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Automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 13: Process data for wire electrical discharge machining (wire-EDM)

Systèmes d'automatisation et intégration — Commande des dispositifs physiques — Modèle de données pour les contrôleurs numériques informatisés —

Partie 13: Données de procédé pour l'usinage de fils électriques (fils EDM)

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 1, *Physical device control*.

ISO 14649 consists of the following parts, under the general title *Automation systems and integration — Physical device control — Data model for computerized numerical controllers*:

— *Part 1: Overview and fundamental principles*

— *Part 10: General process data*

— *Part 11: Process data for milling*

— *Part 12: Process data for turning*

— *Part 13: Process data for wire electrical discharge machining (wire-EDM)*

— *Part 14: Process data for sink electrical discharge machining (sink-EDM)*

— *Part 111: Tools for milling machines*

— *Part 121: Tools for turning machines*

— *Part 201: Machine tool data for cutting processes* [Technical Specification]

Gaps in numbering were intentionally left in order to allow further additions. ISO 14649-10 is the ISO 10303 Application Reference Model (ARM) for process-independent data. ISO 10303 ARMs for specific technologies are added after ISO 14649-10. ISO 14649 is harmonized with ISO 10303 in the common field of Product Data over the whole life cycle. ISO 14649-1 describes the different fields of standardization between ISO 14649, ISO 10303 and CNC manufacturers with respect to implementation and software development.

Introduction

ISO 14649-10 describes the general process data for numerical controlled machining and includes its schema. The subject of this schema (called machining_schema) is the definition of data types, which are generally relevant for different technologies (e.g. milling, turning, wire-EDM). It includes the definition of the workpiece, a feature catalogue containing features, which might be referenced by several technologies, the general executables and the basis for an operation definition. Not included in this schema are geometric items and presentations, which are referenced from the generic resources of ISO 10303, and the technology-specific definitions, which are defined in separate parts of ISO 14649.

ISO 14649-10 is not a stand-alone standard. Its implementation needs at least one additional technology-specific part (e.g. ISO 14649-11 for milling). This part of ISO 14649 describes wire Electrical Discharging Machining (wire-EDM) and it defines technology-specific data types representing the machining process for wire-EDM.

The main text of this part of ISO 14649 provides definitions and explanations of the data entities needed to provide control data information to an EDM controller.

The EXPRESS forms of the entities are given again in Annex A without the explanatory text for information.

Annex B provides an alternative view of these entities, with the different figures showing graphical representations of different elements. These figures are purely informative: a detailed explanation of the entities in the figures is given in the corresponding text definitions in Clause 4.

Two examples of ISO 14649 files, providing illustrations of possible uses, are given in Annex C and Annex D.

In addition, the schema uses machining features similar to ISO 10303-224. The description of process data is carried out using EXPRESS language as defined in ISO 10303-11. The encoding of the data is carried out using ISO 10303-21.

Automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 13: Process data for wire electrical discharge machining (wire-EDM)

1 Scope

This part of ISO 14649 specifies the technology-specific data element needed as process data for wire-EDM. Together with the general process data described in ISO 14649-10, it describes the interface between computerized numerical controller and the programming system (i.e. CAM system or shop-floor programming system) for wire-EDM. It can be used for wire-EDM operations on this kind of machine.

The scope of this part of ISO 14649 does not include tools for any other technologies (e.g. turning, grinding). Tools for these technologies are described in other parts of ISO 14649.

2 Normative references

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

ISO 14649-10, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 10: General process data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14649-10 and the following apply.

3.1
roughing
machining operation used to cut a part

Note 1 to entry: While the aim of roughing is to remove large quantities of material in a short time, the surface quality is usually not important.

Note 2 to entry: The roughing operation is usually followed by the *finishing* (3.2) operation.

3.2
finishing
machining operation whose aim is to reach the tolerance of the feature required

Note 1 to entry: The finishing operation is usually preceded by the *roughing* (3.1) operation and followed by the *surface finishing* (3.3) operation.

3.3
surface finishing
machining operation whose aim is to reach the required surface quality

Note 1 to entry: The surface finishing operation is usually preceded by the *finishing* (3.3) operation.

4 Process data for wire-EDM

4.1 Header and references

The following listing gives the header and the list of entities that are referenced within this schema.

```
SCHEMA wire_edm_schema;
(*
Version 5 of Feb 28, 2003
Author: Gabor Erdos <gabor.erdos@epfl.ch>
Modified by: Willy Maeder <wmaeder@cadcamation.ch>
Jacques Richard <i-tech@eig.unige.ch>
*)
REFERENCE FROM machining_schema (*ISO 14649-10*)
(
bounded_curve,
cartesian_point,
direction,
identifier,
label,
length_measure,
machine_functions,
machining_operation,
machining_feature,
machining_tool,
material,
pressure_measure,
property_parameter,
speed_measure,
plane_angle_measure,
technology,
machining_strategy,
toolpath_list
);
```

4.2 Manufacturing features for wire-EDM

4.2.1 General

The wire-EDM features defined in this subclause are the features that are specific for wire-EDM technology, and are not defined in ISO 14649-10. The base class for all wire-EDM features is the machining_feature, defined in ISO 14649-10.

4.2.2 General_path

The most general 4-axis wire-EDM operation is a manufacturing feature described by a ruled surface, but in many cases a curve based feature description is sufficient. The general_path feature is characterized by the fact that the tool movements are curve driven.

The general_path feature can be specified in two ways:

a) by one curve, an optional side angle and an optional transition type;

b) defined by two synchronized curves.

```
ENTITY general_path
SUPERTYPE OF (ONEOF(general_single_path, general_twin_path))
SUBTYPE OF (machining_feature);
END_ENTITY;
```

4.2.3 General_single_path

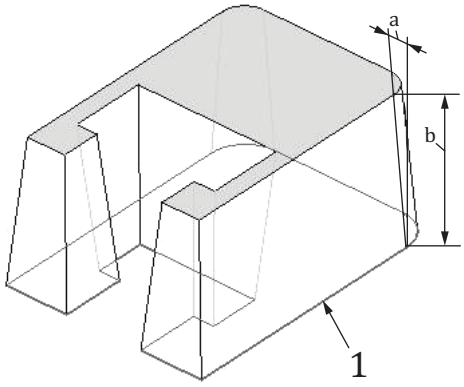
The general_single_path (see Figure 1) is defined by a general 2D or 3D curve with a slope angle specification and some specific parameters. The 2-axis wire-EDM operation, which is very usual, is a particular case of general_single_path where the slope angle is equal to 0 degrees.

```
ENTITY general_single_path
SUBTYPE OF (general_path);
feature_principal_boundary: bounded_curve;
slope: OPTIONAL plane_angle_measure;
transition_types: OPTIONAL EDM_transition;
END_ENTITY;
```

feature_principal_boundary: The outline or shape that forms the principal edge of the general_path. When travelling along the curve base as defined by its sense, the material lies on the left side of the curve according to the axis2_placement_3d orientation (i.e. when projecting the curve in the local xy plane). It is the axis2_placement_3d inherited from the machining_feature that defines the local z-axis and the local xy plane. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

slope: Optional angle of the border of the general_path measured against the local z-axis. Default is 0 degree. Implicitly a secondary curve boundary is defined: this is done by extending a line from each point on the principal boundary curve, at the specified angle, until it intersects the secondary local plane at the distance depth along the negative local z-axis. The shape of this implicit secondary boundary is also governed by the transition_types.

transition_types: The type of transition between non-tangent segments.



Key

1 feature_principal_boundary

a slope

b depth

Figure 1 — General_single_path

4.2.4 General_twin_path

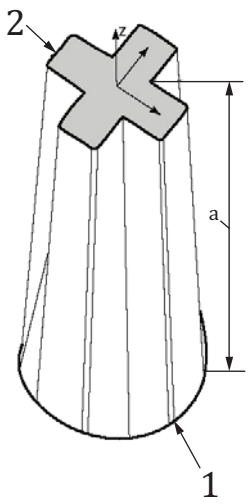
The general_twin_path is defined by two general 2D or 3D curves. The two curves are synchronized by the curve parameterization. This means that the side wall is defined by connecting the points on the principal and the secondary boundary curves corresponding to the same parameter value with a line. The depth attribute defined in the machining_feature is not useful for this definition and is ignored.

```
ENTITY general_twin_path
SUBTYPE OF (general_path);
```

```
feature_principal_boundary: bounded_curve;
feature_secondary_boundary: bounded_curve;
END_ENTITY;
```

feature_principal_boundary: The outline or shape that forms the principal edge of the general_path. When travelling along the curve base as defined by its sense, the material lies on the left side of the curve according to the axis2_placement_3d defined in the machining_feature (see Figure 2). IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

feature_secondary_boundary: The outline or shape that forms the secondary edge of the general_path.



