Development of a Semantic Wiki-based Feature Library for the Extraction of Manufacturing Feature and Manufacturing Information

Hendry Muljadi, Hideaki Takeda, and Koichi Ando

***Abstract*—**A manufacturing feature can be defined simply as a geometric shape and its manufacturing information to create the shape. In a feature-based process planning system, feature library that consists of pre-defined manufacturing features and the manufacturing information to create the shape of the features, plays an important role in the extraction of manufacturing features with their proper manufacturing information. However, to manage the manufacturing information flexibly, it is important to build a feature library that can be easily modified. In this paper, the implementation of Semantic Wiki for the development of the feature library is proposed.

***Keywords*—**Manufacturing feature, feature library, feature ontology, process planning, Wiki, MediaWiki, Semantic Wiki.

I. Introduction

COMPUTER Aided Process Planning (CAPP) as means to support human effectively to generate process plans has been a research topic for over 35 years [1]. It offers the ability to integrate a Computer Aided Design (CAD), which allows automation of product design, and a Computer Aided Manufacturing (CAM) system, which allows automation of manufacturing. In order to allow the CAD system to interface with the CAPP system, feature technology has emerged as the enabling technology to convert CAD product data to manufacturing information [2]. Many different approaches have been developed to extract features from the CAD product data [3].

For the extraction of manufacturing features for the generation of process plans, it is necessary to develop a feature library that consists of pre-defined features and the manufacturing information to create the shape of the features [4].The manufacturing information consists of the required machine and tool data, the estimated cost and time data, etc [5]. It is necessary to develop a feature library which is easy to modify or to customize, since manufacturing technologies are progressing, and also that manufacturing information used in a particular factory may not be the same as in the other factory. However, in general, feature libraries are not developed in a way that is easy to modify, especially by people without information technology background.

On the other hand, in the context of collaboration on the web, Wiki has proven itself to be a user-friendly interface. For example, the community of Wikipedia.org, the free content encyclopedia is becoming larger and larger. There have been more than 600,000 people who gave their contributions, either by creating or editing articles in Wikipedia. Wiki is a discussion medium, a repository of ideas and a tool for collaboration. It is a simple publishing system that is easy to learn and quick to use [6]. In Wiki, people can create or edit a Wiki page using a simple syntax to write content. So, it is normal to make an assumption that an extended Wiki will be useful for the development of a feature library which can be easily modified.

However, for the development of a structured feature library, semantic extension of Wiki is necessary. In this paper, the implementation of Semantic Wiki for the development of a feature library is proposed.

The structure of this paper is as follows. Section 2 describes the semantic extension of MediaWiki. Section 3 describes the structure of the feature library. The implementation of the Semantic Wiki for the development of the feature library is described in section 4. Section 5 presents a case study of how the feature library may support the extraction of manufacturing features and their proper manufacturing information. Section 6 states the conclusions drawn from the research.

II. MewKISS – Media Wiki with Simple Semantics

A. Extension of MediaWiki

MewKISS is an abbreviation for MediaWiki with Simple Semantics. The word “KISS” is written with full capital letters to stress that the proposed Semantic Wiki is developed by following the KISS principle that emphasizes simplicity. The word “KISS” is originally an abbreviation for “Keep It Simple, Stupid!” or “Keep It Short and Simple”.

MediaWiki is the Wiki software used for the development of MewKISS. It is a Wiki software that is written in PHP and uses MySQL database. It is being used to run the Wikipedia and also other encyclopedia and dictionary sites. MediaWiki is a very

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useful tool for collaborative content management.

MediaWiki has the category management function that allows a Wiki page under the namespace ("Category:") to be used as a metadata. Metadata is simply defined here as data about data [7]. This function allows user to create class-sub-class relation and class-instance relation of Wiki pages. However, the metadata cannot be processed nor manipulated easily by computer applications.

