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Tools and Methods Stimulate Virtual Team Co-operation at Concurrent Engineering

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Abstract. Tools and methods are an important part of product development process. Advantages of different methods are growing with product novelty and complexity. Moderation of product development team meeting is a challenge at face to face meetings. Moderation has to be conducted with additional care at spatially distributed or virtual teams. The workshops or meetings related to different tools and methods are the core of concurrent engineering. Use of different methods stimulate co-operation inside Product Development team and at the end provides better products. The methods give content and structure to communication inside a product development team. An optimal percentage of team work depends on product novelty and complexity. Twenty percentage of activities need to be conducted as different kind of teamwork according to study [1]. There need to be creative dialog, conflicts of ideas and decision making. Team members stimulate each other's creativity. This paper presents what tools and methods are needed in different phases of the product development process. The generalised model of a virtual team workshop with maturity assessment criteria is presented next. On the example of the FMEA (Failure Modes and Effects Analyses) and customer's complaint workshops it is demonstrated what are specific requests for effective execution of the team workshop in distributed environment.

Keywords. Tools and methods, virtual team, maturity level, concurrent engineering, creative dialog, moderation

Introduction

A new product development begins with an idea (Figure 1). In the first invention loop the specification needs to be transformed into development goal, into the first version of product specification [2]. In the planning phase that includes system engineering and research the new product idea is transformed into a project definition. Product design is finally conducted inside the golden loop. The product level and complexity determine how dominant is a particular design phase [3]. At the original and innovative design the research loop is very important. Designing process inside the golden loop dominates at the variation and adaptive design level. CE principles are included inside several iterations or loops [2], [10]. When conceptual design is created inside the golden loop it is checked several times through all the criteria. If there is a decision at assessment point that a product design is not ready to market requests and specification the design iteration is repeated.
At each product development process (PDP) phase specific knowledge and recognised working methods need to be used. In the Figure 1 is on the left side presented the specific knowledge and on the right side the working methods. If necessary, additional

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team or individual meetings can be planned. It is vital to ensure coordination and cooperation between the development process, production arrangement (technology, tool manufacturer), production process and the company's management.