Key

1 feature_principal_boundary
2 feature_secondary_boundary
a depth

Figure 2 — General_twin_path

4.2.5 General_path_pocket

This is the abstract base class for wire-EDM pockets. Derived from this base class are closed pockets and open pockets. The geometry of the pocket is defined with a general path. The pocket may possess one or more bosses.

```
ENTITY general_path_pocket
ABSTRACT SUPERTYPE OF (ONEOF(general_path_closed_pocket, general_path_open_pocket))
SUBTYPE OF (machining_feature);
its_hole: SET [0:?] OF general_path;
END_ENTITY;
```

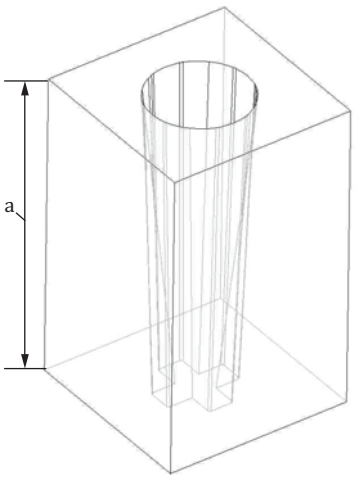
its_hole: Optional list of general_path entities which define the outline of the holes. This defines one or more parts of the pocket which are not cut during manufacturing of the pocket. When cutting the pocket the hole(s) is(are) cut simultaneously. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

4.2.6 General_path_closed_pocket

Derived from the class general_path_pocket, a general_path_closed_pocket (see Figure 3) is a general_path_pocket that is surrounded by material everywhere along its circumference.

```
ENTITY general_path_closed_pocket
SUBTYPE OF (general_path_pocket);
feature_boundary: general_path;
END_ENTITY;
```

feature_boundary: The shape that describes the principal and secondary edges of the pocket. It is an enclosed area that has completely closed profile curves. The general_path entity specifies the volume required by a closed pocket. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>



a depth

Figure 3 — General_path_closed_pocket

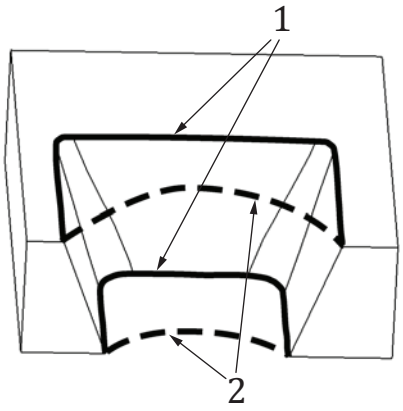
4.2.7 General_path_open_pocket

Derived from the class general_path_pocket class, a general_path_open_pocket is a general_path_pocket which is not a general_path_closed_pocket. The wall_boundary specifies the limit of the pocket from the open side.

```
ENTITY general_path_open_pocket
SUBTYPE OF (general_path_pocket);
open_boundary: general_path;
wall_boundary: OPTIONAL general_path;
END_ENTITY;
```

open_boundary: The shape that describes the principal and secondary edges of the pocket. The general_path entity specifies the volume required by the pocket. When travelling along the curve base as defined by its sense, the material lies on the left side of the curve according to the axis2_placement_3d defined in the machining_feature. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

wall_boundary: Optional general_path entity which describes the shape of the pocket from the open side. Note that it is necessary to define this contour only if it differs from the side wall obtained by connecting the start and end points of the open_boundary with straight lines (see Figure 4).



Key

1 open_boundary

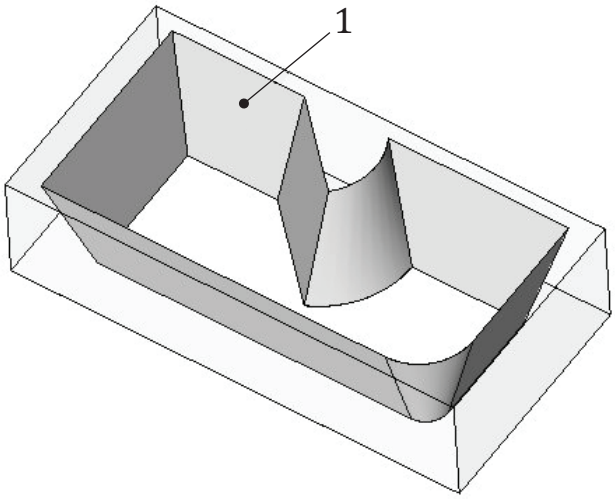
2 wall_boundary

Figure 4 — General_path_open_pocket

4.2.8 Ruled surfaces

The description of the shape by ruled surfaces (see Figure 5) is used when normal vectors of the surfaces are necessary for the calculation of the wire offset, e.g. when the calculation of the offset in the two horizontal planes is not accurate enough.

The final shape of the cut is described by a list of ruled surface. The entity region_surface_list, which is a subtype of the entity manufacturing_feature, is used to describe the ordered and oriented list of surfaces. The normal vector of the surface defines the direction away from the material.



Key

1 region_surface_list

Figure 5 — Ruled surfaces

4.3 Additional types and entities

4.3.1 General

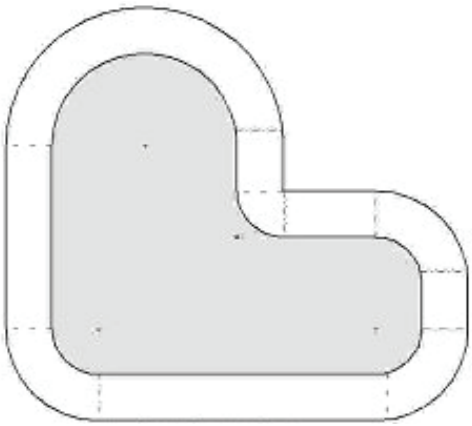
This subclause includes some further types and entities that are used in the declaration of the machining features described above.

4.3.2 EDM_transition

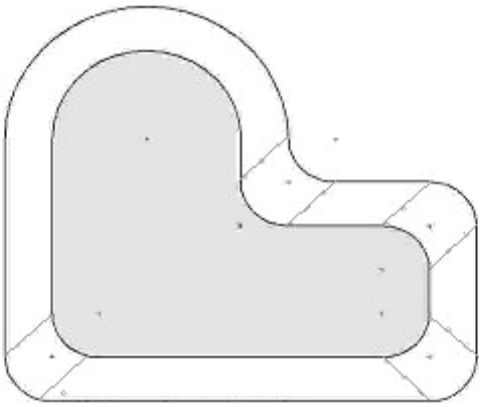
The entity EDM_transition is used in the context of the general_path class declaration. In the case when the general_path class is defined by one curve (feature_principal_boundary) and a wall angle (slope) the transition has to be specified in order that the shapes of the angles are correctly defined.

```
TYPE EDM_transition = ENUMERATION OF (constant_radius, conical, sharp);
END_TYPE;
```

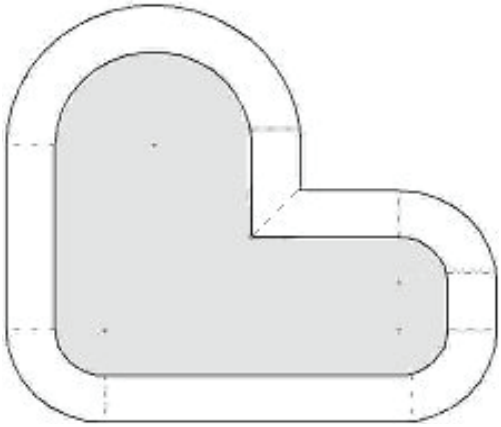
The conical transition signifies that the secondary boundary curve is defined as the offset curve of the principal boundary curve. The constant radius transition defines the secondary curve by keeping the corner radius constant on the principal and secondary boundary curves (see Figure 6).



a) Feature_principal_boundary conical



b) Feature_principal_boundary constant radius



c) Feature_principal_boundary sharp

Figure 6 — EDM_transition types

4.4 Machining operation for wire-EDM

4.4.1 General

In this subclause, all machining operations and technology-specific data needed for wire-EDM are introduced.

4.4.2 Wire_edm_machining_operation

The wire_edm_machining_operation classes define the machining process for a limited area of the workpiece, i.e. the contents of a machining workingstep. This entity is inherited by the machining_workingstep class defined in ISO 14649-10. This class defines additional information needed by the wire-EDM machining. It is a subtype of entity machining_operation defined in ISO 14649-10.

```
ENTITY wire_edm_machining_operation
SUBTYPE OF (machining_operation);
offset_length: OPTIONAL length_measure;
approach: OPTIONAL wire_edm_approach_retract_strategy;
retract: OPTIONAL wire_edm_approach_retract_strategy;
thread_point: LIST OF [1:2] OF cartesian_point;
cut_end_point: OPTIONAL cartesian_point;
END_ENTITY;
```

offset_length: Optional offset value defining the distance of the wire centre from the boundary curve of the feature. The controller based on the required tolerance and surface quality can determine this value. When travelling along the boundary curve of the feature based as defined by its sense, the offset curve lies on the left side of the curve (see Figure 7). IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

approach: Defines the wire movement from the thread_point to the cut_start_point. If this is not defined the wire will start from the end point of the previous machining_workingstep.

retract: Defines the wire movement from the cut_end_point to the thread_point. If this is not defined the wire will stop at the cut_end_point.

thread_point: Defines the starting point of the cutting process. This point defines the threading hole’s position where the wire can be threaded. In the case of the four axis wire-EDM operation the inclined threading hole can be defined by two points. The first point is defined in the xy plane (z = 0) while the second point is defined in the xy plane (z = -depth) of the feature coordinate system (see Figure 7).

cut_end_point: Optional point defined on the principal boundary curve that specifies the end point of the cutting operation. If it is not defined the cut_start_point is considered as the end point
(see Figure 6).

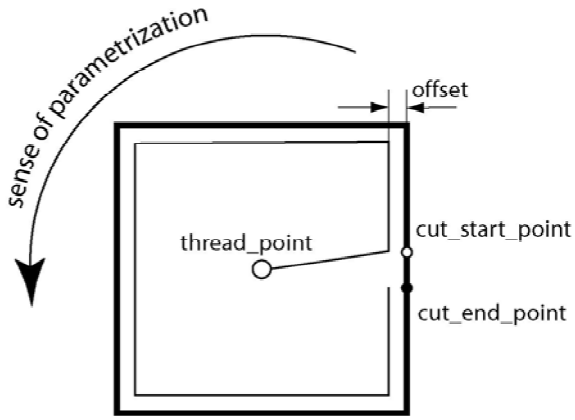


Figure 7 — Wire_edm_machining_operation

4.4.3 Wire_edm_machining_strategy

4.4.3.1 General

The wire_edm_machining_strategy class specifies the strategy to be used when executing the operation. When it is specified it will modify the final offset toolpath generation method or gives a hint for an auxiliary operation like fixation or slug removal. It is a subtype of entity machining_strategy, defined in ISO 14649-10.

```
ENTITY wire_edm_machining_strategy
ABSTRACT SUPERTYPE OF (ONEOF (backmotion,cut_through,slug_removal))
SUBTYPE OF(machining_strategy);
END_ENTITY;
```

