The Ontology based FMEA of Lead Free Soldering Process

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Abstract: *Paper is directed to improvement of a FMEA (Failure Mode and Effects Analysis) procedure in the area of reflow lead free soldering by the use of an ontology paradigm. Some ontology editor tools suitable for our intention are presented. Particular phases of ontology utilization for development of more exact approach to the FMEA procedure of reflow lead free soldering are analyzed. The goal of our work, a proposal of a user's guide for the FMEA procedure based on an ontology paradigm is presented. This user's guide is included in our university courses Management of Production Quality and Complex Quality Control provided by the Department of Electro-Technology of our faculty.*

1. Introduction

FMEA is a tool that examines potential product or process failures and evaluates risk priorities. It also helps to determine remedial actions to avoid potential problems. FMEA is a systematic approach, which makes identification of potential failure modes in a product (caused by design) and manufacturing process possible. Therefore FMEA operates with a wide spectrum of information without deeper organization of this information and mutual feedbacks. Significant improvement of this situation can be achieved by application of an ontological approach to this procedure [1]. This approach has been used for FMEA of a lead free soldering process.

The most significant problem of FMEA is that this procedure is not formalized or that its formalization is on a very low level. The computer processing of FMEA having a standard structure is therefore difficult, or impossible. Conceptions definitions are often missing and therefore it is possible to meet with their different interpretations. Therefore reusability of a main structure of FMEA for creating a new solution is problematic.

2. FMEA of Lead Free soldering process

Lead free soldering is a joining technology, which substitutes for the long time used Sn-Pb soldering. The reason is that Pb is not a nature friendly metal and therefore solders based on an alloy Sn and Pb have been interdicted from the use since the year 2006. However, the use of new types of lead free solders is joined with new problems, e.g. with the use of new types of fluxes, with higher temperature of soldering, or with worst surface quality of the joints and others. Therefore it is necessary to carry out a new FMEA analysis to find critical possible failures of lead free soldering process and lead free joints.

FMEA represents a very effective tool in measuring "control" of and process from design to manufacturing and service of a product. FMEA can be used for products and production processes as well. FMEA is a tool that examines not only potential product or process failures and evaluates risk priorities, but it helps to determine remedial actions to avoid potential problems [8]. FMEA is focused on inspection and improvement of weak parts of a technological process, defines methods of failures diagnostics, shows how to do away with the failures, set deadlines for elimination of failures and defines responsibilities as well.

FMEA is usually conducted in following steps:

- Product or process is described.
- Functions are defined.
- Potential failure modes are identified.
- Effects of failures are described.
- Causes are determined.
- Detection methods are chosen.
- Possible risk is calculated.
- Actions are taken.
- Results are assessed.

An FMEA composition is shown in Fig.1.

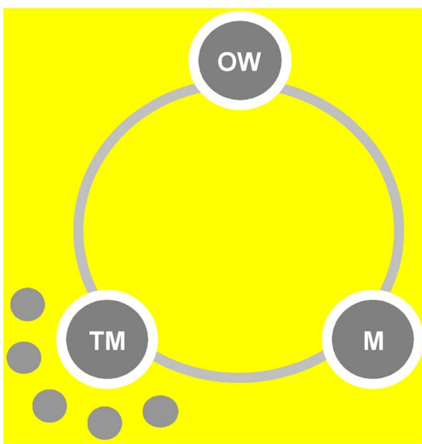

Fig. 1. Composition of a FMEA team. OW ... owner of FMEA, TM ... team manager, M ... moderator.

In most formal systems the consequences are evaluated by three criteria and associated risk indices:

- Origin (S).
- Significance (O)
- Detectability (D).

Each index varies from 1 (lowest risk) to 10 (highest risk). The overall risk is called Risk Priority Number (RPN) and is calculated according the following formula:

$$RPN = S \times O \times D \quad (1)$$

The RPN (in the range 1 to 103) is used to prioritize all possible failures and to decide about actions leading to minimizing of occurrence of these failures together with improvement of methods for control and detection of failures.

The process of soldering using Sn-Pb solders is known for the very long time and steps of a process of lead free soldering do not differ from this process in principle. Differences are in the use of fluxes, in the soldering temperature and in the final inspection, if it is based on optical inspection, because the surface properties of joints soldered using lead free solders and using Sn-Pb solders are different. The most frequent failures, which can occur by the process of lead free soldering, are as follows:

- Too high soldering temperature can damage a mounted component or decrease its life time.
- Improper surface finish (e.g. finish with low wettability) can cause worst mechanical and electrical properties of the joint.
- Improper flux can cause worst mechanical and electrical properties of the joint.
- Too high time of soldering can cause recrystalization of solder and decrease a soldered joint quality.

There are many other failures joined with this process instead above mentioned ones.

After the process analysis it is necessary to establish rating of different failure types. Rating consists of three parameters: of failure origin, of failure significance and of failure detestability. Every failure type is evaluated by points, in the range from 1 to 10 usually, according to the probability or significance.

The process of FMEA is rather complicated and therefore it seems to be effective to find some ontology, which will formalize it.

3. Our Approach

The goal of the work is to verify if application of an ontology approach will help to solve problems mentioned above. A proper ontology editor tool must be chosen and applied for FMEA of a Lead free soldering process. The results will show how the use such an editor can improve FMEA formalism.