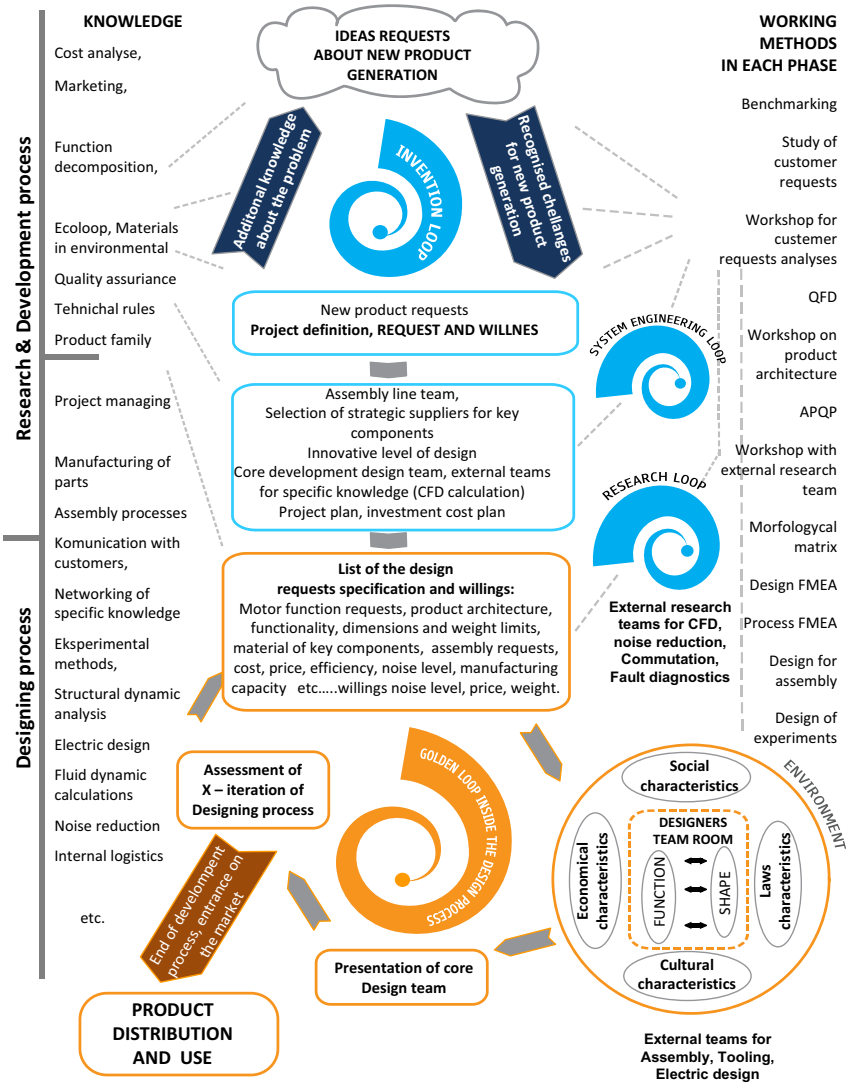

Figure 1. Product development process and working methods in each phase [3].

1. Generalized model of the virtual team workshop

Different kinds of workshops are a meeting point of the interdisciplinary product development team and sub-teams. Creative dialog is happening during workshops, therefore it is very important how the workshops are conducted. It influences creativity

and productivity of the workshop. Preparation activities before the beginning of a project need to be done. The goals should be set clearly; adequately trained individuals should be selected with care. Each team member must be independent and he must show initiative. Infrastructure for seamless communication has to be set up [9].

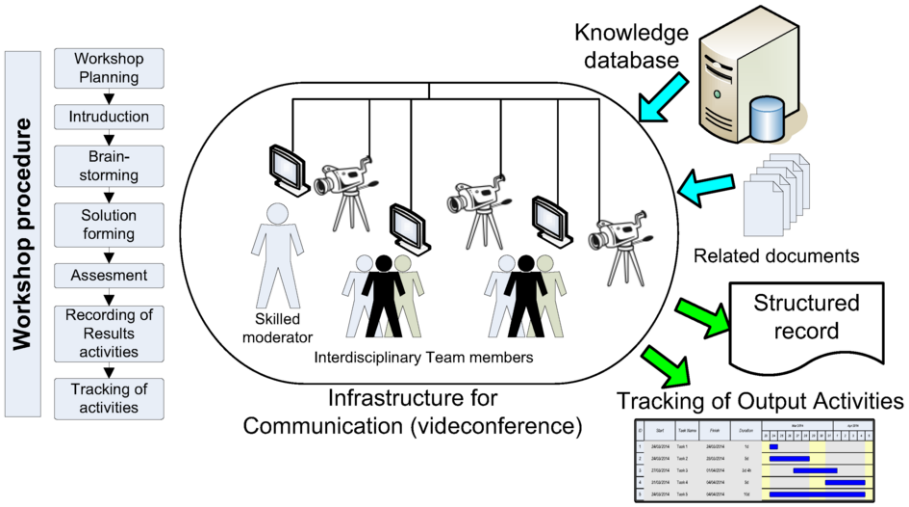

Figure 2. Generalized model of the virtual team workshop

The virtual team workshops have several common characteristics. A workshop structure was setup into the generalized workshop model that is presented in Figure 2. The team members are not limited to one location. They can join the workshop via video conference. The team members need beside specific expertise the skills for team work and communication in virtual environment. Virtual teams are formed to carry out a specific workshop.

The way of moderation has additional importance at non-permanent and virtual teams. A skilled moderator has to lead the team to the predefined workshop goals. He has to establish trustful and creative atmosphere. It is important to follow planed schedule and keep the focus. Moderation includes: time planning, checking if all the needed data is ready before the workshop start and focused introduction to the problem. Good organisation and creative atmosphere stimulate participants.

Beside the well conducted moderation it is important to have a predefined workshop framework. It helps the team to work in a systematic way and improve the workshop outputs. It is important to split workshop into several sections like introduction, generation of ideas, syntheses of ideas, assessment and further planning. At the creative phase all “creasy ideas” are allowed without criticism. A clear decision making procedure that includes all virtual team members is an important element of efficient team work. The predefined framework is helpful especially at more complex tasks and inside heterogenic teams.