4.4.3.2 Backmotion

If the backmotion strategy is specified it defines that the wire tool should move backwards on the feature contour curve, starting from the cut_end_point towards the cut_start_point along the negative sense of parametrization. This strategy can be applied on features having closed contour curves (see Figure 8).

```
ENTITY backmotion
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
```

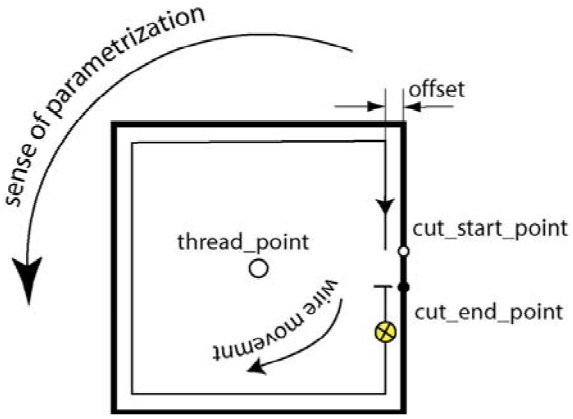


Figure 8 — Backmotion strategy

4.4.3.3 Cut_through

The cut_through strategy specifies that the operation will cut a slug. This strategy signifies that the slug might have to be fixed before this operation starts in order to avoid the fall out of the slug causing a short circuit. The wire tool should start moving from the cut_end_point towards the cut_start_point along the positive sense of parametrization. This strategy can be applied to features having closed contour curves (see Figure 9).

```
ENTITY cut_through
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
```

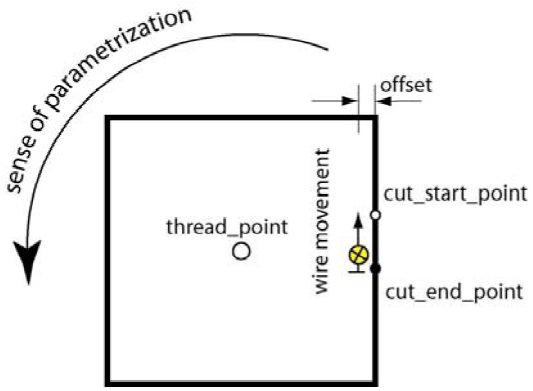


Figure 9 — Cut_through strategy

4.4.3.4 Slug_removal

The slug_removal strategy defines that the operator should remove the slug. The machining_operation having slug_removal strategy usually follows an operation having cut_through strategy. The wire should not move during this operation. This strategy can be applied to features having closed contour curves. It might signify to the controller that the wire should be cut before this operation and re-threaded after.

```
ENTITY slug_removal
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
```

4.4.3.5 Wire_edm_machine_functions

The entity describes the state of various functions of the machine (e.g. coolant) to be applied during the time span of an operation. It is a subtype of entity machine_functions, defined in ISO 14649-10.

```
ENTITY wire_edm_machine_functions
SUBTYPE OF (machine_functions);
coolant: BOOLEAN;
coolant_pressure: OPTIONAL pressure_measure;
lower_nozzle: BOOLEAN;
upper_nozzle: BOOLEAN;
other_functions: SET [0:?] OF property_parameter;
END_ENTITY;
```

coolant: If true, the coolant is activated. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

coolant_pressure: Optional specification of the pressure of the coolant system. Only valid if coolant is true.

lower_nozzle: If true, lower nozzle is activated. Only valid if coolant is true.

upper_nozzle: If true, the upper nozzle is activated. Only valid if coolant is true.

other_functions: Optional list of other functions of generic type.

4.4.3.6 Wire_edm_technology

This entity defines the technological parameters of the wire-EDM operation. It is a subtype of entity technology defined in ISO 14649-10. Since the number of technology parameters are machine dependent the technology will be derived from independent parameters. Most of the wire-EDM machines use an expert system or technology tables to define the spark generator parameters from the following data:

— material of the wire (its_wire_material of wire_tool entity)

— diameter of the wire (its_diameter of wire_tool entity)

— material of the workpiece (its_material of workpiece entity)

— cutting height (its_geometry of workpiece entity)

— final surface quality (roughness)

```
ENTITY wire_edm_technology
SUBTYPE OF (technology);
small_corner_strategy: OPTIONAL BOOLEAN;
other_generator_parameters: OPTIONAL SET [0:?] OF property_parameter;
END_ENTITY;
```

small_corner_strategy : If true, the special strategy to handle the small radius corners is activated. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

other_generator_parameters: Set of other property parameters of the generator of generic type.

4.4.4 Wire_edm_approach_retract_strategy

4.4.4.1 General

Base class for the approach and retract strategy. All approach and retract strategies are defined relative to the start or end point of the cutting operation. The start point of the approach or end point of the retract movement are defined to be the thread point of the operation.

```
ENTITY wire_edm_approach_retract_strategy
ABSTRACT SUPERTYPE OF (ONEOF (along_path_strategy, linear_strategy, arc_strategy));
its_technology: OPTIONAL wire_edm_technology;
technology_switch_point: OPTIONAL LIST [1:2] OF cartesian_point;
END_ENTITY;
```

its_technology: Optional technology setting for the approach/retract path. If it is not set the technology specified for the main cutting is used. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

technology_switch_point: Specifies the point where the technology specified for the approach/retract movement should switch to the technology of the main cut. Only valid if its_technology is specified.

4.4.4.2 Along_path_strategy

The along path strategy (see Figure 10) specifies the movement of the wire from the thread_point (to the thread_point) to the start point (from the end point) of the cutting operation with a list of tool paths. This class can describe an arbitrary approach or retract strategy.

```
ENTITY along_path_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
path: toolpath_list;
END_ENTITY;
```

path: Specifies the path of the wire IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

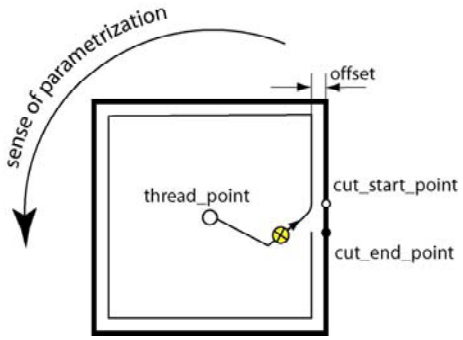


Figure 10 — Along_path_strategy

4.4.4.3 Linear_strategy

The approach/retract path connects the thread point with the start/end point of the cutting operation with a linear segment (see Figure 11).

```
ENTITY linear_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
END_ENTITY;
```

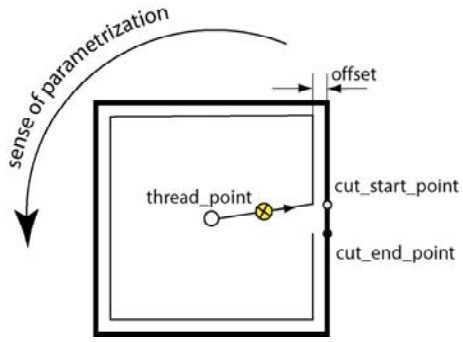


Figure 11 — Linear_strategy

4.4.4.4 Arc_strategy

The approach/retract path connects the thread point with the start/end point of the cutting operation with a linear-arc segment. The arc segment is tangential to the main cuts curve (see Figure 12).

```
ENTITY arc_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
radius: positive_length_measure;
END_ENTITY;
```

radius: The radius of the approach/retract movement. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>

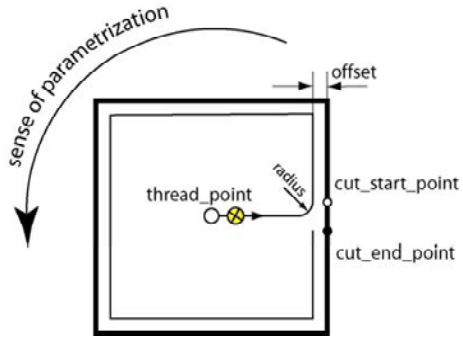


Figure 12 — Arc_strategy

4.4.5 Wire_tool

This class describes the properties of the wire used in wire-EDM machining. It is a subtype of entity machining_tool defined in ISO 14649-10.

```
ENTITY wire_tool
SUBTYPE OF (machining_tool);
its_wire_material: material;
its_diameter: length_measure;
its_tension: OPTIONAL tension_measure;
its_speed: OPTIONAL speed_measure;
other_parameters: SET [0:?] OF property_parameter;
END_ENTITY;
```

its_wire_material:	The material of the wire. IF “x_+3” “<Tbl_no_borders>” “” <Tbl_no_borders> IF “x_-3” “</Tbl_no_borders>” “” </Tbl_no_borders>
its_diameter:	The diameter of the wire.
its_tension:	Optional tension value applied to the wire.
its_speed:	Optional speed value specifying the wire feeding velocity.
other_parameters:	Optional set of parameters of generic type.

