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Case Study of Product Innovation Based on Special Crane Trolley

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Innovation is generally accepted as key factor for development of every production oriented company. In the case study, development of the new product was analysed – new crane trolley which should replace old one, which is not in the function. Main motive for development of the new product is achieving strategic advantage over competition, since competition couldn't offer such product. Since crane trolley as product already exist in company product portfolio, special trolley is considered as incremental innovation. According to innovation strategy, innovation can be considered as adapted market-pull model, since for this kind of product niche-market was noticed and advantage was achieved. As creative method for idea development mind mapping was used and for innovation creation Stage – Gate innovative model. Result of analyses was new product – crane trolley, which was used for modernization of the crane on HE Matka, Skopje, Former Yugoslav Republic of Macedonia.

Keywords: Innovation, idea development, market-pull model, mind mapping, Stage-gate model, crane trolley

1. INNOVATIONS

Innovations are old almost as human race. In order to survive in hostile surrounding, prehistoric human had to fight for existence and to continually develop tools and weapons for hunting, agriculture, building of the shelters, etc. From theoretical point of view, such developments were primordial innovations.

Beginning of the scientific thought regarding innovations can be pinned to renaissance period. In that manner it is essential to mention work of N. Machiavelli "Prince", written in 1505. [1], and paper of F. Bacon "About innovations" written in 1625. [2]

Word innovations, has its root in Latin word "innovare", which has meaning of creation of something new. Innovation is process of developing idea into something useful for practical consumption – realisation. It can be represented with following expression [3]:

Innovation = theoretical concept + technical innovation + commercial exploitation

Development of innovation theory can be connected with work of J. Schumpeter [4], who defined innovation as main starter of industrial development. According to him, innovations are described as "creative destruction" – rejecting on old concepts in order to define and accept new ones, which were generated through process of innovations.

Thirty years later Uterback and Abernathy [5], defined different approach, in which development of each branch of market is induced by certain, radical, innovation in that field. Although definition of the innovations were not drastically changed over the time, dynamics of innovation development was changing. Drucker was observing innovations as initial force for developing of entrepreneurship [6]. According to him innovation is specific tool of entrepreneur, tool with which he can use change as possibility for different business or service. Porter [7] in his work defined innovations as key concept for development of competitive advantage of company. Nowotny [8], had different approach. Contemporary epoch, he defined as "epoch of fascination and quest for innovations". Fascination on innovations goes so far that some members of scientific community think that taking some psychoactive substances, which are generally used in order to develop cognitive functions of certain clinical patients, can stimulate innovation process [9].

In the Serbian legislation innovation was first mentioned in the Law of innovation activity of Republic of Serbia in 2005. In mentioned law, innovation is described as: "new product, process or technology, or service with unique properties, created in connection with results of scientific research through own or not own concept, idea, or method for its development, which is with certain value introduced to market".

Addition to this law was published in 2010 and in it new definition of the innovation was introduced, according to OECD standard of EU [10]. According to this addition, innovation is defined as: "innovation is successful market use of invention, or new, or significant improvement of product or process, or service, or marketing methodology, or new organizational methodology in business, work organization, or relations of company with its surrounding".

2. CLASSIFICATION OF INNOVATIONS

Main criteria for innovation classification are:
- Nature of innovation,
- Type of innovation (typology).

Nature of innovation has two main subcategories. First subcategory are radical, core innovations and second one are incremental, or evolutive innovations. Regarding typology of innovations, there are numerous different classifications.

One of the first classifications was suggested by Schumpeter:
- Innovation based on new product,
- Innovation based on new method of production,
- Opening of the new market,
- Finding new source of raw materials or components,
- Reorganization of the industry.

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Key types of innovations are ones included in first two types of innovations – innovations based on products and innovations based on new method of production.

Contemporary approach to classification of innovations is coming from Oslo manual, published in 2005, which is core document which gives directions for gathering and interpretation of data about innovations (OECD and Eurostat). [11]

In the manual there are elements of typology with four (five if services are considered as separate element) types of innovation:
- Innovation of product/service,
- Innovation of process,
- Innovation of organization,
- Innovation of marketing.

3. INNOVATION OF THE PRODUCT

Innovation of the product is "introduction of the product/service, which is completely new, or significantly improved – meaning improved characteristics or use" [3].