The infrastructure for communication includes videoconferencing system and other means for communication like: e-mail, telephone, common server. At creative dialog there has to be as much as possible of communication means. It is a reason why face to face meetings have advantages. The skilled users can work with proper technical equipment efficiently also in distributed environment.

The structure of the workshop record has to be clearly defined (for example FMEA form). Team members have access rights to update records or at least to add comments. If the results are integrated with other documents it makes later updates more transparent and tracking of output activities is easier.
The information support has an important role. All related documents and information that is needed in the workshop has to be accessible in a transparent and user friendly way. The PLM database is a meeting point where team members can get and upload product data. In this way they can work more efficiently. It is an advantage if the PLM database enables advanced searching tools between documents and information in real time during workshop. The level of the information system support is defined also with the way of integration of the workshop outputs into other documents and databases.

2. Workshop concurrent engineering (CE) assessment criteria

The seven key criteria that define the level of CE in the product development process were recognised [3]. The same criteria can be used for assessment of the virtual team workshops. The CE models from literature [5] were compared with specific requests at virtual teams and known CE assessment models [6, 7]. The authors have tested and supplemented the CE criteria during several PLM application project, process analyses and virtual workshop practising. The assessment criteria are presented bellow first in general form, later are applied to workshop case studies. The recognised key criteria for CE [5] are:

1. Interaction with customers (sales, distribution)
2. Involvement of suppliers (supply chain)
3. Communication (human interaction)
4. Team formation (different skills, all skills involved)
5. Process definition (workflow)
6. Organisation (soft organisation)
7. Information system (interoperability, dynamic structures)

3. FMEA workshop in a virtual team

Failure Mode and Effect Analysis (FMEA) is a methodology that helps identify the activities that are potential risks in the introduction of a new product, process or service. The FMEA is one of the most basic requirements of QS-9000 [8]. FMEA is a key document that forces the development team to analyse the new product design or process in a structured way. In the distributed environment FMEA has to be conducted with additional care. We believe that FMEA workshop can stimulate interdisciplinary team and guide the team work at the product improvement process. The FMEA form is guiding team at micro level [8]. For each component / operation needs to be defined failure modes, effects of failure, cause mechanisms and controls. The assessment of fault severity, probability of occurrence and detectability is done in the next step. In the more complex cases it is better to separate the assessment of failure modes into additional meeting. We have analysed execution of FMEA workshop with the seven key criteria that define the level of CE. The FMEA workshop guidelines have been tested at the automotive system supplier.

3.1. Interaction with customers

It is an advantage if a customer can be involved in the FMEA team especially at the introduction meeting or at so called system FMEA. It is a must that the customers' requests are well defined and formally written down. The customers' requests have to be well understood to all FMEA team members. It is recommended that the team members participate actively at collection of the customers' requests. The customers' requests have to be presented and discussed in FMEA team at the introduction meeting.

1	**Interaction with customers**	**2**	**Involvement of suppliers**
1.1	Written specification of customer's requests (input for the workshop)	2.1	Suppliers are selected as long term strategic partners
1.2	Workshop team members are in a direct contact with of customers	2.2	Established information connection for document exchange with suppliers
1.3	Customer is directly involved at workshop	2.3	Active participation of suppliers in virtual workshop
3	**Communication**	**4**	**Team formation**
3.1	Skilled moderator is available	4.1	Multidisciplinary core team with specific product knowledge is available
3.2	There are established communication rules and time tables	4.2	Team members have workshop specific skills and knowledge on Q-methods
3.3	Infrastructure for communication with external team members is ready	4.3	External team members are well integrated and character compatibility is checked
5	**Process definition**	**6**	**Organisation**
5.1	Workshop phases with inputs and outputs are defined	6.1	Company organisation supports interdisciplinary team formation
5.2	Workshop is well understood and practiced by team's members	6.2	Team has good conditions for workshop execution (no disturbance, technical support, enough time)
5.3	Workshop is integrated into related processes (process development, Q-documents management)	6.3	Organisation supports integration with external teams (with formal agreement, technical support)
7	**Information system**		
7.1	Definition of a formal workshop document that is transparent and easy accessible to team members		
7.2	There exist a database (PLM) that enable searching for specific input data for the workshop in real time		
7.3	Integration of workshop records with other documents (control plan, list of activities, customers complaints)		

Figure 3. Virtual team workshop maturity assessment criteria

3.2. Involvement of suppliers

Early involvement of suppliers is a key request for CE. There is an open question do we want that the supplier participate in the whole FMEA, do we want to share all specific knowledge. FMEA workshop can be split into several sections. Some of the FMEA workshops with the supplier's participation can be focused to supplied components and integration into the whole product. Small improvements can have a significant influence on product or process robustness. The knowledge of suppliers has to be brought into FMEA core team by selected engineers who work close with suppliers.

