.1000000000,44.9000000000,4);
#119=TOLERANCED_LENGTH_MEASURE(45.0000000000, #118);
#120=THROUGH_BOTTOM_CONDITION();
#121=ROUND_HOLE('DRILLHOLE 45MM', #19, (#112), #114, #117, #119,s, #120);
#122=MACHINING_WORKINGSTEP('CIRCULAR POCKET MILLING - DRILLHOLE 45MM',
#59, #121, #112,s);
#123=MILLING_TECHNOLOGY(s,. CCP. ,s,100.0000000000,0.1000000000,s,. F. ,. F. ,s);
#124=CUTTING_COMPONENT(132.0000000000,s,876.0000000000, #123);
#125=ENDMILL('ENDMILL 20', (#124, #124, #124), 132.0000000000, 20.0000000000,
40.0000000000,. RIGHT. ,. F. ,3,0.2000000000,0.0000000000);
#126=BOTTOM_AND_SIDE_FINISH_MILLING(s,s,'OPERATION FOR FINISH MILLING OF
SLOTS',10.0000000000, #110, #125, #123, #87, 0.0000000000, s, s, #111, 2.5000000000,
20.0000000000,0.0000000000,0.0000000000);
#127=CARTESIAN_POINT('',(135.0000000000,0.0000000000,30.0000000000));
#128=AXIS2_PLACEMENT_3D('POSITION 135-0-30', #127, #91, #57);
#129=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-5.0000000000));
#130=AXIS2_PLACEMENT_3D('', #129, #91, #57);
#131=PLANE('', #130);
#132=PLUS_MINUS_VALUE(100.1000000000,99.9000000000,2);
#133=TOLERANCED_LENGTH_MEASURE(100.0000000000, #132);
#134=DIRECTION('',(0.0000000000,1.0000000000,0.0000000000));
#135=LINEAR_PATH(s, #133, #134);
#136=PLUS_MINUS_VALUE(22.0000000000,19.5000000000,4);
#137=TOLERANCED_LENGTH_MEASURE(21.9000000000, #136);
#138=PLUS_MINUS_VALUE(0.1900000000,0.2100000000,2);
#139=TOLERANCED_LENGTH_MEASURE(0.2000000000, #138);
#140=PLUS_MINUS_VALUE(0.1900000000,0.2100000000,2);
#141=TOLERANCED_LENGTH_MEASURE(0.2000000000, #140);
#142=SQUARE_U_PROFILE(s, #137, #139,90.0000000000, #141,90.0000000000);
#143=RADIUSED_SLOT_END_TYPE();
#144=SLOT('SLOT - OPEN SLOT', #19, (#126), #128, #131, #135, #142, (#143, #143));
#145=MACHINING_WORKINGSTEP('OPEN SLOT - 5MM DEPTH', #59, #144, #126,s);
#146=CARTESIAN_POINT('',(135.0000000000,54.9000000000,30.0000000000));
#147=DIRECTION('',(0.0000000000,-1.0000000000,0.0000000000));
#148=AXIS2_PLACEMENT_3D('POSITION 135-54-30', #146, #91, #147);
#149=PLUS_MINUS_VALUE(50.1000000000,49.9000000000,3);
#150=TOLERANCED_LENGTH_MEASURE(50.0000000000, #149);
#151=DIRECTION('',(0.0000000000,-1.0000000000,0.0000000000));
#152=LINEAR_PATH(s, #150, #151);
#153=SLOT('SLOT - CLOSED SLOT -135.0-54.9-30.0', #19, (#126), #148, #131, #152,
#142, (#143, #143));

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#154=MACHINING_WORKINGSTEP('CLOSED SLOT - 5MM DEPTH', #59, #153, #126,s);
#155=CARTESIAN_POINT('',(0.0000000000,0.0000000000,1.0000000000));
#156=MILLING_TECHNOLOGY(0.0100000000,.TCP.,s,110.0000000000,0.0000000000,.F.,.
