Development and Analysis of Design-Engineering Workflows (mentioned as an instance a radio engineering enterprise)

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***Abstract*—The authors analyse the current situation in the field of Product Life Management. The problem of the coordination of design-engineering documentation was examined. The author's model of the Petri net modeling model flows of project works in coordination with design-engineering documentation is developed. RV-grammar used for analyzing and control of diagrams of workflows.**

***Index Terms*—Workflows, business process, enterprise.**

I. Introduction

Activity of any enterprise can be considered as set of the processes directed to achievement of any collective purpose, whether it be design, production, work with clients and so forth. During these processes basic data will be transformed to the end result which quality depends on a set of factors. Let's list some of them:

- existence of the modern means of production allowing to gain the maximum income from activity of the enterprise at simultaneous minimization of expenses;
- use of the professional software, and also optimum compliance of its opportunities to solvable production tasks;
- organization and quality of management of productions and resources of the enterprise (financial, technical, human);
- quantity and qualification of employees.

Pay to the first and last points a close attention, including them the factors which are not subject to doubt, pompously the second point today the majority already agrees. The importance of the third factor (the organization and quality of management of productions), perhaps, yet is not so obvious.

One of conditions of productive work of the enterprise is effective interaction of all divisions and structures making it. The information flows capturing the production essence move on a chain. Tasks are transferred from the performer to the performer. Owing to a set of the reasons (organizational, technical, subjective) the speed and reliability of data transmission are not always satisfactory. Information can be distorted, delayed, not be transferred at all. All this not in the best way affects the speed of achievement of the end result and its quality.

Will help to remove these problems (at least partly) the technology designed to arrange activity of the enterprise, having presented it in the form of the sequence of accurate procedures - business processes, control of which is exercised automatically, according to the predetermined rules. Such technology in modern systems of document flow is called Workflow.

For the last 20 years the set of program systems for management of flows of works is developed. Most of them is oriented to electronic document management (for example, 1C [1], DocVision [2]). And only some organizations develop the software for project management (for example, MS Project [3] or Pilot-Ace of the company ASCON [4], ELMA [5]). These systems have a number of problems when developing Workflow which will be considered below in more detail.

Now in software solutions of most of the advanced vendors of data management systems there is a Workflow module: Siemens PDM [6], Lotsia PDM [7]. The ASCON company has such development and: The PILOT of Workflow is one of system modules of management of engineering data and life cycle of the product LOODSMAN: PLM [8]. It is intended for modeling of worker processes and management automation by job flows.

To show opportunities the PILOT of Workflow, we will consider stages of creation and implementation of the business process capturing the essence of mining process of a set of design documentation. The PILOT of Workflow is the key to effective work correctly performed tuning of system which should take place in close cooperation of the qualified system administrators and specialists possessing the complete information about productions and information flows of the enterprise.

Article has the following structure. In section 2 the list of standard problems with workflows is submitted briefly. Section 3 supports level structure of the organization of business processes. In section 4 the model of standard business process of approval of design-engineering documentation is presented. In section 5 development of the method for analyzing and control of diagrams of workflows is presented. Outputs and the further directions of researches are presented in the conclusion.

II. THE LIST OF STANDARD PROBLEMS IN WORKFLOWS

Processing of design-engineering workflows of a large industrial enterprise requires the solution of the following tasks.

1) Analysis, systematization and development of normative diagrammatic workflows models.

2) Analysis and control of properties of diagrammatic models, primarily topological ones.

3) Analysis of the business process integrity for such failures as hangs, loops and finitudes.

4) Workflow interpretation, including the implementation of workflow management systems based on the developed business process. If there is a lot of software for the development of the business process scheme, such as MS Project, etc., the implementation of workflow management systems is performed by most major PDM and ERP system developers independently of each other. This category of developers consists of document management system developers (1C, DocVision) and project management system developers (Pilot-Ace of the ASCON company).

The lack of modern tools for processing these workflows of effective methods and means to solve these problems determines the subject of research and its effectiveness.

III. STRUCTURE OF FLOWS OF PROJECT WORKS IN LARGE DESIGN MANUFACTURING ENTERPRISE

Let's allocate the following coordinated workflows: The 6th main process of design and 3 processes of support. In Figure 1 the scheme of problems of a stream "Design-engineering preparation of production" which is one of examples of standard workflow is developed.