3.3. Communications

Open communication defines creativity level in a team. The role of the FMEA workshop moderator is very important to guide the workshops through planned phases, establish creative climate and to enable each team member to express his ideas. The communication infrastructure has to enable smooth communication through all channels: high resolution graphics, audio and videoconference at all team locations. It is recommended to split presentation or computer screen and video. That means computer enables presentation of 3D models with full resolution. Video system has to enable a detailed presentation of discussed objects. It is expected that team members has skills for using communication tools and common technical language [9].

3.4. Team formation

FMEA team needs to have interdisciplinary knowledge on the end-user requests, design, manufacturing and assembly process, tooling, service and disposal after use. Team members need to have complementary specific knowledge in also some general knowledge that enables co-operation [4], [14]. The moderator must ensure clarity of the product requests, building of trust in the initial phases of the FMEA workshop, as well as encourage communication. The team members need beside specific knowledge on product, skills on FMEA method, other quality tools and awareness on how important is FMEA [9]. Compatible characters of the team's members are an advantage. It is recommended that the product development project manager is responsible for FMEA. He can authorise a specialist to execute some activities (like moderation or recording), but the responsibility has to stay at the project manager.

3.5. Process definition (workflow)

FMEA workshop has to have a clear structure that is obvious to all team members. Product / process analyses consist from several workshops that take from 3 to 4 hours (Figure 4A). Time schedule of workshops need to be consistent with product development process [12], [13]. At more complex products or processes FMEA team can be split into several sub-teams. There has to be good cross Sub-teams communication. Structure of a single FMEA workshop is presented in Figure 4B. Product / process requests have to be presented at the beginning. It is important to split the workshop into phases: searching for fault modes, fault mechanisms, solutions and assessment of solutions. Additional methods like 5xWHY or Ishikawa can be helpful. There is a clear procedure on how to take decisions if there is a disagreement inside the team. It is clear where product / process data is accessible and how to do records. Time of the team has to be dedicated to creative dialog and not watching how one of members is doing records. It is a good practice to do basic records in real time. Detailed records are done immediately after meeting by moderator or a selected person. All team members have to be asked to approve or supplement the FMEA records.

3.6. Organisation

An organisation has to support a consistent execution of the FMEA workshops. There is clear procedure on how to convene the workshop and inform the team members. The project leader has to be able to assure attendance of the needed external experts. One option is to determine days in the organisation that are intended for FMEA workshops. The organisation has to guaranty execution of corrective actions that were determined at FMEA. The workshop has to be executed with attendance of all team members in concentrated way. That means it should not be disturbed with urgent mobile calls or e-mails. It is an advantage if a FMEA team can isolated from other everyday activities.

3.7. Information system

FMEA is a structured record of product / process knowledge. On one side it has to be kept safe because of the importance of specific knowledge and it has to be easy accessible for re-use. There is an advantage if FMEA is kept in a database that enables advanced search tools. For example online search according to the specific failure mode through all FMEA forms. Related documents like product 3D model, process layout and failure modes have to be accessible. At invitation for FMEA workshop has to include links to all needed documents. The main output from FMEA workshop are corrective activities that has to be implemented. It is an advantage if supporting software enables tracking of activities for each team members.