F.,.F.,s);
#157=CUTTING_COMPONENT(174.0000000000,s,899.0000000000,#156);
#158=TWIST_DRILL('TWIST DRILL
10MM',(#157,#157),174.0000000000,10.0000000000,50.0000000000,.RIGHT.,.F.,
116.0000000000);
#159=DRILLING_TYPE_STRATEGY(1.0000000000,1.0000000000,0.0000000000,s,s,
30.0000000000);
#160=DRILLING(s,s,'OPERATION TO DRILL 10MM DRILLHOLES',5.0000000000,#155,
#158,#156,#87,1.0000000000,30.0000000000,0.0000000000,0.0000000000,s,#159);
#161=CARTESIAN_POINT('',(42.0000000000,79.9000000000,30.0000000000));
#162=AXIS2_PLACEMENT_3D('POSITION 42-79-30',#161,#91,#57);
#163=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-30.0000000000));
#164=AXIS2_PLACEMENT_3D('',#163,#56,#57);
#165=PLANE('DEPTH OF 18MM ROUND HOLE',#164);
#166=PLUS_MINUS_VALUE(10.1000000000,9.5000000000,4);
#167=TOLERANCED_LENGTH_MEASURE(9.9000000000,#166);
#168=THROUGH_BOTTOM_CONDITION();
#169=ROUND_HOLE('ROUND HOLE 10MM',#19,(#160),#162,#165,#167,s,#168);
#170=MACHINING_WORKINGSTEP('SINGLE DRILLHOLE - 10MM DIAMETER',#59,
#169,#160,s);
#171=CARTESIAN_POINT('',(0.0000000000,0.0000000000,1.0000000000));
#172=DRILLING(s,s,'DRILLING OPERATION FOR DRILLHOLES IN SLOTS',5.0000000000,
#171,#158,#156,#64,0.0000000000,15.0000000000,0.0000000000,0.0000000000,s,#159);
#173=CARTESIAN_POINT('',(135.0000000000,22.9000000000,30.0000000000));
#174=AXIS2_PLACEMENT_3D('POSITION 135-22-30',#173,#91,#57);
#175=CARTESIAN_POINT('',(0.0000000000,0.0000000000,-15.0000000000));
#176=AXIS2_PLACEMENT_3D('',#175,#56,#57);
#177=PLANE('DEPTH OF 10MM DRILLHOLES',#176);
#178=PLUS_MINUS_VALUE(9.9100000000,9.8000000000,2);
#179=TOLERANCED_LENGTH_MEASURE(9.9000000000,#178);
#180=PLUS_MINUS_VALUE(2.1000000000,1.9000000000,1);
#181=TOLERANCED_LENGTH_MEASURE(2.0000000000,#180);
#182=CONICAL_HOLE_BOTTOM(60.0000000000,#181);
#183=ROUND_HOLE('ROUND HOLE 10MM - FIRST IN OPEN SLOT',#19,(#172),#174,
#177,#179,s,#182);
#184=MACHINING_WORKINGSTEP('1ST DRILLHOLE IN OPEN SLOT - 10 MM
DIAMETER',#59,#183,#172,s);
#185=CARTESIAN_POINT('',(135.0000000000,86.9000000000,30.0000000000));
#186=AXIS2_PLACEMENT_3D('POSITION 135-86-30',#185,#91,#57);
#187=ROUND_HOLE('ROUND HOLE 10MM - SECOND IN OPEN SLOT',#19,(#172),

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# 186, # 177, # 179, s, # 182);
# 188 = MACHINING _ WORKINGSTEP (' 2ND DRILLHOLE IN OPEN SLOT - 10 MM
DIAMETER', # 59, # 187, # 172, s);
# 189 = CARTESIAN_POINT('', (102.0000000000, 54.9000000000, 30.0000000000));
# 190 = AXIS2_PLACEMENT_3D('POSITION 102-54-30', # 189, # 91, # 57);
# 191 = ROUND_HOLE('ROUND HOLE 10MM - IN CLOSED SLOT', # 19, (# 172), # 190, # 177,
# 179, s, # 182);
# 192 = MACHINING _ WORKINGSTEP('DRILLHOLE IN CLOSED SLOT - 10 MM DIAMETER',
# 177, # 191, # 172, s);
# 193 = CARTESIAN _ POINT (' CUTSTARTPOINT', (0.0000000000, 0.0000000000,
2.0000000000));