In the scope of this paper is incremental innovation based on development of the product which performance is changed. Further classification is done according to:
- Products which are improved (better or different performances, or cut costs) with usage of new components or better performance materials,
- Products which consists of numerous of subassemblies or elements and development was achieved by partial change of one or more subassemblies or elements.

One of the frequently asked questions is difference between incremental innovation of the product and product differentiation. Difference is in the fact that in the product differentiation there is no significant change of performance, or cost of materials or components on which product is made of. Or, to be more precise, in the differentiation of the products there is only minor change in technical or aesthetic change in the product.

4. MOTIVE FOR DEVELOPMENT OF THE NEW PRODUCT

There are numerous motives for development of the new product. Most often these motives are strategic in nature, which can provide certain benefits to the company:
- Source of competitive advantage,
- Possibility for improvement or change of strategic course of the company,
- Improvement of corporative image,
- Return of investment and capitalization of results of research and development,
- Improvement of marketing/brand,
- Positive influence on human resource.

It is crucial to emphasise what are key performance elements for development of certain product attributes:
- Design (design and construction of the product),
- Reliability (projection of lifetime of product),
- Quality (components and product),
- Flexibility (adaptiveness and components),
- Simplicity of use,
- Functionality ,
- Price,
- Technical-technological performances.

Based on mentioned above, new products can be classified as:
- Products new to the world (new products for both company and the market),
- New product lines (products new to the company, but not new to the market),
- Addition to new lines (subtype of new product line),
- Development of the product (replacement of existing product with new one),
- Cost reduction (cutting production costs),
- Repositioning (new use of existing product).

5. INNOVATION PROCESS MODELS

Mostly used classification of innovation process models is one proposed by Troth (Table 1). [12]

Table 1: Models of innovation process

Period	Model	Characteristics
1950/60	Technology push	Simple linear-sequence process. R&D are emphasised, market is accepting results from R&D
1970	Market pull	Simple linear-sequence process; market is source of directing of R&D; R&D has reactive role
1980	Coupling model	Integration of R&D and marketing is emphasised
1980/90	Interactive model	Combination of push and pull model
2000	Network model	Knowledge and external integration is emphasised

This is general classification, based on technology development (technology push), or customer related (market pull).

Process innovation models are also classified as:
- Linear-sequence models (phases of innovation process are following each other),
- Simultaneous models (sequence models adjusted to stochastic surrounding),
- Flexible models (adjusted to surrounding, special demands, etc.),
- Integrative models (connecting with surrounding through company strategic development and creation of reversible connection to phases of innovation process),
- Model of innovation diamond (model of support of management to innovation of product),
- Stage-Gate model,
- Model of open innovations.

In order that innovation process can start, it is necessary to generate idea, what and on which way should be developed in order that it can be considered as innovation.

6. IDEA GENERATION

There are lot of different methods and techniques for idea generation. Some of mostly used [3]:
- Creative model for idea generation,
- Model of life cycle,
- Methods of portfolio analyses,
- Predictive methods,
- Methods of strategic evaluation and alternative selection,
- Information support to innovation management.

One of the most used methods is creative model for idea generation. There are lot of techniques which are connected to this subject, but mostly used are [3]:

- Brainstorming (suggesting numerous ideas by expert teams),
- Mind mapping (graphical-symbolic representation of basic concepts),
- Lateral thinking (using non-conventional way of thinking, which would be ignored by everyday logical thinking),
- Inventive problem solving (use of generic solution and external information, supported by creative thinking).

7. RISK IN INNOVATION PROJECTS

Risk management is one of the most important aspects of project management. Innovation, by its nature, can be described as stochastic event, since results are not exact. Risk is connected to possibility and it can be defined as: "possibility that some achievement or project suffers failure and consequences which are outcome of this failure" [13].

Some other authors define risk as: "state in which exist possibility of negative deviation from wanted outcome, which one expects". It can be said that in order that risk can be defined some prerequisite have to be fulfilled: that project has to exist, that it can cause economic damage, it has to be independent and it has to have elements of possibility.

From the definition of the risk, two main elements are derived:

- Possibility of unwanted event happening,
- Consequence of that unwanted event on complete project, financial aspect, labour, property and surrounding.