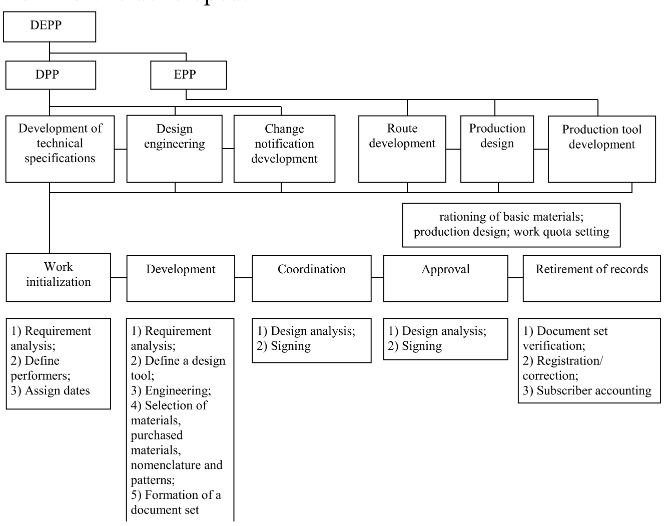

Fig. 1. Workflows "Design-engineering preparation of production"

In the DEPP (Design-Engineering Preparation of Production), DPP (Design Preparation of Production), EPP (Engineering Preparation of Production), Development of technical specification, Design engineering, Change notification development, Route development, Production design, Production tool development are shown standard tasks.

For example, Development of technical specifications: Work initialization, Development, Coordination, Approval, Retirement of records. In turn "Work initialization" contains the following list of works: Requirement analysis, Definition of performers, Assign dates.

IV. MODEL OF STANDARD BUSINESS PROCESS OF APPROVAL OF DESIGN-TECHNOLOGY DOCUMENTATION

The stage of coordination of design-engineering documentation contains two types: top (Fig. 2) and lower (Fig. 3). The top type represents laboratory coordination in respect of a correctness of the scheme (verification of electric circuits, nomenclatures, etc.). The lower type represents coordination of construct (technology of radio installation, etc.). The specified workflows are presented in the specialized language allowing to organize conditional and parallel performance of work. The topological correctness (especially in respect of remote "And", "OR" branching and their merges) is offered to be carried out by means of the author's device of RV-grammars [9-11], considered in section 5. Authors developed the coordination model on the basis of Petri's (Fig. 4) network allowing to carry out the analysis "in general", and its specification to solve a problem of integrity of business process.