Using the existing category management function as a reference, MediaWiki is extended. The extension has enabled MediaWiki to write labeled links. In other words, the extension has enabled MediaWiki to write Resource Description Framework (RDF) statement, which consists of subject-predicate-object triple. RDF is a language to express metadata about information resource on the Web proposed by the WWW Consortium (W3C) [8]. RDF has a simple data model that is understandable by human and is easy for computer applications to process and manipulate.

The Wiki syntax to write the RDF triple is [[Term:target_page|property]]. The RDF triple is <source_page><property><target_page>. Each time the Wiki syntax is used, the Wiki engine will store the RDF triple into a table in the Wiki database.

Fig.1 shows the example of the Wiki syntax writing on a Wiki page. The Wiki page on which the syntax is written will become the source page of the RDF triple. Fig.2 illustrates an RDF triple that is stored in the new table of the Wiki database. Fig.3(a), (b), (c) show how the labeled link relations are displayed on the source_page page, target_page page and property page respectively. The running system of the extended MediaWiki is available at http://semanticwiki.jp.

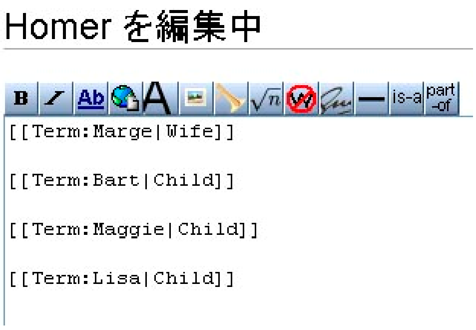


Fig. 1 Wiki syntax to write the labeled link: [[Term:target_page|property]]

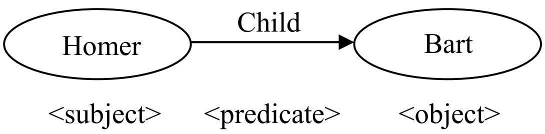


Fig. 2 RDF Triple

(a) Display of the source_page page ->property->target_page

(b) Display of the target_page page <-property<-source_page

(c) Display of the property page source_page->target_page

Fig. 3 Display on the Wiki pages

B. *Features of MewKISS*

Fig. 4 shows the overall structure of the MewKISS. The features of the MewKISS can be summarized as follows.

1) A collaborative lightweight metadata management. By enabling the writing of labeled links with simple syntax, users can create and manage relations between Wiki pages easily and flexibly. The writing of labeled links allows users to write and edit RDF triples even though users have no knowledge about it.
2) Navigation support. Displaying labeled links, as shown in Fig.3, allows users to navigate the relation between Wiki pages easily.
3) Mapping to other Semantic Web application. MewKISS handles only simple RDF statements. By converting the RDF triples, which are stored in the table of MewKISS, into XML-encoded RDF data format, the RDF triples can be exported to RDF database such as Sesame (http://openrdf.org). Using Sesame, users can explore the exported RDF triples, make queries etc [9]. Sesame can also bridge MewKISS to other Semantic Web applications. In other words, metadata created in MewKISS environment can be mapped to other Semantic Web applications.
4) An integrated content and metadata management. By extending MediaWiki, the Semantic Wiki has the benefit of having all the functions available in MediaWiki as a

collaborative content management system. Thus, the Semantic Wiki can be used as a collaborative and integrated content and metadata management system [10].

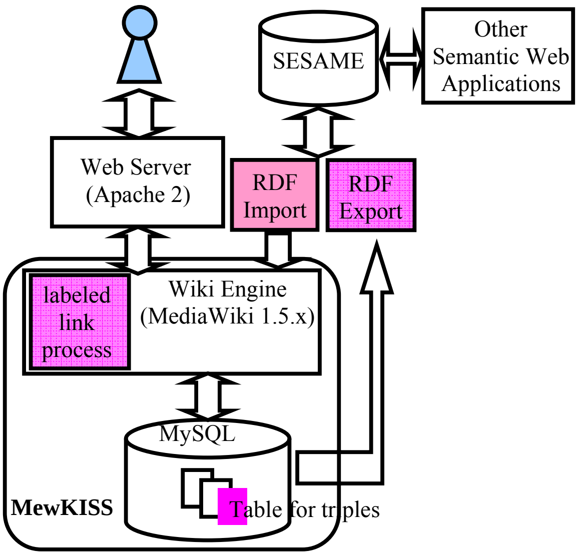


Fig. 4 Overall structure of MewKISS

III. The Structure of the Feature Library

A. Considering the Designer's Intention for the Extraction of Manufacturing Features with their Proper Manufacturing Information