Risk can be divided on [14]:

1. Financial and non-financial risk – in the field of financial risk exist possibility of financial loss appearance, while in non-financial this possibility is excluded.
2. Static and Dynamic risk – dynamic risk occurs because of change in economic relations, while static risk can be defined as possibility of loss, even if there are no economic changes.
3. Fundamental and special risks – fundamental risk is defined as possibility of loss which can't be divided by it's nature, while special risks are possibility of loss occurrence which are consequences of certain single events.
4. Pure and speculative risk – speculative risk is possibility of gain or loss in the economic transactions, while pure risk is possibility of loss without possibility to gain.

Innovation risks are including following risks [3]:

- Risks in technical sector,
- Risks in marketing sector,
- Risks of interception,
- Risks of time consumption dynamics,
- Risks of obsolescence,
- Risks connected to subjective factors.

In the scope of innovation projects, risks are usually connected to all factors which are important for innovation process. This methodology is connected through analyses of certain phases:

- Determination of risk factors,
- Evaluation of risk factors based on possibility,
- Combination – possible outcomes and possibility of their realization.

8. DEFINING SCOPE OF THE PROJECT – CASE STUDY

Investors request was to modernize old manually driven crane which is used to lift up and down lock on damn on hydro plant Matka in Skopje, FYRM (Figure 1). Modernisation is consisted of replacing old crane trolley with new one, electrically driven. New trolley has following technical characteristics: (Table 2)

Table 2: Main technical characteristics of equipment

Main technical characteristics	Values
Crane location	Mechanical
Nominal value	8 t
Speeds (high/low)	6.0 / 1.0 m/min
Crane rail height from	5 550 mm
Span of the crane	5 410 mm
Length of rails on the crane	5 800 mm
Lifting height	36.0 m
Voltage	400 V, 50 Hz
Control voltage	48 V, 50 Hz
IP Class of electrical	IP 55
Supply	Festoon system
Movement of trolley	Electrical
Working temperature	-5/+40 °C
Maximal humidity	80%
Handling device	Hook with pulley

Problem is that trolley with such characteristics does not exist in company product portfolio, so new innovative solution has to be made. By solving this technical problem company can achieve strategic advantage in this project over the competitors.

Figure 1: Picture of old crane trolley

9. INNOVATION ANALYSES

According to existing company product portfolio and innovation classification and nature of innovation this innovation can be considered as incremental innovation. Crane trolleys exist in company product portfolio, but they don't fit to required technical description which was part of investor demand.

According to type of innovation, this innovation can be considered as product innovation. Motive for innovation of the product is defining market niche, since there is not even one competitor that can offer such product, since they don’t have it in their product portfolio. There is also one more strategic advantage, since competitors don’t have experience and technical capacity to develop custom product which is needed in this project. According to mentioned above it can be concluded that main reason for new product development is strategic goal of the company – getting competitive advantage.

Essence of innovation is innovation of product performance. Existing crane trolley has to be completely re-engineered, new design has to be made with completely new superstructure construction. Main limitation in design is fact that functionality of the trolley has to remain the same.

According to classification of categories of development of new products, innovation is widening existing lines, or it can be said that it is subtype of existing product line (crane trolley).

If innovation process model is analysed, it can be said that it is adapted market pull model, since in the case of innovation of crane trolley, marketing department is not included in the process (Figure 2).

Figure 2: Addapted market-pull model

Stage Gate model was applied in order to create innovative product (Figure 3).

Based on the market demand (investor demand) technical description of the problem was sent to the company commercial department. After preliminary analyses, it was concluded that there is no standard product in company production portfolio, which can be used to satisfy market demand. Also, additional analyses was conduced, if it is possible to do minor changes to the one of the existing products in order to get adjusted product. It was concluded that there isn’t such product which can be improved in that way that it can satisfy all technical demands. Final conclusion was made that it is necessary to develop new product with demanded technical characteristics.

After that business case was analysed. In the business case was stated that there is the need for new product in the situation in which competition doesn’t have similar product or has potentials to develop it. It was estimated that it can be considered as monopolistic situation, in which is possible to ask for higher price in order to cover research and development costs, along with cost of developing complete product documentation and product certification and in the end to bring required profit margin.

After analyses of business case, decision is made that company has to go into new product development.