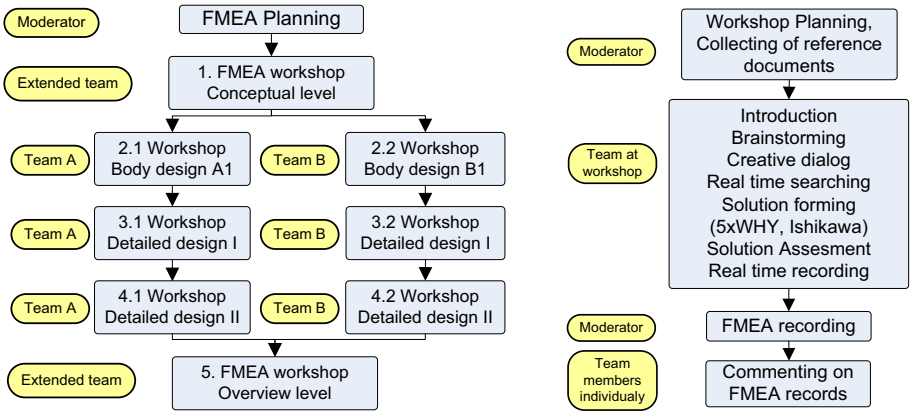

Figure 4. A - Overall FMEA process definition; B – Single workshop structure.

The maturity level of FMEA workshop can be assessed by the criteria for virtual workshops that are presented in Figure 3. FMEA specific requests presented in section from 3.1 to 3.7 has to be considered. The maturity level criteria in Figure 3 are in the same time the workshop reference model, the target is to fulfil all criteria.

4. Customer's complaint workshop

The customers' complaint workshop is not a typical workshop during the new product development process. But it is an indispensable part of the product life cycle therefore it has a special importance. The key requests are fast response, finding of root causes and avoiding of repetition of failure mode. In the automotive industry customers specify all details about the response deadlines and contents of 8D reports. In this paper the focus is on a customer's complain workshop execution.

Customers' complaints are coming unplanned. The interdisciplinary team has to be setup in a short time, typically in between 12 to 48 hours. It is an important advantage if the team members are familiar with the products; the best option is if they had participated in the product development. It should be defined who is receiving complaints and who define 8D team. A recommended practice is that this is the responsibility of the quality manager (Figure 5). The customer's complained workshop is analysed with seven key criteria that define level of CE. The specific request has to be used together with the general maturity assessment for the virtual workshop (Figure 3).

4.1. Interaction with customers

It is important to have open and trustful relation with the customer. The 8D team has to get all relevant information from the customer. The expected deadlines and prompt feedback to the customer has to be assured. The typically first response on short term corrective actions has to be defined in 24 hours. For each complaint the contact persons on both sides has to be defined. The root causes and corrective actions have to be reported to the customer typically in a two week time. The corrective actions have to be convincing and implemented in time.

4.2. Involvement of suppliers

The sub-suppliers are often the root cause of the non-conformity. It is important to have long term relationship and immediate response on request for participation in the 8D team. The pre-requests are the contact persons on both sides and established way for reliable and fast documents and data exchange.

4.3. Communications

Inside the team and organisation has to be open and constructive communication. Discussions have to be focused into searching for root cause mechanisms and long term solution and not searching for the guilty person. The proposal for guided communication during the second workshop:

1 – Problem presentation (5 minutes)
2 – Presentation of already done analyses (25 minutes)
3 – Brainstorming on root causes (30 minutes)
4 – Recording of fault causes (5 minutes)
5 – Decision making on the primary root cause (10 minutes)

Critical can be decision making. A dominant person can push forward his root cause and it can generate personal conflicts. The solution can be the voting system where each team member can equally participate. The final decision is impersonal and therefore more acceptable for everyone. In the second phase of the workshop searching for solutions on the base of recognised root causes is following. The sequence of activities during the workshop can be similar to the first phase. The face to face meeting has its advantages. At temporary 8D teams specialists should come together that are already involved in new projects. The virtual teams are therefore the only option. The skilled team members and video conferencing infrastructure is a prerequisite for efficient work.

4.4. Team formation

The established team has to consist of people who can contribute at solving the problem and implementing a solution. The team members have to be familiar with product, manufacturing and logistics processes. It is an advantage if they had been involved in the product development process because it enables smooth transfer of knowledge through product life cycle. At smaller enterprises it is not possible to have permanent teams to work on customers' complaints. The 8D team is setup temporally. Q-planners with responsibility for team moderation and overall customer complaint co-ordination are a good practice.