Annex A
(informative)

EXPRESS listing

The following EXPRESS is the whole schema of this part of ISO 14649.

```
SCHEMA wire_edm_schema;
(*
Version 5 of Feb 28, 2003
Author: Gabor Erdos <gabor.erdos@epfl.ch>
Modified by: Willy Maeder <wmaeder@cadcamation.ch>
Jacques Richard <i-tech@eig.unige.ch>
*)
REFERENCE FROM machining_schema (*ISO 14649-10*)
(
bounded_curve,
cartesian_point,
direction,
identifier,
label,
length_measure,
machine_functions,
machining_operation,
machining_feature,
machining_tool,
material,
pressure_measure,
property_parameter,
speed_measure,
plane_angle_measure,
technology,
machining_strategy,
toolpath_list
);
(* ************************************************************ *)
(* Type definitions *)
(* ************************************************************ *)
TYPE EDM_transition = ENUMERATION OF(constant_radius, conical, sharp);
END_TYPE;
TYPE tension_measure = REAL;
END_TYPE;
(* ************************************************************ *)
(* Machining feature *)
(* ************************************************************ *)
ENTITY general_path
SUPERTYPE OF (ONEOF(general_single_path, general_twin_path))
SUBTYPE OF (machining_feature);
END_ENTITY;
ENTITY general_single_path
SUBTYPE OF (general_path);
feature_principal_boundary: bounded_curve;
slope: OPTIONAL plane_angle_measure;
transition_types: OPTIONAL EDM_transition;
END_ENTITY;
ENTITY general_twin_path
SUBTYPE OF (general_path);
feature_principal_boundary: bounded_curve;
feature_secondary_boundary: bounded_curve;
END_ENTITY;
ENTITY general_path_pocket
ABSTRACT SUPERTYPE OF (ONEOF(general_path_closed_pocket, general_path_open_pocket))
SUBTYPE OF (machining_feature);
its_hole: SET [0:?] OF general_path;
END_ENTITY;
```

```
ENTITY general_path_closed_pocket
SUBTYPE OF (general_path_pocket);
feature_boundary: general_path;
END_ENTITY;
ENTITY general_path_open_pocket
SUBTYPE OF (general_path_pocket);
open_boundary: general_path;
wall_boundary: OPTIONAL general_path;
END_ENTITY;
(* ********************************************************** *)
(* Wire tool *)
(* ********************************************************** *)
ENTITY wire_tool
SUBTYPE OF (machining_tool);
its_wire_material: material;
its_diameter: length_measure;
its_tension: OPTIONAL tension_measure;
its_speed: OPTIONAL speed_measure;
other_parameters: SET [0:?] OF property_parameter;
END_ENTITY;
(* ********************************************************** *)
(* Wire-EDM Machining strategy *)
(* ********************************************************** *)
ENTITY wire_edm_machining_strategy
ABSTRACT SUPERTYPE OF (ONEOF (backmotion,cut_through,slug_removal))
SUBTYPE OF(machining_strategy);
END_ENTITY;
ENTITY backmotion
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
ENTITY cut_through
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
ENTITY slug_removal
SUBTYPE OF(wire_edm_machining_strategy);
END_ENTITY;
(* ********************************************************** *)
(* wire_edm_approach_retract_strategy *)
(* ********************************************************** *)
ENTITY wire_edm_approach_retract_strategy
ABSTRACT SUPERTYPE OF (ONEOF (along_path_strategy, linear_strategy, arc_strategy));
its_technology: OPTIONAL wire_edm_technology;
technology_switch_point: OPTIONAL LIST [1:2] OF cartesian_point;
END_ENTITY;
ENTITY along_path_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
path: toolpath_list;
END_ENTITY;
ENTITY linear_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
END_ENTITY;
ENTITY arc_strategy
SUBTYPE OF (wire_edm_approach_retract_strategy);
radius: positive_length_measure;
END_ENTITY;
(* ********************************************************** *)
(* Wire-EDM operation *)
(* ********************************************************** *)
ENTITY wire_edm_machining_operation
SUBTYPE OF (machining_operation);
offset_length: length_measure;
approach: OPTIONAL wire_edm_approach_retract_strategy;
retract: OPTIONAL wire_edm_approach_retract_strategy;
thread_point: cartesian_point;
cut_end_point: OPTIONAL cartesian_point;
END_ENTITY;
(* ********************************************************** *)
(* Wire-EDM technology *)
(* ********************************************************** *)
ENTITY wire_edm_technology
SUBTYPE OF (technology);
```

```
small_corner_strategy: OPTIONAL BOOLEAN;
other_generator_parameters: OPTIONAL SET [0:?] OF property_parameter;
END_ENTITY;
(* ************************************************************ *)
(* Wire-EDM technology machine functions *)
(* ************************************************************ *)
ENTITY wire_edm_machine_functions
SUBTYPE OF (machine_functions);
coolant: BOOLEAN;
coolant_pressure: OPTIONAL pressure_measure;
lower_nozzle: BOOLEAN;
upper_nozzle: BOOLEAN;
other_functions: SET [0:?] OF property_parameter;
END_ENTITY;
END_SCHEMA; (*wire_edm_schema *)
```

Annex B
(informative)

EXPRESS-G

The figures in this annex show the graphical representations of different elements:

— Figure B.1 shows the wire tool structure;

— Figure B.2 shows the wire-EDM machining operation structure;

— Figure B.3 shows the wire-EDM machining strategy and the wire-EDM feature reference;

— Figure B.4 shows the EDM machine functions and the general path structure;

— Figure B.5 shows the single path, double path and retract strategies;

— Figure B.6 shows the EDM machine technology and the general path pocket;

— Figure B.7 shows more detailed strategies;

— Figure B.8 shows the open pocket definition and the tension definition;

— Figure B.9 shows the closed pocked definition.

These figures are purely informative: a detailed explanation of the entities in the figures is given in the corresponding text definitions in Clause 4.