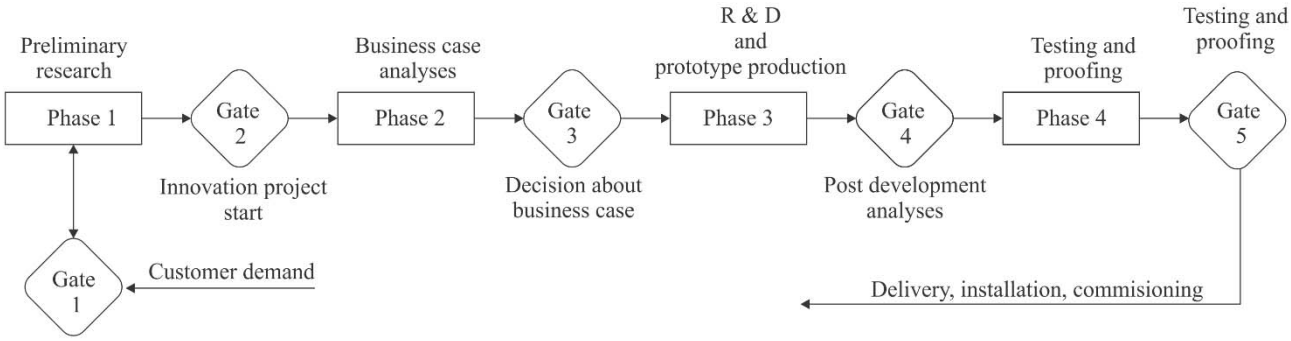

Figure 3: Stage gate diagram of innovation process

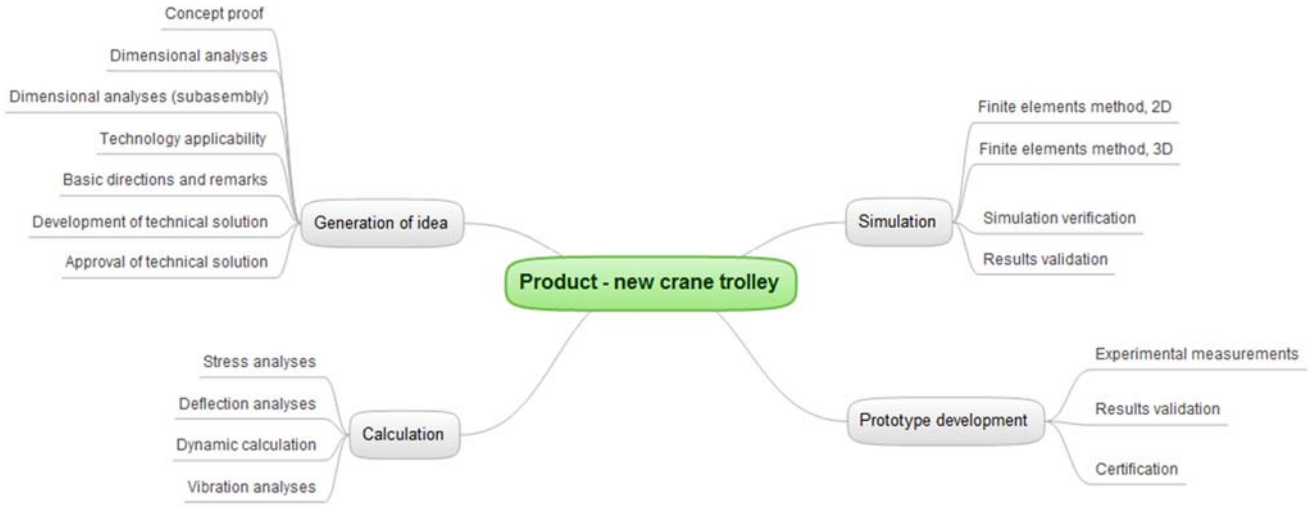

Figure 4: Mind map of idea generation

In the next phase, technical demand was brought to R&D sector in the company. R&D sector made decision based on that for generating idea concept, some of creative methods for idea generation must be used. Method which was used was mind mapping, since it provides fast visual concept of production of new crane trolley (Figure 4).

Process of innovation creation is divided in four basic phases. First phase is development of new idea. Base for development of idea is strongly connected to systematic approach to engineering, or to system engineering.