# 194 = MILLING_TECHNOLOGY(0.0100000000, .TCP, s, 100.0000000000, s, .F, .F, .F, s);
# 195 = CUTTING_COMPONENT(169.0000000000, s, 999.0000000000, # 194);
# 196 = TWIST_DRILL('TWIST
DRILL', (# 195, # 195), 169.0000000000, 18.0000000000, 60.0000000000, .RIGHT, .F,
116.0000000000);
# 197 = DRILLING(s, s, 'DRILLING OPERATION FOR 18MM DRILLHOLES', 5.0000000000,
# 193, # 196, # 194, # 64, 1.0000000000, 30.0000000000, 0.0000000000, 2.0000000000, s, # 159);
# 198 = CARTESIAN_POINT('', (20.0000000000, 79.9000000000, 30.0000000000));
# 199 = DIRECTION('', (0.0000000000, 0.0000000000, 1.0000000000));
# 200 = DIRECTION('', (1.0000000000, 0.0000000000, 0.0000000000));
# 201 = AXIS2_PLACEMENT_3D('POSITION 20-79-30', # 198, # 199, # 200);
# 202 = PLUS_MINUS_VALUE(17.9000000000, 17.8000000000, 2);
# 203 = TOLERANCED_LENGTH_MEASURE(17.9000000000, # 202);
# 204 = THROUGH_BOTTOM_CONDITION();
# 205 = ROUND_HOLE('DRILLHOLE 18MM 20-79.9-30.', # 19, (# 197), # 201, # 165, # 203, s,
# 204);
# 206 = MACHINING _ WORKINGSTEP('1ST DRILLHOLE - 18 MM DIAMETER', # 59, # 205,
# 197, s);
# 207 = CARTESIAN_POINT('', (57.5000000000, 59.9000000000, 30.0000000000));
# 208 = AXIS2_PLACEMENT_3D('POSITION 57-59-30', # 207, # 91, # 57);
# 209 = THROUGH_BOTTOM_CONDITION();
# 210 = ROUND_HOLE('DRILLHOLE 18MM 57.5-59.9-30.', # 19, (# 197), # 208, # 165, # 203,
s, # 209);
# 211 = MACHINING _ WORKINGSTEP('2ND DRILLHOLE - 18 MM DIAMETER', # 59, # 210,
# 197, s);
# 212 = CARTESIAN _ POINT (' CUT START POINT', (0.0000000000, 0.0000000000,
5.0000000000));
# 213 = CUTTING_COMPONENT(60.0000000000, s, 987.0000000000, s);
# 214 = SPOTDRILL (' SPOTDRILL 45DEG', (# 213, # 213), 60.0000000000, 2.0000000000,
2.0000000000, .RIGHT, s, 45.0000000000);
# 215 = MILLING_TECHNOLOGY(0.0100000000, .CCP, s, 100.0000000000, s, .F, .F, .F, s);
# 216 = MILLING_MACHINE_FUNCTIONS(.F, s, .F, .F, s, (), .F, s, s, ());

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# 217=DRILLING_TYPE_STRATEGY(s,s,0.0000000000,s,s,s);
# 218 = CENTER_DRILLING (s, s, 'CENTER DRILLING', 5.0000000000, # 212, # 214, # 215,
# 216,s,2.0000000000,0.0000000000,1.0000000000,s, # 217);
# 219=CARTESIAN_POINT('',(0.0000000000,0.0000000000,5.0000000000));
# 220=MILLING_TECHNOLOGY(0.0010000000,.CCP.,s,100.0000000000,s,.F.,.F.,.F.,s);
# 221=CUTTING_COMPONENT(120.0000000000,s,987.0000000000, # 220);
# 222=TWIST_DRILL('TWIST DRILL 8.5MM',( # 221, # 221),120.0000000000,8.5000000000,
40.0000000000,.RIGHT.,.F.,116.0000000000);
# 223=MILLING_MACHINE_FUNCTIONS(.F.,s,.F.,.F.,s,( ),.F.,s,s,( ));
# 224=DRILLING(s,s,'DRILLING 8.5',5.0000000000, # 219, # 222, # 220, # 223,1.0000000000,
30.0000000000,0.0000000000,1.0000000000,s,s);
# 225=CARTESIAN_POINT('',(0.0000000000,0.0000000000,0.0000000000));
# 226 = TAPPING _ CUTTING _ TOOL ( ' TAP M12' , ( ), 120.0000000000, 12.0000000000,
50.0000000000,.RIGHT.,.F.,'METRIC',12.0000000000,1.5000000000,s);