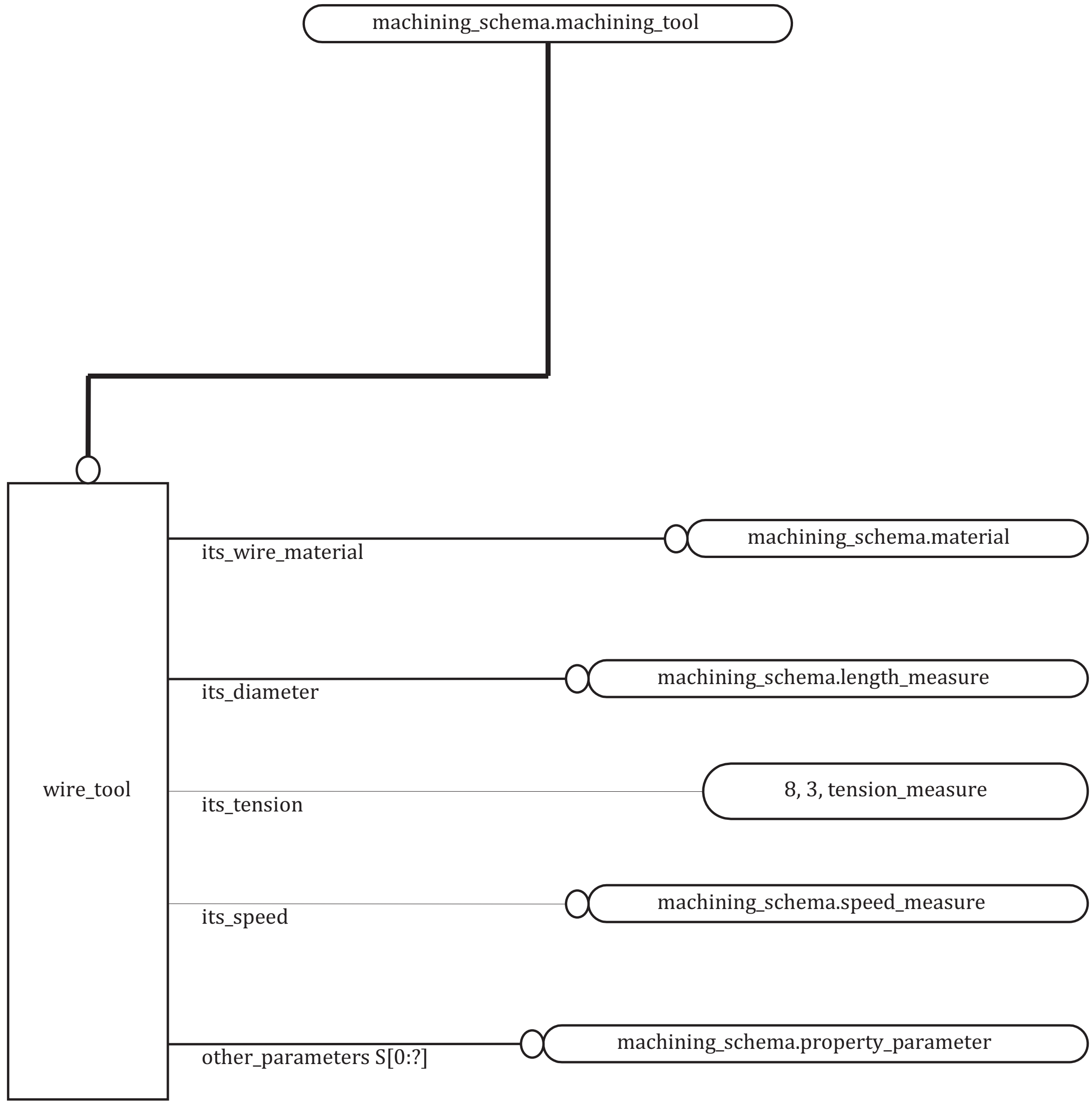


Figure B.1 — Express-G diagram 1

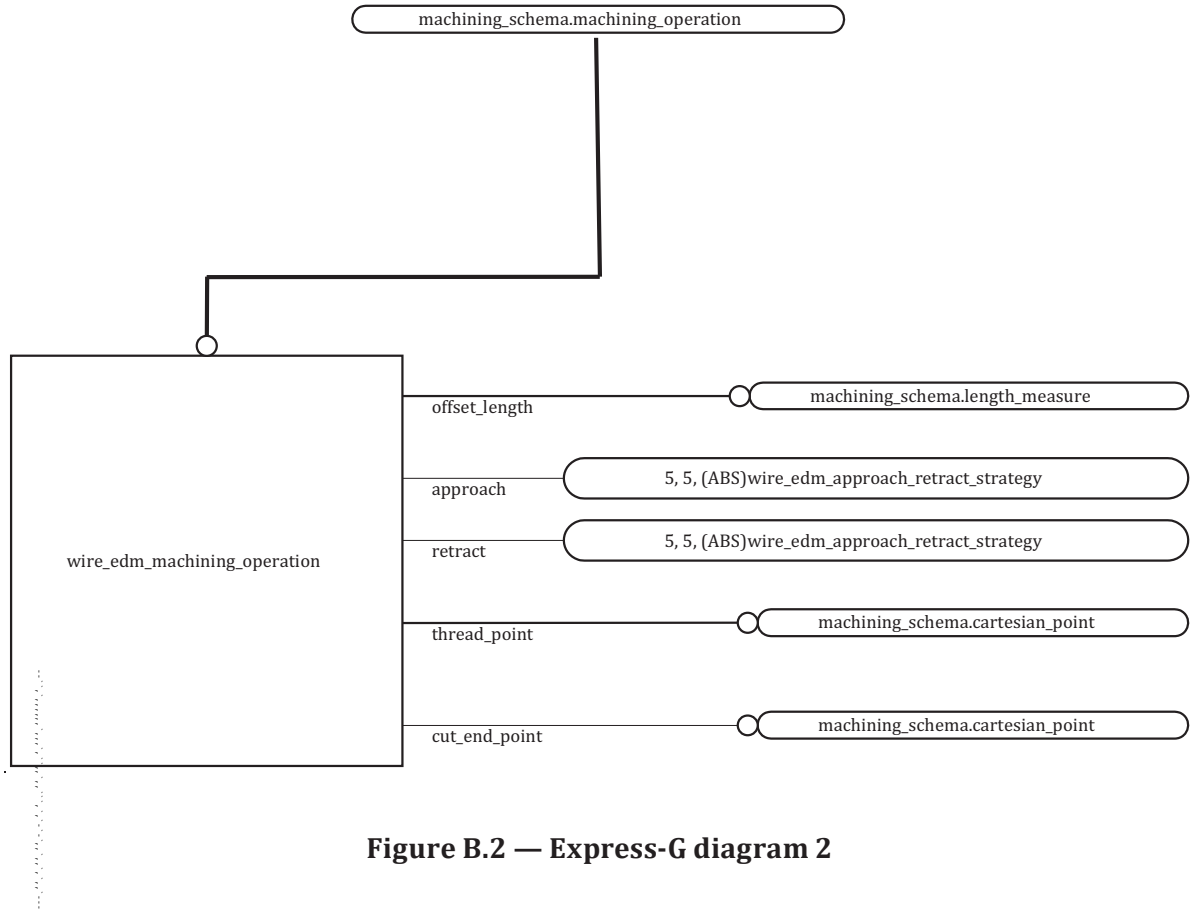


Figure B.2 — Express-G diagram 2

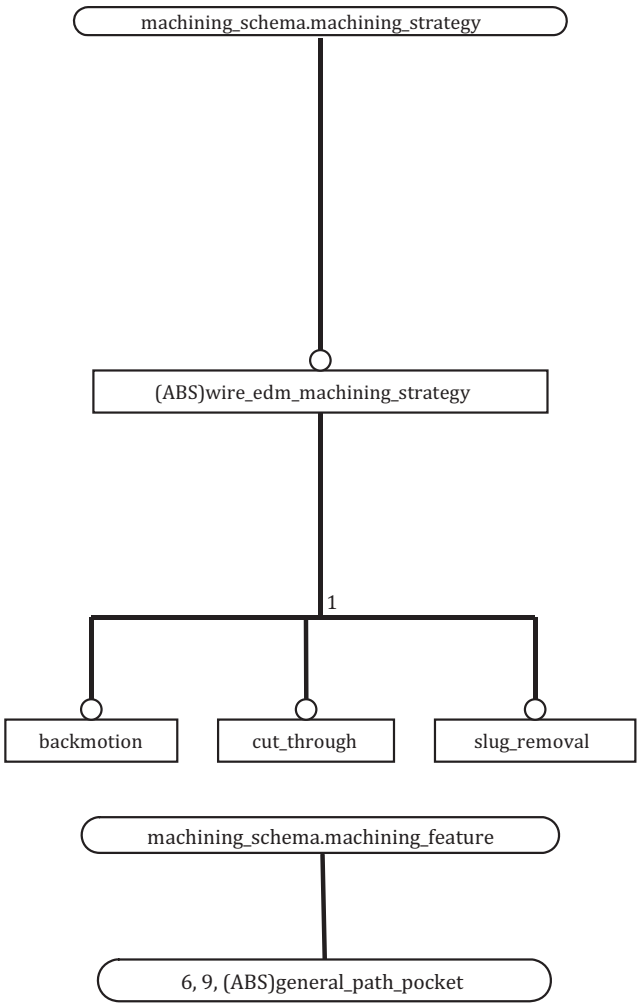
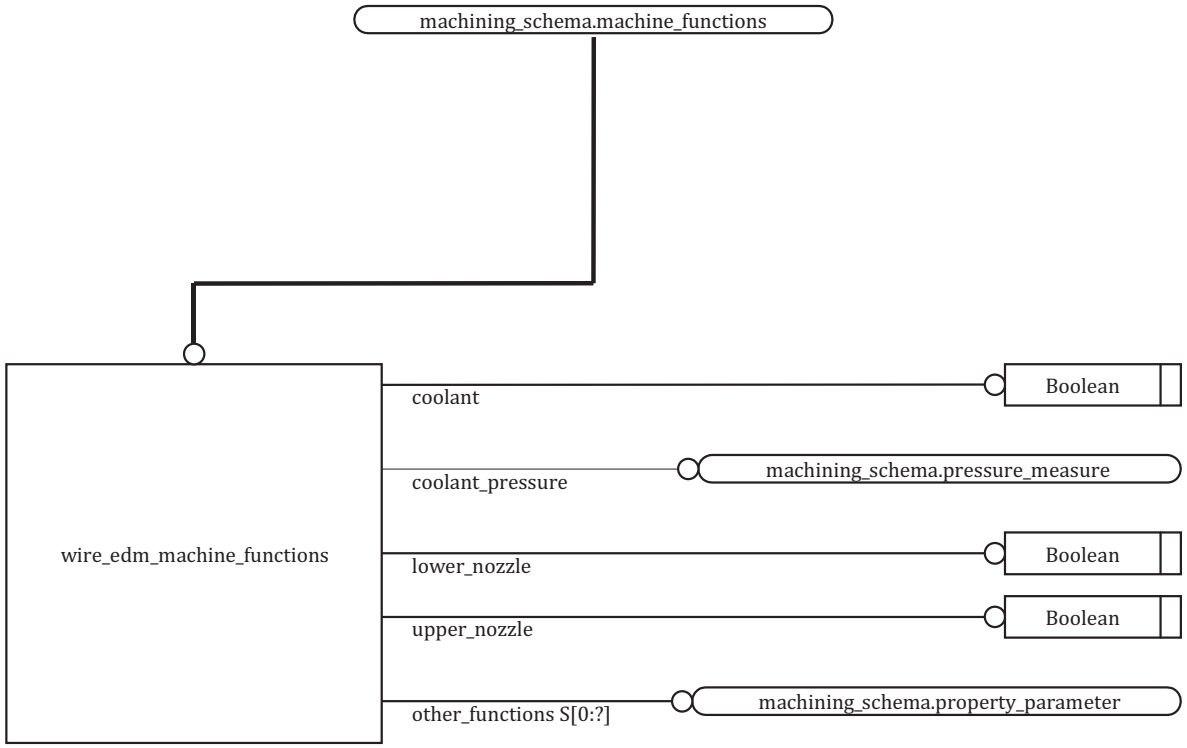