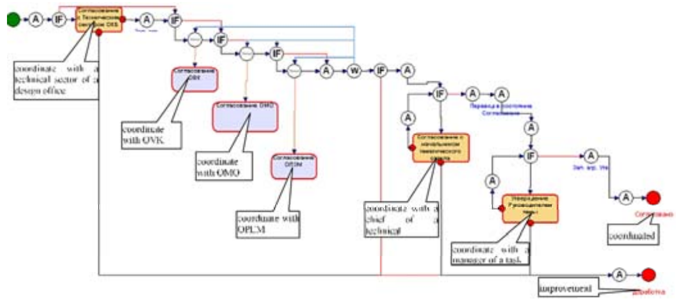

Fig. 2. Top type of approval

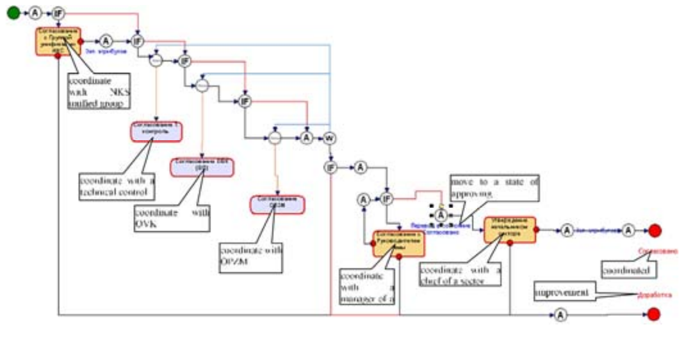

Fig. 3. Bottom type of approval

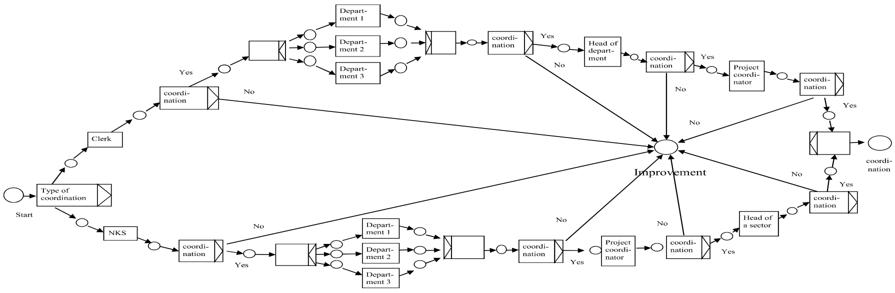

Fig. 4. Dynamic model of types of approval on the basis of a Petri net

V. Development of the Method for Analyzing and Control of Diagrams of Workflows

The specialized visual language allows to organize an enclosure of processes at the expense of several elements. The curtailed subprocess is developed for visualization of workflows in the form of diagrams in software products of ASCON. A creation of parallel workflows is supported in this language. Control of such workflows is possible by means of two elements “Events” and “Semaphore” which work together with the expectation element and additional type of communication of “Synchro action”. There is “Phantom” element which allows to connect parts of the diagram at the different levels of an enclosure. A number of graphic elements of language is shown in Table 1.

TABLE I. Elements of the ASCON Specialized Language

Name	Graphics	Description
Procedure		The curtailed subprocess which is possible for causing repeatedly. Has only one entering communication like “To pass into the procedure”
Task		The curtailed subprocess in which action is obligatory to performance by the user
Iteration		The curtailed subprocess which performance is required repeatedly
Call procedure	Call	It is used together with “to pass into the procedure” and the procedure block
Create workflow	Thread	Create a new workflow
Intransitive	E	The operation which is carried out by the user
Script (Auto operation)	A	
Branching	IF	Has only two proceeding communications. True and false respectively
Phantom		Allows to connect parts of the chart at the different levels of an enclosure. In fact, is communication
Event	Ev	It is used together with “Expectation”. Rub entering, one of them “Synchro action” notifying on performance of an event.
Semaphore	Se	It is used together with "Expectation". Rub entering, one of them “Synchro action” notifying on the beginning and completion of events.
Activate	F	Two proceeding branches, one of them “Synchro action” notifying “Event” on a successful completion of an event have
Waiting	W	Two proceeding branches, one of them “Synchro actrion” monitoring the status of performance of an event have. Passes a workflow only in case of a successful completion of an event
Increment	Inc	Two proceeding branches, one of them “Synchro action” notifying “Semaphore” on the beginning of execution of an event have
Decrement	Dec	Two proceeding branches, one of them “Synchro action” notifying “Semaphore” on completion of execution of an event have

The developed automatic RV-grammar of language (Table 2) allows to carry out the analysis of topology of diagrams of the specified language and to reveal mistakes.

TABLE II. ASCON Language RV-Grammar

Start State	Quasiterm	End State	Operations with memory
r0	A0	r3	o
r1	return	r2	$w_2(b^{4m})$
r2	vA	r1	$w_1(s^{1m},t^{4m})$, CALL vA
	vIT	r1	$w_1(s^{1m},t^{4m})$, CALL vIT
	Ak	r4	o
	Akm	r5	$w_1(1^{t(1)},i^{t(2)})/w_2(e^{t(1)})$
	_Akm	r5	$w_1(inc(m^{t(1)}))/w_3(m^{t(1)}<k^{t(2)}-1)$
	Akme	r4	$w_1(inc(m^{t(1)}))/w_3(m^{t(1)}=k^{t(2)}-1)$
	CL	r6	$w_1(t^{4m})$
	TH	r6	$w_1(1^{t(7)}, i^{t(8)}, t^{4m})$
	SC	r3	o
	SCm	r5	$w_1(1^{t(3)},i^{t(4)})/w_2(e^{t(3)})$
	_SCm	r5	$w_1(inc(m^{t(3)}))/w_3(m^{t(3)}<k^{t(4)}-1)$
	SCme	r3	$w_1(inc(m^{t(3)}))/w_3(m^{t(3)}=k^{t(4)}-1)$
	C	r7	$w_1(t^{2m})$
	EV	r3	$w_1(0^{t(5)}, 0^{t(9)},0^{t(11)})/w_2(e^{t(5)})$
	S	r3	$w_1(0^{t(6)}, 0^{t(10)},0^{t(12)})/w_2(e^{t(6)})$
	F	r11	$w_1(t^{3m})$
	W	r9	$w_1(t^{3m})$
	IN	r11	$w_1(t^{3m})$
	D	r12	$w_1(t^{3m})$
r3	rel	r2	o
r4	no_label	r17	*
r5	labelC	r2	$w_2(b^{2m})$
r6	prel	r13	o
r7	nrel	r2	o
r8	PHsp	r6	o
r9	arel	r14	o
r10	PHsa	r9	o
r11	airel	r15	o
r12	adrel	r16	o
r13	vPR	r1	$w_1(s^{1m})$, CALL(vPR)
	PHep	r8	o