# 227=MILLING_TECHNOLOGY(0.0015000000,.TCP.,s,1.0000000000,s,.F.,.F.,.F.,s);
# 228=MILLING_MACHINE_FUNCTIONS(.F.,s,.F.,.F.,s,( ),.F.,s,s,( ));
# 229 = TAPPING (s, s, ' TAPPING OPERATION' , 10.0000000000, # 225, # 226, # 227, # 228,
1.0000000000,30.0000000000,8.5000000000,0.0000000000,1.5000000000,s,.F.);
# 230=CARTESIAN_POINT('LOCATION',(115.0000000000,34.9000000000,30.0000000000));
# 231=DIRECTION('AXIS',(0.0000000000,0.0000000000,1.0000000000));
# 232=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
# 233 = AXIS2_PLACEMENT_3D(' PLACEMENT OF THE PATTERN RELATIVE TO THE
WORKPIECE' , # 230, # 231, # 232);
# 234=CARTESIAN_POINT('LOCATION',(0.0000000000,0.0000000000,0.0000000000));
# 235=DIRECTION('AXIS',(0.0000000000,0.0000000000,1.0000000000));
# 236=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
# 237 = AXIS2_PLACEMENT_3D(' PLACEMENT OF A SINGLE THREAD WITHIN THE
PATTERN' , # 234, # 235, # 236);
# 238=CARTESIAN_POINT('LOCATION',(0.0000000000,0.0000000000,-30.0000000000));
# 239=DIRECTION('AXIS',(0.0000000000,0.0000000000,1.0000000000));
# 240=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
# 241=AXIS2_PLACEMENT_3D('', # 238, # 239, # 240);
# 242=PLANE('DEPTH OF THE THREAD', # 241);
# 243=CARTESIAN_POINT('LOCATION',(0.0000000000,0.0000000000,0.0000000000));
# 244=DIRECTION('AXIS',(0.0000000000,0.0000000000,1.0000000000));
# 245=DIRECTION('REF-DIR',(1.0000000000,0.0000000000,0.0000000000));
# 246=AXIS2_PLACEMENT_3D('', # 243, # 244, # 245);
# 247=PARTIAL_AREA_DEFINITION(30.0000000000, # 246,30.0000000000);
# 248=DESCRIPTIVE_PARAMETER('', '');
# 249=DESCRIPTIVE_PARAMETER('', '');
# 250=DESCRIPTIVE_PARAMETER('', '');
# 251=NUMERIC_PARAMETER('M12X1.5',1.5000000000, '');
# 252=DESCRIPTIVE_PARAMETER('', 'RIGHT HAND');

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# 253 = THREAD('THREAD M12', # 19, (# 218, # 224, # 229), # 237, # 242, # 247, (), . T ,
# 248, # 249, # 250, 12.0000000000, # 251, # 252);
# 254 = PLUS_MINUS_VALUE(39.9800000000, 40.1000000000, 2);
# 255 = TOLERANCED_LENGTH_MEASURE(40.0000000000, # 254);
# 256 = DIRECTION('', (1.0000000000, 0.0000000000, 0.0000000000));
# 257 = PLUS_MINUS_VALUE(40.1000000000, 39.1000000000, 2);
# 258 = TOLERANCED_LENGTH_MEASURE(40.0000000000, # 257);
# 259 = RECTANGULAR_PATTERN('RECTANGULAR PATTERN
4XTHREADM12X1.5', # 19, (# 218, # 224, # 229), # 233, # 253, # 255, # 256, 2, 2, # 258, s, (),
());
# 260 = MACHINING_WORKINGSTEP('CENTER DRILLING; RECTANGULAR PATTERN THREAD
4XM12X1.5', # 59, # 259, # 218, s);
# 261 = MACHINING_WORKINGSTEP('DRILLING; RECTANGULAR PATTERN THREAD
4XM12X1.5', # 59, # 259, # 224, s);
# 262 = MACHINING_WORKINGSTEP('TAPPING; RECTANGULAR PATTERN THREAD
4XM12X1.5', # 59, # 259, # 229, s);