For the extraction of proper manufacturing information to create the shape of manufacturing features, it is important to understand the designer's intention. For example, a thru-hole feature may require a cylindrical grinding to create the shape, while the other thru-hole feature may require threading to create the shape, depending on why the designer designed the geometrical shape. Thus, it is necessary to consider the designer's intention for the extraction of manufacturing feature with their proper manufacturing information.

In this research, the designer's intention is represented by the functions of the face elements that construct the features. The face element is defined as a geometrical entity that is bounded by a set of edges. The functional data of the face elements can be described as basic function, mechanism utilized for realization of the basic function, and condition and direction of the motion. The detail explanation of the functional data elements is given in other reports [11][12]. Table I shows the contents of functional properties of face elements that are used for the creation of the function feature ontology.

Fig. 5 shows an object with a screw thru-hole. Table II shows the representation of function of the face elements that construct the screw hole. The basic function is fixation of motion. The mechanism utilized for realization of the basic function is bolt-only. The condition and direction of the motion is stationary-object.

Fig. 6 illustrates that by dealing with the geometrical data and the functional data of the product design data, the automatic extraction of manufacturing features with their proper manufacturing information can be realized [13].

TABLE I
CONTENTS OF FUNCTIONAL PROPERTIES

Basic Function	Mechanism utilzed for realization of the basic function	Condition and direction of the motion
Transmission of motion	1: friction-mech., 2: gear-mech., 3: link-mech., 4: cam-mech.	1: liner, 2: smooth-liner, 3: very-smooth-liner, 4: round, 5: smooth round, 6: very smooth round
Constraint of motion	1: rigidity-mech., 2: ball-bearing-mech., 3: sliding-mech.	1: liner, 2: weak-radial, 3: strong-radial, 4: weak-thrust, 5: strong-thrust
Fixation of motion	1: bolt-and-nut, 2: bolt-only, 3: friction-mech., 4: bearing-fit, 5: key-fit, 6: rivet-fit, 7: shrinkage-fit	1: stationary-object, 2: revolutionary-object

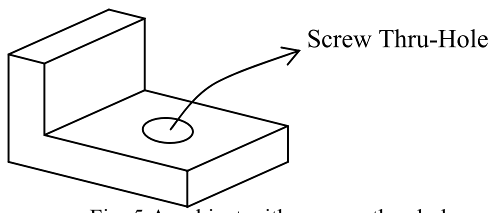


Fig. 5 An object with a screw thru-hole

TABLE II
THE REPRESENTATION OF FUNCTION OF THE FACE ELEMENTS THAT CONSTRUCT THE SCREW HOLE

Basic Function	Mechanism utilized for realization of the basic function	Condition and direction of the motion
Fixation of motion	bolt-only	stationary-object

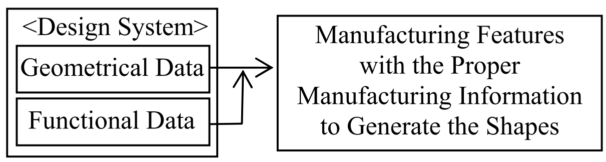


Fig. 6 Geometrical data and functional data for the automatic extraction of manufacturing features with their proper manufacturing information

B. Creation of the Function Feature Ontology, the Manufacturing Feature Ontology, and the Relation Between the Two Ontologies

Fig.6 shows the function feature ontology, the manufacturing feature ontology, and the relation between the two ontologies. Two steps for the creation of the function feature ontology, the manufacturing feature ontology, and the relation between the two ontologies are as follows.