Figure B.3 — Express-G diagram 3



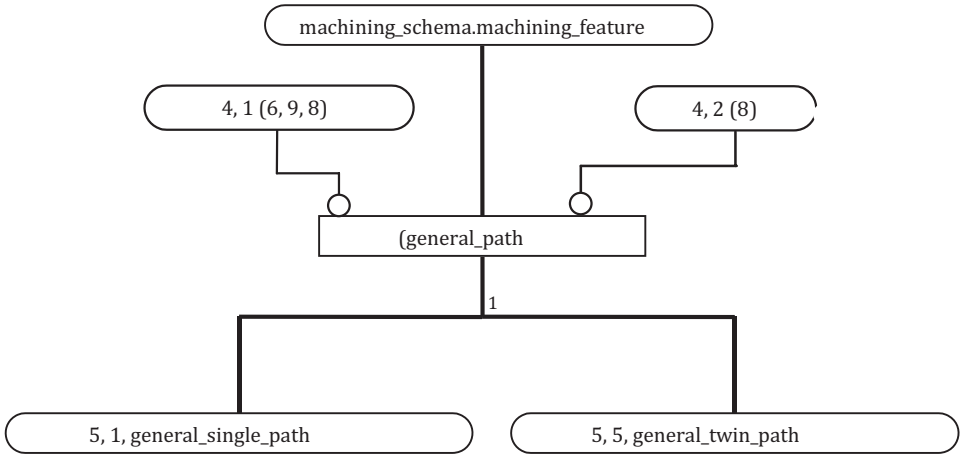


Figure B.4 — Express-G diagram 4

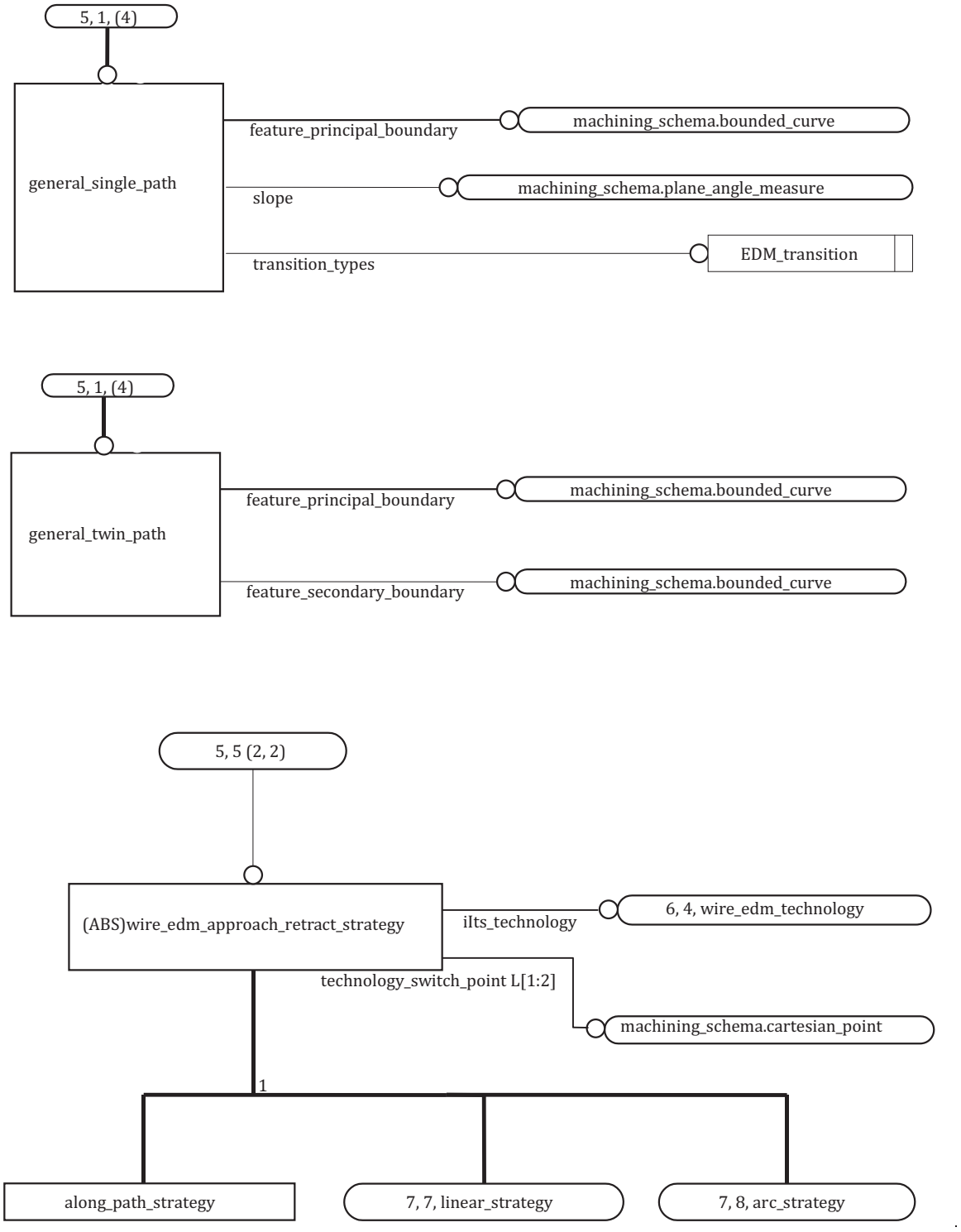


Figure B.5 — Express-G diagram 5

Figure B.6 — Express-G diagram 6

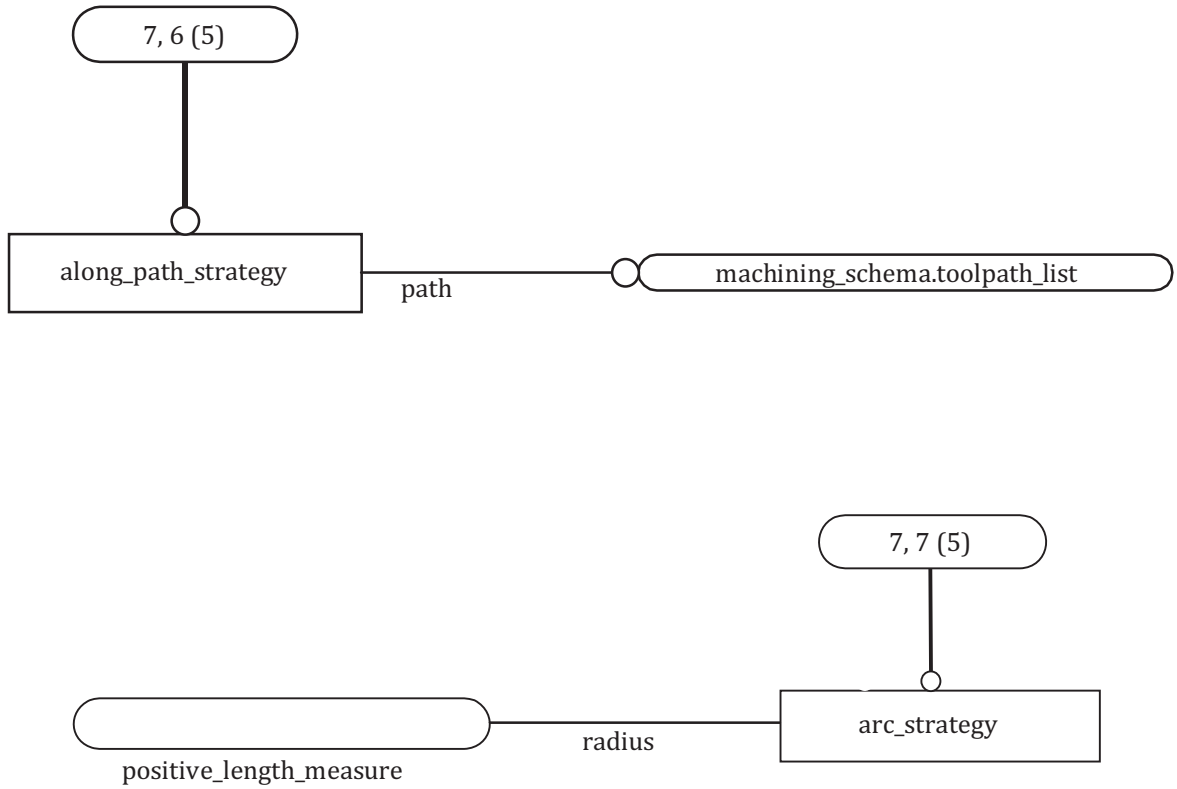


Figure B.7 — Express-G diagram 7

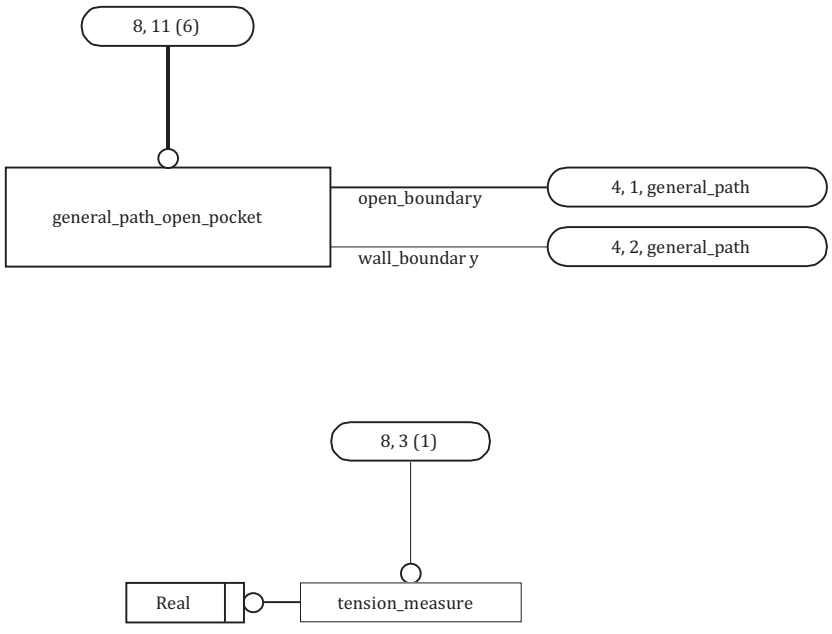


Figure B.8 — Express-G diagram 8

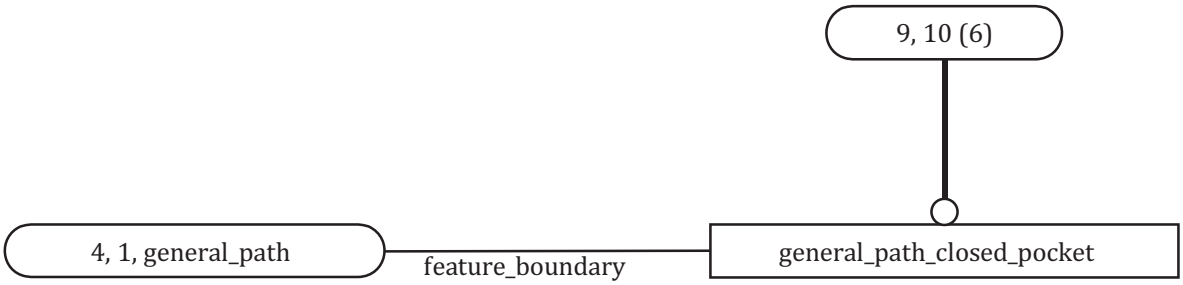


Figure B.9 — Express-G diagram 9

Annex C
(informative)

Simple wire-EDM example 1

Figure C.1 illustrates one example of simple wire-EDM.