4.5. Process definition (workflow)

The process is in general defined with 8D report steps. The first workshop is coming after team formation (Figure 5). Important is prompt response and definition of short term corrective actions. The team has to come together as soon as possible and check what is happening in the production, is there a need for checking parts in the storehouse or at the customer. The second workshop has to be planned and organised in a systematic way; typically in one week time. The goal is to find root cause mechanism in the first phase and corrective actions in the second. The structure of the second workshop can be similar to FMEA workshop presented in Figure 4B. Additional methods like 5xWHY or Ishikawa diagram can stimulate systematic searching. After testing of corrective actions the team meets third time. Decision on implementation in serial production has to be taken. In the next phase new knowledge is transferred as preventive actions to similar products or processes.

4.6. Organisation

The enterprise has to have a balance between the new product development projects and the support of existing manufacturing processes. The organisation has to put priority to the customers' complaints. The product / process specialists and external team members have to be available to temporally teams on request. If the experts are already involved into the new product development projects than it can be risk at achieving the new projects milestones. The bigger enterprises can split staff into the group for new projects and into the group for support of existing manufacturing processes. In the last case the transfer of the new product into serial production has to be executed with additional care that specific knowledge from R&D process is not lost for manufacturing. The 8D team needs support at implementation phase of corrective actions at prototyping, testing and tooling. The support increase team efficiency.

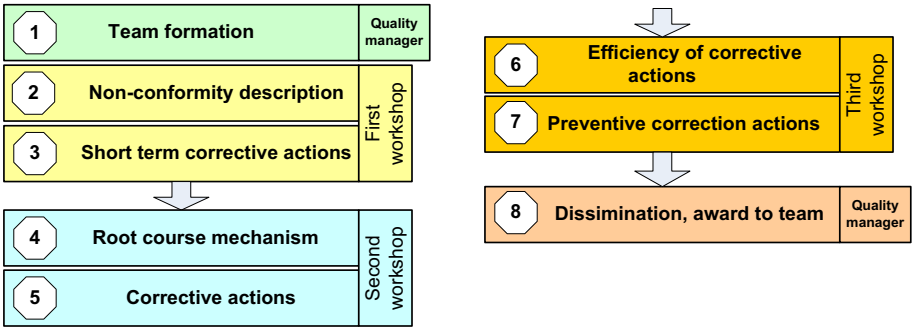

Figure 5. 8D report procedure.

4.7. Information system

The customers' complaints procedure is a typical process that can be well supported with workflow. The appropriate software solution can accelerate work. All team members need related information in each phase of the workshop. They are invited with an e-mail with a link to key documents. Integration of the customers' complaint processes to other processes can significantly improve productivity and process robustness. Few examples: the new fault mode is of key importance for the product / process developers. FMEA document has to be updated with new findings. Updated FMEA is then the source of knowledge for the next generation of the product. It is an advantage if searching tools enable context specific searching through all FMEA documents / database. Integrated database for activities, costs and material handling is additional tool at workshop data tracking. Important is also link to updated quality plan.

An example of the customers' complaint IT solution from a system supplier Iskra Mehanizmi in automotive industry: 8D form is implemented in the document system Lotus Notes. Each file is stored once only on the server. It is possible to interconnect different related documents - from 8D report are documents accessed with a mouse click: received customer's complaint, a product drawing, 3D model, additional tests report and material master data. The activities from all 8D reports can be summarised for each person in a special view. The related costs to the complaint are reported automatically through a connection to ERP system. The PPM (parts per million) report is updated automatically by using information on number of non-conforming products. The presented application for customers' complaints includes also workflow. The

designated person receives an e-mail with links according to activity status and the 8D report phase. Such application is a must for efficient work in the virtual teams. All team members are well informed even if they miss one of the meetings. There are several commercial software solutions with the described functionality. The added value of the application is a seamless integration with related processes.

5. Conclusions

The virtual workshops have been recognised as the key interdisciplinary team meeting point and as a source of creativity during the product development process. The workshops have to be conducted in a proper way. The generalized model of the virtual team workshop has been set up. The model with the seven CE criteria for assessment of the virtual workshop maturity level was created. The assessment model was applied to FMEA and to customer's complaint workshop. The case study helps to recognise the key criteria at different kinds of workshops. The authors believe that the presented generalised model for the virtual team workshop can be applied to the other kinds of workshops.

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