1) Creating a function feature ontology. A function feature is defined here as a geometric shape and its functions as intended by the designer. For the creation of a function feature ontology, first, features such as thru slot, step etc are listed up. This research uses the list of features proposed in [14]. Then, sub-classes of these features are created by describing the required functions of the face elements that construct the features.
2) Creating the manufacturing feature ontology. First, manufacturing features such as step, thru slot etc are listed up. Sub-classes of these manufacturing features are created by describing the general manufacturing methods to create the parent classes. Sub-classes of these sub-classes are created to have their relation with the function feature ontology. The relation between the classes in the lowest level of the manufacturing feature ontology and the function feature ontology represents how the manufacturing features should be manufactured to fulfill the required functions of the face elements that construct the manufacturing feature.

In Fig.6, an "internal turning and milled blind-hole" feature class is created to relate the round blind-hole feature class of the manufacturing feature ontology with the "round blind-hole with 2 faces require: Basic: fixation, Mechanism: bearing fit, Motion: stationary-object, 1 face requires: Basic:constraint, Mechanism: ball-bearing, Motion: strong-thrust" class of the function feature ontology. This is done since the internal turning and milling can create the round blind-hole as intended by the designer. Then, in the development of the feature library, a collection of possible manufacturing information, such as machine and tool data, etc for the instances of the "internal turning and milled blind-hole" feature class should be prepared so that when a round blind-hole feature is extracted by a feature recognition method, and the functional properties of face elements that construct the round blind-hole feature lead to the extraction of the "internal turning and milled blind-hole" feature class, a proper manufacturing information can be extracted automatically from the instances of the manufacturing feature class. Thus, by developing the feature library based on the proposed structure, the structured feature library is useful to support the automatic extraction of manufacturing features with their proper manufacturing information. The automatic extraction of manufacturing features with their proper manufacturing information is important for the realization of a manufacturing feature-based CAPP system.

IV. The Semantic Wiki-Based Feature Library

A. *Modification of MewKISS*

For the development of the Semantic Wiki-based feature library, further extension of MewKISS is done. New namespaces are created. Namespace ("FF:") is created to deal with the function feature ontology, and namespace ("MF:") for the manufacturing feature ontology. New tables are also created in the MewKISS database to deal with the new namespaces.

B. *Function Feature Ontology*

For the creation of the function feature ontology, the Wiki syntax [[FF:feature_subclass|subclass]] is used (see Fig. 7). When the Wiki syntax is written on the parent class page, the Wiki engine will store the RDF triple into a table which deals with the namespace ("FF:") in the Semantic Wiki database. By directly querying the table, the labeled link relation will be displayed as follows.

1) On the parent class page: -> subclass -> feature_subclass (see Fig. 8)
2) On the feature_subclass page: <- subclass <- parent class (see Fig. 9)
3) On the subclass page: parent class -> feature_subclass (see Fig. 10)

The "FF:subclass" page can be used to see all the class-sub-class relations of the function feature ontology. Fig. 11 illustrates the page relations of the function feature ontology.