Start State	Quasiterm	End State	Operations with memory
r14	THa	r2	$w_1(inc(m^{t(7)}))/w_3(m^{t(7)}<k^{t(8)})$
	PHea	r10	o
	EVa	r2	$w_1(1^{t(9)}), w_2(b^{3m})$
	Sa	r2	$w_1(1^{t(10)}), w_2(b^{3m})$
r15	EVa	r2	$w_1(inc(m^{t(5)}), 1^{t(11)}), w_2(b^{3m})$
	Sa	r2	$w_1(inc(m^{t(6)}), 1^{t(12)}), w_2(b^{3m})$
r16	Sa	r2	$w_1(dec(m^{t(6)}), 1^{t(12)}), w_2(b^{3m})$

Since the notation of the language has subprocesses, the grammar is hierarchical, the CALL and RETURN functions are used to organize the analysis. A global nesting depth independent store is introduced, in which the automaton state is stored before entering the subprocess. Some elements can generate the main type of connection “Go to” many times. All other types of connections come from the elements one time. Therefore, when going to elements with different types of communication, initially there is a transition to “non-typical” element with a reference to the continuation of the main stream

The grammar uses 4 stacks and 12 tapes.

The purpose of the stacks is as follows.

A global stack is to store the state before entering the subprocess; for the “Branch” element; to return to the items after the transition using the type of the “Synchronization” connection, to store the quasiterm, from which the analysis will continue after the return from the subprocess.

The purpose of the tapes is as follows.

Three tapes are to count the analyzed incoming branches of the elements “Exit Point”, “Auto Operation” and “Create Flow”.

Three tapes are to store the total number of incoming branches of the elements “Exit Point”, “Auto Operation” and “Create Stream”.

Two tapes are to count the status of elements “Event” and “Semaphore”.

Two tapes are to control the communication of event elements and “Wait for event”.

Two tapes are to control communication and controlling events.

The condition for successful execution (*) is empty stacks; completely calculated branches of the elements “Exit point”, “Auto-operation” and “Create flow”.

The value 1 for each passed “Event” element in the corresponding tape.

The value 0 for each passed “Semaphore” element in the corresponding tape.

A value of 1 for each passed element in the tapes controlling relationships of the event elements.

The developed RV-grammar allows defining the following types of topological errors: absence of communication, hanging connection, control transfer error, inadmissible connection of elements, “Deadlock”, hang, uncertainty, absence of flow path, violations in complex structures of parallel-sequential processes and others.

Analysis of the text component of the diagram blocks is performed using the method [12], which consists in the dynamic construction of the graph of concepts and the coordination with it of the next text component.

VI. Conclusion and Future Work

The authors analyzed the business processes of design-engineering preparation of a large design and manufacturing enterprise. We developed the author's scheme of typical project work streams as well as developed a workflow of the project process of the design-engineering documentation coordination. Topological analysis of the workflow scheme is proposed to be carried out using author’s automaton RV-grammars. A model of the coordination project process based on Petri nets is developed. It has the properties of liveliness and safety and allows solving the problem of attainability. The future directions of the research work in this subject area is related to the development of mechanisms for the artifacts formation of the enterprise’s intellectual knowledge base based on the analysis of workflow diagrammatic models using RV-grammars.

Acknowledgment

This research is supported by the grant of the Ministry of Education and Science of the Russian Federation, the project № 2.1615.2017/4.6. The reported study was funded by RFBR and Government of Ulyanovsk Region according to the research project № 16-47-732152. The reported study was funded by RFBR according to the research project № 17-07-01417.

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