System engineering has its roots in system approaches to real life problems. According to mentioned fact, four phases of system engineering are defined and they represent activities in system studying.

Phases of system engineering:

- System analyses,
- System synthesis – system design,
- Implementation of the system,
- System operation.

Idea is created in the first two phases of system engineering. System approach means general analyses of physical subject, identification of causes which affect the system and consequences to the subject. After that, boundaries of the system have to be defined, aim of the system work and definition of its required performance.

Next step is anticipation of future system surrounding and formulation of mathematical model (or simulation model), which is used for system operation analyses. On the picture nr. 4, those two phases are given separately, as calculation phase and simulation phase. After this phase, subsystems end elements are defined, as constructive parts of the system.

In the next step analyses of the results is conduced. After that elements of optimised system are defined (both hardware and software) and performance, reliability and some other tests are conduced.

Last step is production of the prototype and its final evaluation. If system doesn't satisfy optimization conditions, it has to be optimised again in order to satisfy initial criteria.

One of the most important analyse are risk analyses and SWAT analysis (Table 3 and Table 4).

Table 3: Innovation risk analyses

	Elements of RBS							Risk evaluation by phases	
Work Breakdown Structure		Innovation team	Budget	Project team	Project management	Development process	Project organization	ΣR	Rank of phases according to risk
	Preliminary research	R=5	R=5	R=5				15	5
	Business case analyses		R=10		R=6			16	4
	Research and development and prototype production	R=5		R=10		R=15	R=8	38	1
	Test and tryouts		R=10	R=7		R=8		25	3
	Delivery, installation and starting			R=8	R=7		R=12	27	2
	ΣR	10	25	30	15	23	20		
	Rank of risk sources	6	2	1	5	3	4		

Table 4: SWOT Analysis

Strengths Strategic position Engineering team Experience Business capacity Production capacity	**W**eaknesses Quick decision making Low analytic High risk taking
Opportunities Special solution development Forming of modular solution which can be used in different future projects Project documentation coordination with different legislation in surrounding countries	**T**hreats Time needed to complete projects Too many employees engaged in the project Standards in FYRM in vertical transport Additional work demanded by investor

Based on SWOT analysis it can be concluded that innovation project of new crane trolley provides excellent strategic position, which derives good sales margin, which is necessary for such special project. This strategic

position is achieved through good engineering team which has necessary knowledge and experience. Strength in SWOT analysis is also described by business and production capacity of the company.

Weaknesses are described by fact that essential decisions are made individually (quickly and usually without all necessary analyses conduced). In the field of opportunities is evident that special solution is developed, which is modular and can be used in different projects in the future. Also, opportunity is in forming project documentation which can be developed according to different legislation procedures in different countries. This is important for developing similar projects in surrounding countries, which are also interesting for company future development. One of the most important potential threats is time consumption for development of the new product. Development of new product acquires significant time consumption from employees included in it, so there is possibility that they will fail to finish their everyday work. Also one of the threats is different standards for vertical transport which are applied in FYRM. Also, one of the threats is if investor wants to do additional work, which would lead to additional time and work time consumption.

According to dimensional analyses mathematical model was developed, which is used for further engineering calculations. Same model was later used as base model for FEA analyses. (Figure 5)

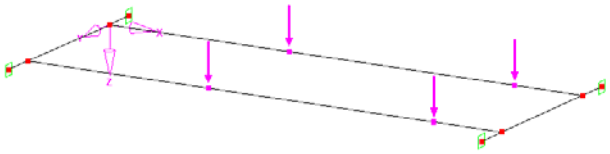

Figure 5: Base for mathematical model of crane trolley

Design of the crane trolley was made based on static and dynamic calculations and dimensional analyses of crane trolley. Such design is presented on Figure 6 in the form of generated 3D model.