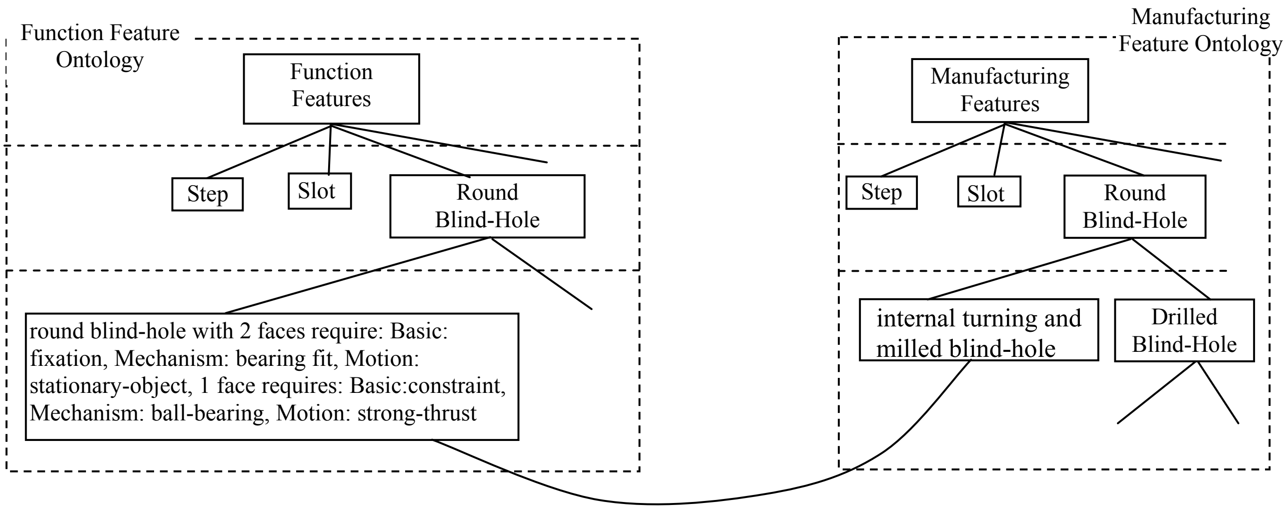


Fig. 6 Function Feature Ontology, Manufacturing Feature Ontology, and the relation between the two ontologies

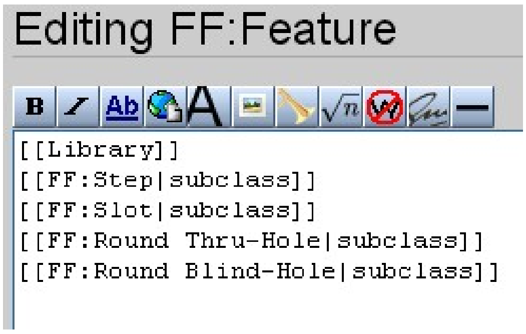


Fig. 7 Writing the Wiki syntax [[FF:feature_subclass|subclass]]

Fig. 8 Display on the parent class page

Fig. 9 Display on the feature_subclass page

Fig. 10 Display on the subclass page

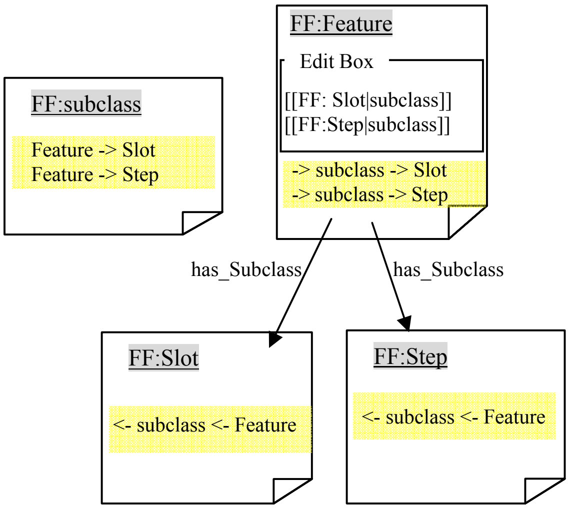


Fig. 11 Page relations in the function feature ontology

C. *Manufacturing Feature Ontology*

For the creation of the manufacturing feature ontology, the Wiki syntax [[MF:feature_subclass|subclass]] is used. When the Wiki syntax is written on the parent class page, the Wiki engine will display the labeled link relations in the same way as in the function feature ontology. The "MF:subclass" page can be used to see all the class-sub-class relations of the manufacturing feature ontology.

For the class-instance relation of the manufacturing feature ontology, Wiki syntax [[Term:instance_page|instance]] is used (see Fig. 12). When the Wiki syntax is written on the manufacturing_feature_class page, the Wiki engine will display the labeled link relation as follows.