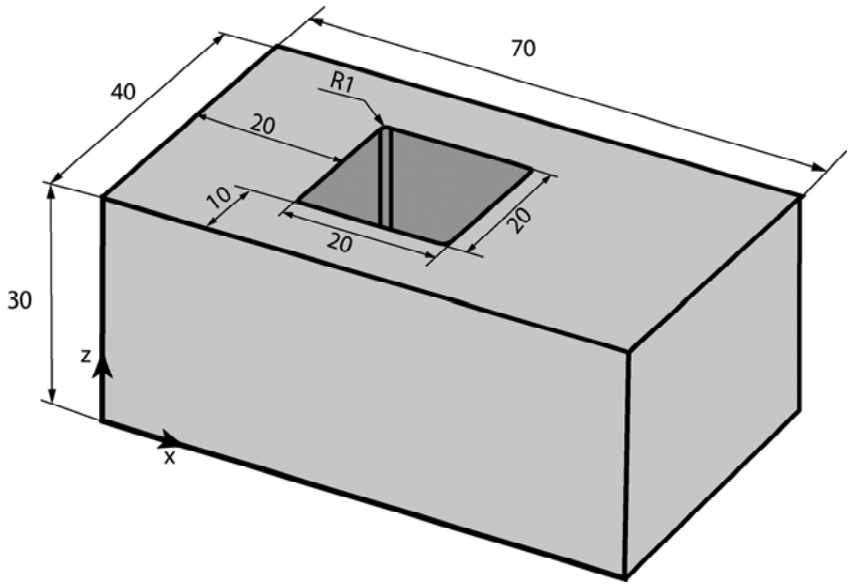


Figure C.1 — Example 1

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(
/* description */ ('This file contains the STEP-NC file of a wire-EDM manufacturing'),
/* implementation_level */ '2;1');
FILE_NAME(
/* name */ 'wire_edm_example',
/* time_stamp */ '2003-02-28T14:17:26+01:00',
/* author */ ('Gabor Erdos'),
/* organization */ ('EPFL-ICAP-LICP, Lausanne Switzerland'),
FILE_SCHEMA (('MACHINING_SCHEMA','WIRE_EDM_SCHEMA'));
ENDSEC;
DATA;
#10=ARC_STRATEGY($,$,1.);
#11=SLUG_REMOVAL();
#12=CUT_THROUGH();
#13=CIRCLE('Circle_009',#83,1.);
#14=CIRCLE('Circle_010',#84,1.);
#15=CIRCLE('Circle_011',#85,1.);
#16=CIRCLE('Circle_012',#86,1.);
#17=TRIMMED_CURVE('Trimmed_Curve_009',#13,(#55),(#56),.T.,$);
#18=TRIMMED_CURVE('Trimmed_Curve_010',#14,(#60),(#61),.T.,$);
#19=TRIMMED_CURVE('Trimmed_Curve_011',#15,(#65),(#66),.T.,$);
#20=TRIMMED_CURVE('Trimmed_Curve_012',#16,(#70),(#71),.T.,$);
#21=POLYLINE('Pline_009',(#52,#53));
#22=POLYLINE('Pline_010',(#57,#58));
#23=POLYLINE('Pline_011',(#62,#63));
#24=POLYLINE('Pline_012',(#67,#68));
#25=COMPOSITE_CURVE_SEGMENT($,.T.,#21);
#26=COMPOSITE_CURVE_SEGMENT($,.T.,#17);
#27=COMPOSITE_CURVE_SEGMENT($,.T.,#22);
```

```
#28=COMPOSITE_CURVE_SEGMENT($,.T.,#18);
#29=COMPOSITE_CURVE_SEGMENT($,.T.,#23);
#30=COMPOSITE_CURVE_SEGMENT($,.T.,#19);
#31=COMPOSITE_CURVE_SEGMENT($,.T.,#24);
#32=COMPOSITE_CURVE_SEGMENT($,.T.,#20);
#33=PROJECT('wire_edm_example',#39,(#34));
#34=WORKPIECE('workpiece',#35,0.005,$,$,#38,$);
#35=MATERIAL('ST221','Cold die Steel',$);
#36=MATERIAL('st234','Cobra Cut A',$);
#37=MATERIAL("","",$);
#38=BLOCK('Block_001',#82,40.,30.,70.);
#39=WORKPLAN('wp',(#40,#41,#42,#43,#44),#115,#117);
#40=MACHINING_WORKINGSTEP('ws_01',$,#89,#91);
#41=MACHINING_WORKINGSTEP('ws_02',$,#89,#92);
#42=MACHINING_WORKINGSTEP('ws_03',$,#89,#93);
#43=MACHINING_WORKINGSTEP('ws_04',$,#89,#94);
#44=MACHINING_WORKINGSTEP('ws_05',$,#89,#95);
#45=TOLERANCED_LENGTH_MEASURE(30.,$,0.,0.);
#46=TOLERANCED_LENGTH_MEASURE(1.,$,0.,0.);
#47=CARTESIAN_POINT('featOrigin',(20.,10.,30.));
#48=CARTESIAN_POINT('workpiece_bbBox_Location',(-10.,-15.,0.));
#49=CARTESIAN_POINT('cut_start_pt',(10.,0.,0.));
#50=CARTESIAN_POINT('thread_pt',(10.,10.,0.));
#51=CARTESIAN_POINT('cut_end_pt',(9.,0.,0.));
#52=CARTESIAN_POINT('Cartesian_Point_001_of_Pline_009',(1.,20.,0.));
#53=CARTESIAN_POINT('Cartesian_Point_002_of_Pline_009',(19.,20.,0.));
#54=CARTESIAN_POINT('Centre_Point_of_Circle_009',(19.,19.,0.));
#55=CARTESIAN_POINT('Start_Point_of_TrimmedCurve_009',(19.,20.,0.));
#56=CARTESIAN_POINT('End_Point_of_TrimmedCurve_009',(20.,19.,0.));
#57=CARTESIAN_POINT('Cartesian_Point_001_of_Pline_010',(20.,19.,0.));
#58=CARTESIAN_POINT('Cartesian_Point_002_of_Pline_010',(20.,1.,0.));
#59=CARTESIAN_POINT('Centre_Point_of_Circle_010',(19.,1.,0.));
#60=CARTESIAN_POINT('Start_Point_of_TrimmedCurve_010',(20.,1.,0.));
#61=CARTESIAN_POINT('End_Point_of_TrimmedCurve_010',(19.,0.,0.));
#62=CARTESIAN_POINT('Cartesian_Point_001_of_Pline_011',(19.,0.,0.));
#63=CARTESIAN_POINT('Cartesian_Point_002_of_Pline_011',(1.,0.,0.));
#64=CARTESIAN_POINT('Centre_Point_of_Circle_011',(1.,1.,0.));
#65=CARTESIAN_POINT('Start_Point_of_TrimmedCurve_011',(1.,0.,0.));
#66=CARTESIAN_POINT('End_Point_of_TrimmedCurve_011',(0.,1.,0.));
#67=CARTESIAN_POINT('Cartesian_Point_001_of_Pline_012',(0.,1.,0.));
#68=CARTESIAN_POINT('Cartesian_Point_002_of_Pline_012',(0.,19.,0.));
#69=CARTESIAN_POINT('Centre_Point_of_Circle_012',(1.,19.,0.));
#70=CARTESIAN_POINT('Start_Point_of_TrimmedCurve_012',(0.,19.,0.));
#71=CARTESIAN_POINT('End_Point_of_TrimmedCurve_012',(1.,20.,0.));
#72=CARTESIAN_POINT('SO1',(0.,0.,20.));
#73=DIRECTION('featZAxis',(0.,0.,1.));
#74=DIRECTION('featXAxis',(1.,0.,0.));
#75=DIRECTION('Axis_Z_of_Block_001',(1.,0,0));
#76=DIRECTION('Axis_X_of_Block_001',(0,1.,0.));
#77=DIRECTION('Z_axis_of_Circle_009',(0.,0.,-1.));
#78=DIRECTION('Z_axis_of_Circle_010',(0.,0.,-1.));
#79=DIRECTION('Z_axis_of_Circle_011',(0.,0.,-1.));
#80=DIRECTION('Z_axis_of_Circle_012',(0.,0.,-1.));
#81=AXIS2_PLACEMENT_3D('feat_frame',#47,#73,#74);
#82=AXIS2_PLACEMENT_3D('Position_of_Block_001',#48,#75,#76);
#83=AXIS2_PLACEMENT_3D('Postion_of_Circle_009',#54,#77,$);
#84=AXIS2_PLACEMENT_3D('Postion_of_Circle_010',#59,#78,$);
#85=AXIS2_PLACEMENT_3D('Postion_of_Circle_011',#64,#79,$);
#86=AXIS2_PLACEMENT_3D('Postion_of_Circle_012',#69,#80,$);
#87=AXIS2_PLACEMENT_3D('SecPlane_Frame',#72,$,$);
#88=COMPOSITE_CURVE('pocket',(#25,#26,#27,#28,#29,#30,#31,#32),.F.);
#89=GENERAL_OUTSIDE_PROFILE('work1',#34,(#91,#92,#93,#94,#95),#81,#45,#46,$,$,$,#88,$,$);
#90=WIRE_TOOL('wire1',#36,0.1,0.2,160.,$);
#91=WIRE_EDM_MACHINING_OPERATION($,$,'rough
ing',$,10.,#49,#90,#100,#114,0.01,#96,#97,#50,#51);
#92=WIRE_EDM_MACHINING_OPERATION($,$,'cut_thro
ugh',#12,10.,#49,#90,#99,$,0.01,$,$,#50,#51);
#93=WIRE_EDM_MACHINING_OPERATION($,$,'slug_removal',#11,10.,#49,#90,#99,$,1.,$,$,#50,#51);
#94=WIRE_EDM_MACHINING_OPERATION($,$,'finishing',$,10.,#49,#90,#98,#114,0.1,$,$,#50,#49);
#95=WIRE_EDM_MACHINING_OPERATION($,$,'surface_finish-
ing',$,10.,#49,#90,#101,#114,0.01,$,#10,#50,#49);
```