# 263 = CARTESIAN_POINT('', (-60.0000000000, 80.0000000000, 263.0000000000));
# 264 = DIRECTION('', (0.0000000000, 0.0000000000, 1.0000000000));
# 265 = DIRECTION('', (1.0000000000, 0.0000000000, 0.0000000000));
# 266 = AXIS2_PLACEMENT_3D('', # 263, # 264, # 265);
# 267 = CARTESIAN_POINT('LOCATION', (0.0000000000, 0.0000000000, 10.0000000000));
# 268 = AXIS2_PLACEMENT_3D('', # 267, # 56, # 57);
# 269 = PLANE('GLOBAL SECURITY PLANE', # 268);
# 270 = CARTESIAN_POINT('', (0.0000000000, 0.0000000000, 0.0000000000));
# 271 = DIRECTION('', (0.0000000000, 0.0000000000, 1.0000000000));
# 272 = DIRECTION('', (1.0000000000, 0.0000000000, 0.0000000000));
# 273 = AXIS2_PLACEMENT_3D('', # 270, # 271, # 272);
# 274 = NC_VARIABLE('', 0.0000000000);
# 275 = NC_VARIABLE('', 0.0000000000);
# 276 = OFFSET_VECTOR((# 274, # 274, # 274), (# 275, # 275, # 275));
# 277 = WORKPIECE_SETUP(# 19, # 273, # 276, s, ());
# 278 = SETUP('SETUP FOR MACHINING THE SIDE WITH SLOTS', # 266, # 269, (# 277));
# 279 = WORKPLAN('WORKPLAN FOR SECOND SETUP - SIDE WITH SLOTS', (# 83, # 109,
# 122, # 145, # 154, # 170, # 184, # 188, # 192, # 206, # 211, # 260, # 261, # 262), s, # 278, s);
# 280 = MACHINING_WORKINGSTEP('MILL PLANAR FACE', # 59, # 82, # 67, s);
# 281 = CARTESIAN_POINT('LOCATION', (0.0000000000, 0.0000000000, 30.0000000000));
# 282 = DIRECTION('AXIS', (0.0000000000, 0.0000000000, -1.0000000000));
# 283 = DIRECTION('REF-DIR', (1.0000000000, 0.0000000000, 0.0000000000));
# 284 = AXIS2_PLACEMENT_3D('', # 281, # 282, # 283);
# 285 = PLANE('SECPLANE OF PLANAR FACE - SIDE WITHOUT SLOTS', # 284);
# 286 = CARTESIAN_POINT('LOCATION', (0.0000000000, 0.0000000000, 0.0000000000));
# 287 = DIRECTION('Z-DIR 0 0 -1', (0.0000000000, 0.0000000000, -1.0000000000));
# 288 = DIRECTION('REF-DIR', (1.0000000000, 0.0000000000, 0.0000000000));

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# 289=AXIS2_PLACEMENT_3D('', # 286, # 287, # 288);
# 290=CARTESIAN_POINT('LOCATION', (0.0000000000, 0.0000000000, -20.0000000000));
# 291=DIRECTION('AXIS', (0.0000000000, 0.0000000000, 1.0000000000));
# 292=DIRECTION('REF-DIR', (1.0000000000, 0.0000000000, 0.0000000000));
# 293=AXIS2_PLACEMENT_3D('', # 290, # 291, # 292);
# 294=PLANE('', # 293);
# 295=CARTESIAN_POINT('', (0.0000000000, -40.0000000000, 0.0000000000));
# 296=CARTESIAN_POINT('', (0.0000000000, -113.9000000000, 0.0000000000));
# 297=CARTESIAN_POINT('', (175.0000000000, -113.9000000000, 0.0000000000));
# 298=CARTESIAN_POINT('', (175.0000000000, 0.0000000000, 0.0000000000));
# 299=CARTESIAN_POINT('', (80.0000000000, 0.0000000000, 0.0000000000));
# 300=CARTESIAN_POINT('', (80.0000000000, -40.0000000000, 0.0000000000));
# 301=POLYLINE('MIRRORED OUTSIDE PROFILE', (# 295, # 296, # 297, # 298, # 299, # 300,
# 295));
# 302=GENERAL_CLOSED_PROFILE(s, # 301);
# 303=GENERAL_OUTSIDE_PROFILE('GENERAL OUTSIDE PROFILE ON SIDE WITH NO
SLOTS', # 19, (# 89), # 289, # 294, s, # 302);