1) On the manufacturing_feature_class page: -> instance -> instance_page
2) On the instance_page page: <- instance <- manufacturing_feature_class
3) On the "instance" page: manufacturing_feature_class -> instance_page

On the instance_page page, relation with manufacturing information can be written using the Wiki syntax [[Term:manufacturing_information|property]] (see Fig.13). Metadata of the manufacturing information can also be created easily using the similar Wiki syntax.

Fig. 14 illustrates the page relations of the manufacturing feature ontology, as well as the page relations between manufacturing feature and manufacturing information.

Fig. 12 Writing the Wiki syntax: [[Term:instance_page|instance]]

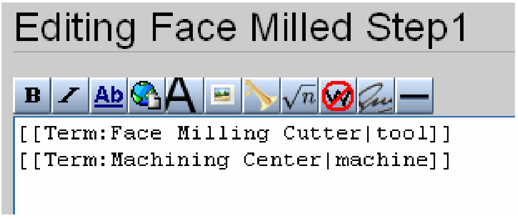


Fig. 13 Writing the Wiki syntax: [[Term:manufacturing_information|property]]

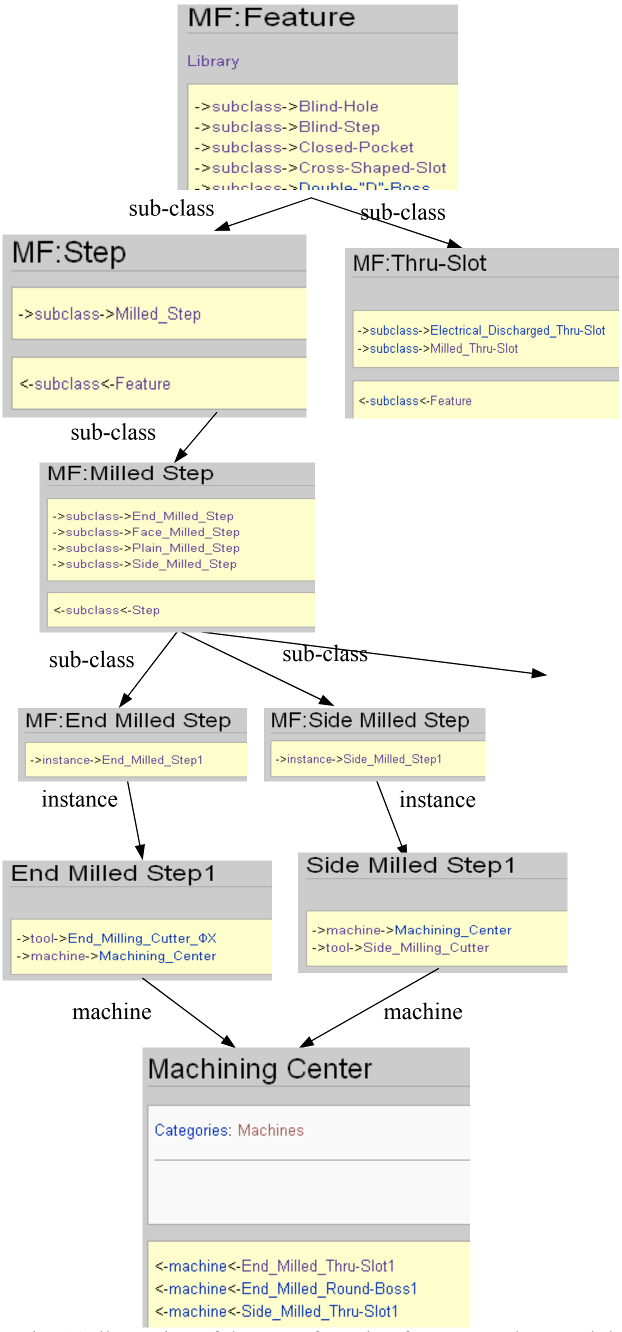


Fig. 14 Illustration of the manufacturing feature ontology and the relation with manufacturing information

D. Relation between Function Feature Ontology and Manufacturing Feature Ontology

To make the relation between the lowest sub-class of the function feature ontology and the lowest sub-class of the manufacturing feature ontology, the Wiki syntax [[MF:manufacturing_feature_class|related]] is used. Fig. 15 shows the Wiki syntax writing on the function_feature_class page. When the Wiki syntax is written on the function_feature_class page, the Wiki engine will display the labeled link relation as follows.