```
#96=LINEAR_STRATEGY($,$);
#97=LINEAR_STRATEGY($,$);
#98=WIRE_EDM_TECHNOLOGY(0.,.TCP.,$,$,#103,#108,#109,#110));
#99=WIRE_EDM_TECHNOLOGY(0.,.TCP.,$,$,());
#100=WIRE_EDM_TECHNOLOGY(0.,$,$,$,(#102,#105,#107,#106));
#101=WIRE_EDM_TECHNOLOGY(0.,.TCP.,$,$,(#104,#111,#112,#113));
#102=DESCRIPTIVE_PARAMETER('Id','Q2');
#103=DESCRIPTIVE_PARAMETER('Id','Q3');
#104=DESCRIPTIVE_PARAMETER('Id','Q8');
#105=NUMERIC_PARAMETER('Ra',1.8,'micm');
#106=NUMERIC_PARAMETER('Tkm',10.,'micm');
#107=NUMERIC_PARAMETER('Te',10.,'micm');
#108=NUMERIC_PARAMETER('Ra',0.8,'micm');
#109=NUMERIC_PARAMETER('Tkm',6.,'micm');
#110=NUMERIC_PARAMETER('Te',6.,'micm');
#111=NUMERIC_PARAMETER('Ra',0.4,'micm');
#112=NUMERIC_PARAMETER('Tkm',3.,'micm');
#113=NUMERIC_PARAMETER('Te',3.,'micm');
#114=WIRE_EDM_MACHINE_FUNCTIONS(.T.,$,.T.,.F.,());
#115=CHANNEL('Chanel_1');
#116=PLANE($,#87);
#117=SETUP('Setup',$,#116,());
ENDSEC;
END-ISO-10303-21;
```

Annex D
(informative)

Simple wire-EDM example 2

Figure D.1 illustrates another example of simple wire-EDM.

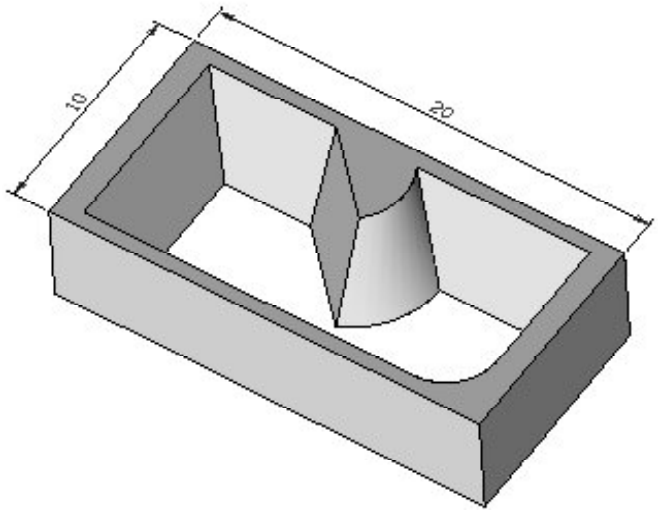


Figure D.1 — Example 2

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(
/* description */ (
'This file contains the STEP-NC file of a wire-EDM manufacturing'),
/* implementation_level */ '2;1');
FILE_NAME(
/* name */ 'sample with ruled surfaces',
/* time_stamp */ '2003-02-28T13:09:21+02:00',
/* author */ ('Willy Maeder'),
/* organization */ ('CADCAMation SA, Onex-Geneva, Switzerland'),
/* preprocessor_version */ 'ST-DEVELOPER v8',
/* originating_system */ '',
/* authorization */ '');
FILE_SCHEMA (('MACHINING_SCHEMA','WIRE_EDM_SCHEMA'));
ENDSEC;
DATA;
#2=CARTESIAN_POINT('',(-50.0,30.0,20.0));
#3=CARTESIAN_POINT('',(0.0,30.0,20.0));
#4=CARTESIAN_POINT('',(-46.0,26.0,0.0));
#5=CARTESIAN_POINT('',(-3.762857145299775,26.0,0.0));
#6=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#2,#4),(#3,#5)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-50.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#7=CARTESIAN_POINT('',(8.786796564403542,8.786796564403606,20.0));
#8=CARTESIAN_POINT('',(6.935595340170893,10.637997788636259,20.0));
#9=CARTESIAN_POINT('',(3.720779449950078,14.827639903211258,20.0));
#10=CARTESIAN_POINT('',(0.689306233719310,22.146263655806401,20.0));
#11=CARTESIAN_POINT('',(-2.645847E-015,27.382006122008541,20.0));
#12=CARTESIAN_POINT('',(0.0,30.0,20.0));
#13=CARTESIAN_POINT('',(8.955855216991068,3.295244424414630,0.0));
#14=CARTESIAN_POINT('',(6.625202790118829,5.131868128801239,0.0));
#15=CARTESIAN_POINT('',(2.447738076337918,9.418653244101920,0.0));
#16=CARTESIAN_POINT('',(-1.940637859416365,17.251877607654784,0.0));
```

```
#17=CARTESIAN_POINT('',(-3.414762067389234,23.053144355453618,0.0));
#18=CARTESIAN_POINT('',(-3.763871791715616,25.999879797732245,0.0));
#19=B_SPLINE_SURFACE_WITH_KNOTS('',3,1,((#7,#13),(#8,#14),(#9,#15),(#10,#16),(#11,#17),(#12
,#18)),
.UNSPECIFIED.,.F.,.F.
,.U.,(4,1,1,4),(2,2),(-3.926990816987240,-3.665191429188091,-3.403392041388941,
-3.141592653589792),(0.0,1.0),.UNSPECIFIED.);
#20=CARTESIAN_POINT('',(8.786796564403602,8.786796564403602,20.0));
#21=CARTESIAN_POINT('',(30.0,30.0,20.0));
#22=CARTESIAN_POINT('',(8.955855216991086,3.295244424414616,0.0));
#23=CARTESIAN_POINT('',(31.656854249492397,26.0,0.0));
#24=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#20,#22),(#21,#23)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-30.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#25=CARTESIAN_POINT('',(30.0,30.0,20.0));
#26=CARTESIAN_POINT('',(70.0,30.0,20.0));
#27=CARTESIAN_POINT('',(31.656854249492397,26.0,0.0));
#28=CARTESIAN_POINT('',(66.0,26.0,0.0));
#29=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#25,#27),(#26,#28)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-40.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#30=CARTESIAN_POINT('',(70.0,30.0,20.0));
#31=CARTESIAN_POINT('',(70.0,-50.0,20.0));
#32=CARTESIAN_POINT('',(66.0,26.0,0.0));
#33=CARTESIAN_POINT('',(66.0,-46.0,0.0));
#34=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#30,#32),(#31,#33)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-80.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#35=CARTESIAN_POINT('',(70.0,-50.0,20.0));
#36=CARTESIAN_POINT('',(-20.0,-50.0,20.0));
#37=CARTESIAN_POINT('',(66.0,-46.0,0.0));
#38=CARTESIAN_POINT('',(-20.0,-46.0,0.0));
#39=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#35,#37),(#36,#38)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-90.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#40=CARTESIAN_POINT('',(-50.0,-20.0,20.0));
#41=CARTESIAN_POINT('',(-50.0,30.0,20.0));
#42=CARTESIAN_POINT('',(-46.0,-20.0,0.0));
#43=CARTESIAN_POINT('',(-46.0,26.0,0.0));
#44=B_SPLINE_SURFACE_WITH_KNOTS('',1,1,((#40,#42),(#41,#43)),.UNSPECIFIED.,.F.,.F.
,.U.,(2,2),(2,2),
(-50.0,0.0),(0.0,1.0),.UNSPECIFIED.);
#45=CARTESIAN_POINT('',(-50.0,-20.0,20.0));
#46=CARTESIAN_POINT('',(-50.0,-22.243994752564106,20.0));
#47=CARTESIAN_POINT('',(-49.494332216275893,-26.731874096003608,20.0));
#48=CARTESIAN_POINT('',(-47.256861435762637,-33.126216647277602,20.0));
#49=CARTESIAN_POINT('',(-43.652618263109133,-38.862332356046295,20.0));
#50=CARTESIAN_POINT('',(-38.862332356046380,-43.652618263109090,20.0));
#51=CARTESIAN_POINT('',(-33.126216647277673,-47.256861435762580,20.0));
#52=CARTESIAN_POINT('',(-26.731874096003700,-49.494332216275879,20.0));
#53=CARTESIAN_POINT('',(-22.243994752564198,-50.0,20.0));
#54=CARTESIAN_POINT('',(-20.0,-50.0,20.0));
#55=CARTESIAN_POINT('',(-46.0,-20.0,0.0));
#56=CARTESIAN_POINT('',(-46.0,-21.940717585790633,0.0));
#57=CARTESIAN_POINT('',(-45.561751785744534,-25.836183427878151,0.0));
#58=CARTESIAN_POINT('',(-43.622623050258596,-31.375547320925282,0.0));
#59=CARTESIAN_POINT('',(-40.498899405998614,-36.347490590759556,0.0));
#60=CARTESIAN_POINT('',(-36.347490590759676,-40.498899405998628,0.0));
#61=CARTESIAN_POINT('',(-31.375547320925357,-43.622623050258554,0.0));
#62=CARTESIAN_POINT('',(-25.836183427878254,-45.561751785744747,0.0));
#63=CARTESIAN_POINT('',(-21.940717585790722,-46.0,0.0));
#64=CARTESIAN_POINT('',(-20.0,-46.0,0.0));
#65=B_SPLINE_SURFACE_WITH_KNOTS('',3,1,((#45,#55),(#46,#56),(#47,#57),(#48,#58),(#49,#59),(
#50,#60),
(#51,#61),(#52,#62),(#53,#63),(#54,#64)),.UNSPECIFIED.,.F.,.F.
,.U.,(4,1,1,1,1,1,1,4),(2,2),
(3.141592653589792,3.365992128846206,3.590391604102619,3.814791079359032,4.039190554615447,
4.263590029871861,4.487989505128275,4.712388980384688),(0.0,1.0),.UNSPECIFIED.);
#110=DESCRIPTIVE_PARAMETER('Tkm','±10 microM');
#111=DESCRIPTIVE_PARAMETER('Te','10-15 microM');
```

```
#112=WIRE_EDM_TECHNOLOGY(0.,$,$,$,(#113,#111,#110));
#113=NUMERIC_PARAMETER('Ra',1.8,'microM');
#114=LINEAR_STRATEGY($,$);
#115=WIRE_EDM_MACHINE_FUNCTIONS(.T.,2.3,.F.,.F.,());
#116=WIRE_TOOL('Wire Tool',#120,0.25,0.,0.,$);
#117=PROJECT('sample 2',#121,(#118));
#118=WORKPIECE('Workpiece',#119,$,$,$,$,$);
#119=MATERIAL('','Cold die Steel',$);
#120=MATERIAL('','Cobra Cut',$);
#121=WORKPLAN('Workplan1',(#122),$,$);
#122=MACHINING_WORKINGSTEP('Step1',$,#125,#163);
#125=REGION_SURFACE_LIST('Region1',#18,(#163),$,(#6,#19,#24,#29,#34,#39,#44,#65));
#163=WIRE_EDM_MACHINING_OPERATION($,$,'Oper1',$,$,#94,#116,#112,#115,2.,$,#114,#95,#96);
ENDSEC;
END-ISO-10303-21;
```

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[4] ISO 14649-1, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 1: Overview and fundamental principles*

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