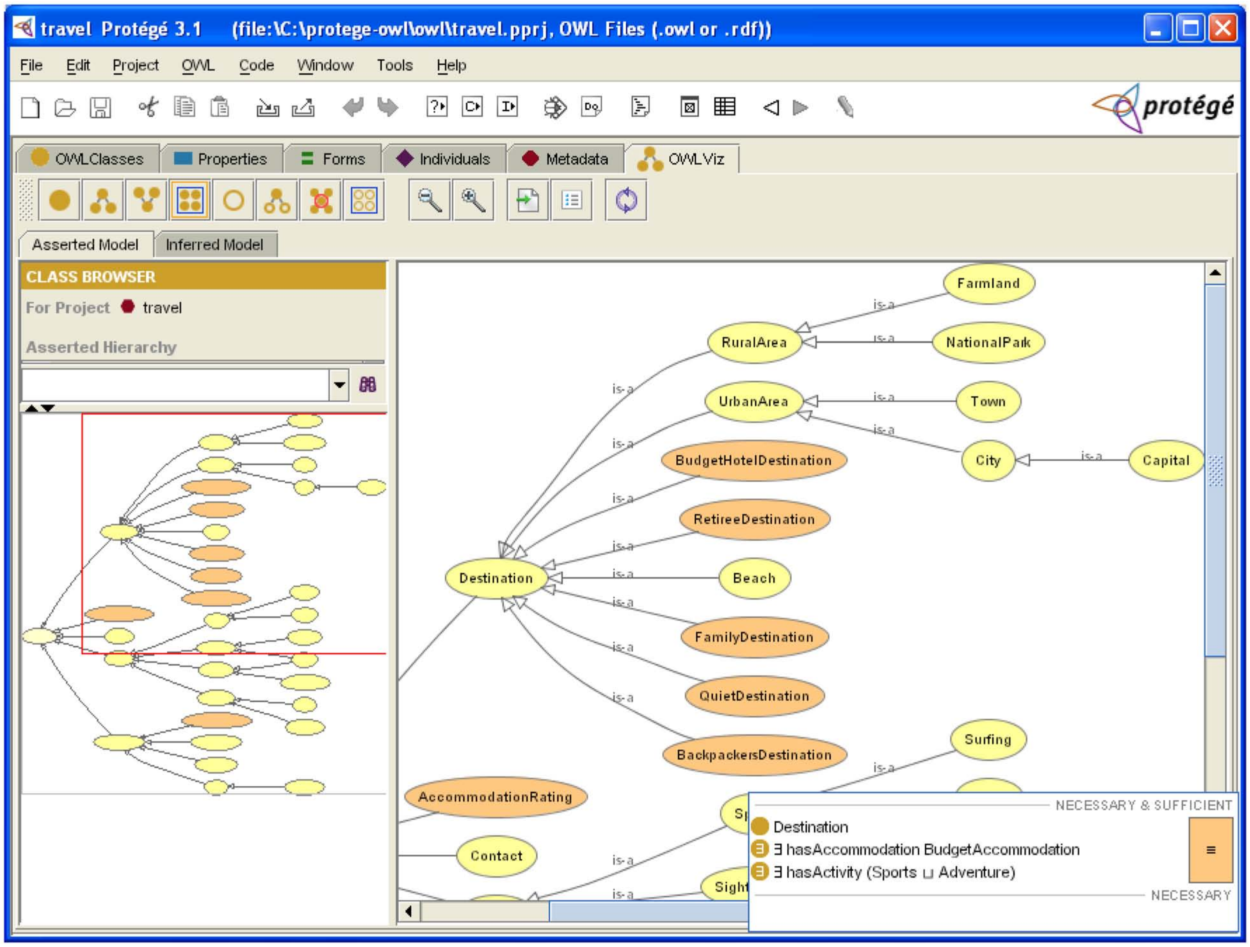

Fig. 2. Protégé - an ontology editor.

Our approach is based on ontology paradigm. Ontology in philosophy is the study of the nature of being, existence or quality in general, as well as of the basic categories of being and their relations [1]. In our work we deal with the more specialization kind of ontology, i.e., the informatics or upper ontology [2].

As noted in [3] and [4], ontology can support the development and performance of an FMEA in two ways.

- First, it offers a common understanding of the concepts of the domain of our focus and the FMEA procedure ourselves as well.
- Second, the knowledge held in the ontology based model can be computationally processed.

Both these basic facts support the idea to use an ontological approach for improvement of the FMEA procedure.

The FMEA analysis is performed according to the following five main phases [4]:

1) Structural analysis.
2) Functional analysis.
3) Migration of environmental agents.
4) Searching for degradations.
5) Selection and application of degradations.

We propose a strong support of the analysis process by performing ontology of FMEA domain. Basically ontology is a part of philosophy science, but for the case of our intention, we will use more simple definition. As defined by Wikipedia: "*Ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used to reason about the properties of that domain, and may be used to define the domain*".

The main contribution of ontology based approach is a clear and consistent graphical description and visual presentation of all FMEA concepts and dependencies. More simply, the FMEA ontology performs a synergy effect for an analyst. Despite the fact that storage of all FMEA concepts and dependencies in form of the ontological model in computerised form allows us a computerized processing, searching and reporting of these facts.

4. Results

An ontology editor suitable for our needs has been chosen. Three types of editors of such the type have been examined, Protégé [5]. SWOOP [6] and JOE [7]. It has been decided that the best one will be Protégé for our application. An example of graphic user interface is shown in Fig. 2. A primary ontology scheme of the knowledge of the lead free soldering process is under constructing and assessing.

According to our opinion mainstreaming of ontology approach in the FMEA procedure is a valuable contribution to the field of quality management in general. The results of this research have also been utilized in courses Management of Production Quality and Complex Quality Control provided by the department of Electro-Technology.

Acknowledgement

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