1) On the function_feature_class page: -> related -> manufacturing_feature_class (see Fig. 16)
2) On the manufacturing_feature_class page: <- related <- function_feature_class (see Fig. 17)
3) On the “related” page: function_feature_class -> manufacturing_feature_class (see Fig. 18)

The “MF:related” page can be used to see all the relations between the lowest sub-class of the function feature ontology and the lowest sub-class of the manufacturing feature ontology.

Fig. 15 Page relations in the function feature ontology

Fig. 16 Display on the lowest sub-class of the function feature ontology

Fig. 17 Display on the lowest sub-class of the manufacturing feature ontology

Fig. 18 Display on the "MF:Related" page

E. Discussion

As shown above, the modified MewKISS provides an environment for the feature library to construct the function feature ontology, the manufacturing feature ontology, the relation between the two ontologies, and the relation between manufacturing feature and manufacturing information. The modified MewKISS also provides a collaborative environment where many people can work together to manage the Semantic Wiki-based feature library.

And since users can write page relations in RDF triple representation, even though they have no knowledge about it, the page relation can be processed and manipulated by other computer applications. In other words, by storing the metadata in RDF triples, the metadata can also be mapped easily to other applications.

V. Case Study

Fig. 20 shows a part of a flywheel shown in Fig. 19 that is used for the case study here. As shown in Fig.20, a bearing will be fixed in the hole and a shaft will rotate inside the hole smoothly. Table 3 shows the functional data properties of each face elements.

For the extraction of manufacturing features from the product design information, a feature extraction method called the Extended Super Relation Graph (SRG) Method is used. The Extended SRG Method is an extension of SRG Method, a feature recognition method which uses the graph-based approach [15]. The detail explanation of the Extended SRG Method is given in other report [16].

Using the Extended SRG Method, three manufacturing features are extracted : a thru hole feature (f_4, f_5) (Fig. 21(a)), a blind hole feature (f_1, f_2, f_3) (Fig. 21(b)), and a stepped-thru hole (f_1, f_2, f_3, f_4, f_5) (Fig. 21(c)).

Then, using the functional data shown in Table III, the extracted features find the matched manufacturing feature classes from the feature library. Thru hole feature (f_4, f_5) matches the "rough internal turning thru hole" feature class, since the faces of the thru hole have no basic function, but are needed by other functional faces. Blind hole feature (f_1, f_2, f_3) matches the "internal turning and milled blind hole" feature class, where internal turning process is used to machine face f_1 and face f_2 , and milling process to machine face f_3 . Stepped-hole feature (f_1, f_2, f_3, f_4, f_5) matches the "rough internal turning and internal step turning stepped-hole" feature class, where rough internal turning and internal step turning process are required to manufacture the shape.