# 304=MACHINING_WORKINGSTEP('GENERAL OUTSIDE PROFILE - SIDE WITHOUT
SLOTS', # 285, # 303, # 89, s);
# 305=CARTESIAN_POINT('', (0.0000000000, 0.0000000000, 2.0000000000));
# 306=MILLING_TECHNOLOGY(s, CCP, s, 120.0000000000, 0.1000000000, .F., .F., .F., s);
# 307=CUTTING_COMPONENT(123.0000000000, s, 987.0000000000, # 306);
# 308=ENDMILL('ENDMILL 22MM', (# 307, # 307, # 307, # 307), 123.0000000000,
22.0000000000, 40.0000000000, .RIGHT., .F., 4, 0.2000000000, 0.0000000000);
# 309=DRILLING_TYPE_STRATEGY(1.0000000000, 1.0000000000, 0.0000000000, s, s, s);
# 310=DRILLING(s, s, 'DRILLING OPERATION FOR 22MM
DRILLHOLE', 10.0000000000, # 305, # 308, # 306, # 87, 0.0000000000, 17.5000000000,
18.0000000000, 1.0000000000, s, # 309);
# 311=CARTESIAN_POINT('', (20.0000000000, 79.9000000000, 0.0000000000));
# 312=DIRECTION('Z-DIRECTION 0 0-1', (0.0000000000, 0.0000000000, -1.0000000000));
# 313=DIRECTION('X-DIRECTION 0 0
+1', (1.0000000000, 0.0000000000, 0.0000000000));
# 314=AXIS2_PLACEMENT_3D('', # 311, # 312, # 313);
# 315=CARTESIAN_POINT('', (0.0000000000, 0.0000000000, -17.5000000000));
# 316=AXIS2_PLACEMENT_3D('', # 315, # 91, # 57);
# 317=PLANE('', # 316);
# 318=PLUS_MINUS_VALUE(22.0000000000, 19.5000000000, 4);
# 319=TOLERANCED_LENGTH_MEASURE(21.9000000000, # 318);
# 320=FLAT_HOLE_BOTTOM();
# 321=ROUND_HOLE('ROUND HOLE 22MM - POS 20.0-79.9-0.0', # 19, (# 310), # 314,
# 317, # 319, s, # 320);
# 322=MACHINING_WORKINGSTEP('DRILL HOLE 22MM - SIDE WITH NO SLOTS', # 59,
# 321, # 310, s);

```

```

# 323=CARTESIAN_POINT('',(57.5000000000,59.9000000000,0.0000000000));
# 324=DIRECTION('Z-DIRECTION 0 0 -1',(0.0000000000,0.0000000000,-1.0000000000));
# 325=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 326=AXIS2_PLACEMENT_3D('',# 323,# 324,# 325);
# 327=ROUND_HOLE('ROUND HOLE 22MM - POS 57.5-59.9-0',# 19,(# 310),# 326,# 317,
# 319,s,# 320);
# 328=MACHINING_WORKINGSTEP('DRILL 2ND HOLE 22MM - SIDE WITH NO SLOTS',
# 59,# 327,# 310,s);
# 329=CARTESIAN_POINT('',(-60.0000000000,80.0000000000,250.0000000000));
# 330=DIRECTION('Z 0 0 -1',(0.0000000000,0.0000000000,-1.0000000000));
# 331=DIRECTION('',(1.0000000000,0.0000000000,0.0000000000));
# 332=AXIS2_PLACEMENT_3D('',# 329,# 330,# 331);
# 333=SETUP('SETUP FOR MACHINING THE SIDE WITH NO SLOTS',# 332,# 269,
(# 277));
# 334=WORKPLAN('WORKPLAN FOR THIRD SETUP - SIDE WITH NO SLOTS',(# 280,
# 304,# 322,# 328),s,# 333,s);
# 335=WORKPLAN('MAIN WORKPLAN',(# 54,# 279,# 334),s,s,s);
# 336=PERSON('WG7','LAST NAME','FIRST NAME',(),(),());
# 337=PERSON_AND_ADDRESS(# 336,s);
# 338=CALENDAR_DATE(2004,10,4);
# 339=LOCAL_TIME(10,15,10.0000000000,s);
# 340=DATE_AND_TIME(# 338,# 339);
# 341=PROJECT('PROJECT TO MACHINE EXAMPLE 2',# 335,(# 19),# 337,# 340,s);
ENDSEC;
END-ISO-10303-21;

```

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