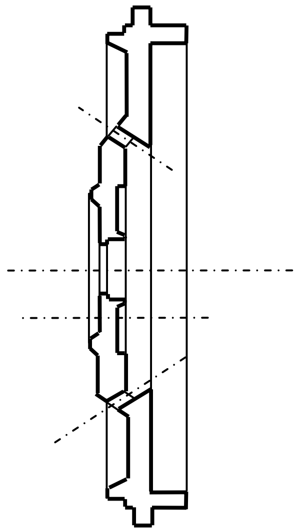


Fig. 19 A sketch of a Flywheel

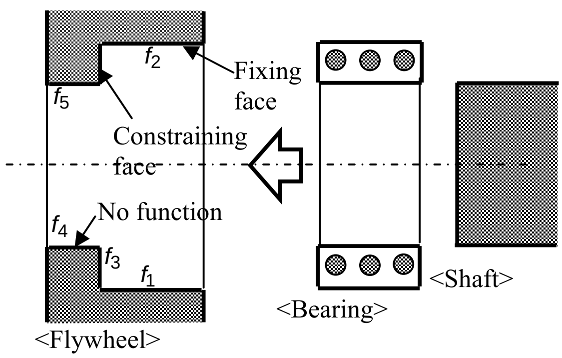


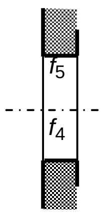
Fig. 20 The area of the Flywheel used for the case study and its connection with other parts

TABLE III
FUNCTIONAL DATA OF FACE ELEMENTS

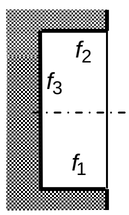
Face Elements	Basic Function	Mechanism utilized for realization of the basic function	Condition and direction of the motion
f_1	Fixation	Bearing Fit	Stationary-Object
f_2	Fixation	Bearing Fit	Stationary-Object
f_3	Constraint	Ball-Bearing	Strong-thrust
f_4	No function	-	-
f_5	No function	-	-

Fig. 22 and Fig. 23 illustrate two different kind of process plans that can be generated to manufacture the area of the flywheel shown in Fig. 20 based on the extracted manufacturing features and their manufacturing information.

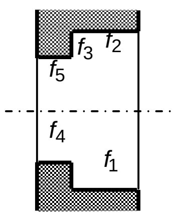
In the first process plan, this stepped-hole will be manufactured by three different manufacturing processes: internal turning, milling and rough internal turning. In the second process plan, the stepped-hole will be manufactured by two different manufacturing processes: rough internal turning and internal step turning. Thus, the feature library can be useful for the extraction of manufacturing features and their manufacturing information that can lead to the generation of process plans of a part.



(a) Thru Hole

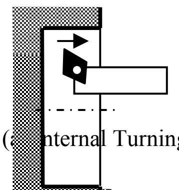


(b) Blind Hole

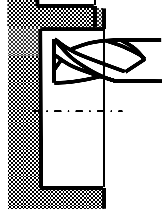


(c)Stepped-Hole

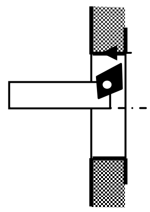
Fig. 21 Features extracted by the Extended SRG Method



(a) Internal Turning

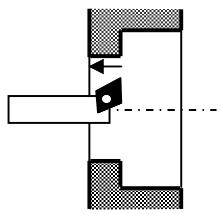


(b) Milling

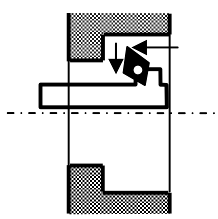


(c) Rough Internal Turning

Fig. 22 Processes in Process Plan 1



(a) Rough Internal Turning



(b) Internal Step Turning

Fig. 23 Processes in Process Plan 2

VI. CONCLUSION

This research can be summarized as follows.

1) The feature library consists of the function feature ontology, the manufacturing feature ontology and the manufacturing information. The relation between the classes in the lowest level of the manufacturing feature ontology and the function feature ontology represents how the manufacturing features should be manufactured to fulfill the required functions of the face elements that construct the manufacturing feature.
2) MewKISS is modified for the development of the feature library. The Semantic Wiki-based feature library is able to construct the function feature ontology, the manufacturing feature ontology, the relation between the two ontologies, and the relation between manufacturing feature and manufacturing information.
3) As shown in the case study, the feature library is useful to support the automatic extraction of manufacturing features and their proper manufacturing information for the generation of process plans of a part.
4) The Semantic Wiki-based feature library is a very simple system, and people can collaborate to manage the feature library. And since users can write page relations in RDF triple representation, even though they have no knowledge about it, the metadata can be processed and manipulated by other applications.

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