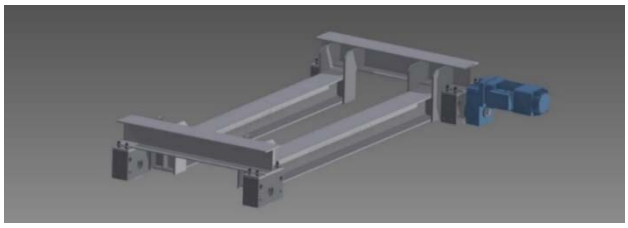

Figure 6: Crane trolley 3d model

According to FEM regulation load of the crane trolley was applied and entering parameters for static and dynamic simulation were introduced. (Figure 7)

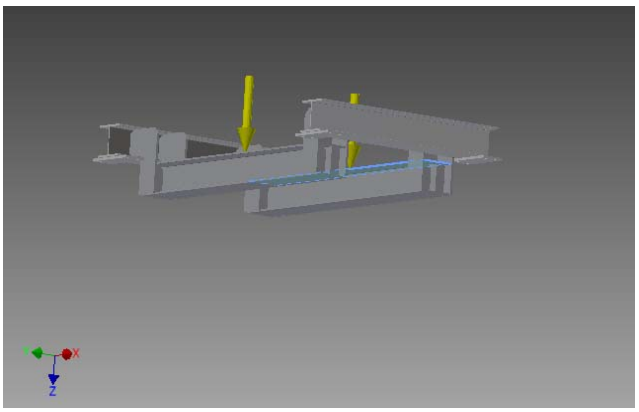

Figure 7: Simulation model

Simulation was started and all main design criteria for steel superstructure were checked (stress, deflection, buckling, torsion buckling, vibrations, etc.). (Figures 8 and 9).

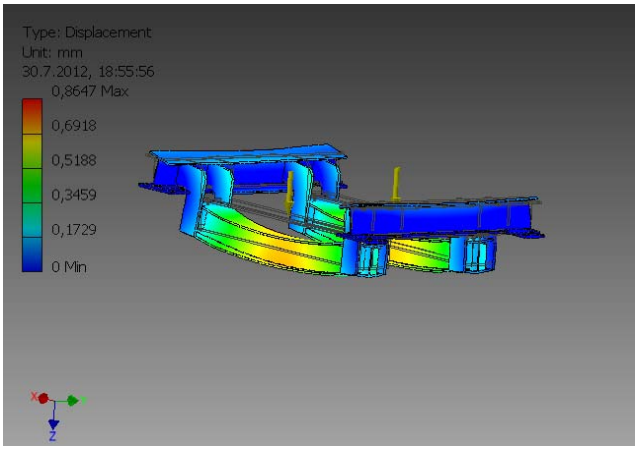

Figure 8: Displecement of the model

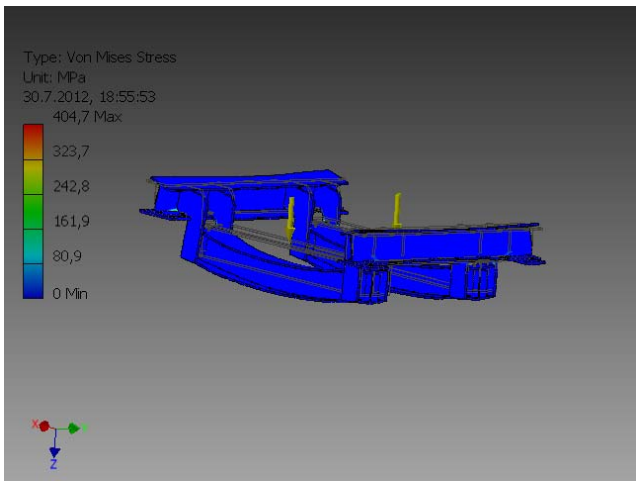

Figure 9: Equivalent stress

Based on results from simulation, prototype of crane trolley was made. Verification of the simulation is done by experimental measurement on prototype.

Table 5: Equipment characteristics

Producer	Hottinger Baldwin Messtechnik, Germany
Type of measurement tape	6/120 K-LY41
Nominal resistance	120 Ω ± 0.35%
Measurement base	6 mm
Maximum measuring voltage	9 V
K factor	2.02 ±1%
Longitudinal sensitivity	-0.1%
Temperature adjustment for steel	$\alpha=10.8\cdot10^{-6}$ 1/°C

Signal change of relative deformation of measurement tapes is processed in measurement-acquisition device Spider8 (producer HBM, Table 5), which is connected to notebook computer. For data acquisition and recording is used software package Catman Express.

Schematic representation of measurement chain is on the Figure 10. Signals are recorded with frequency of 200 samples in second, without filtration.

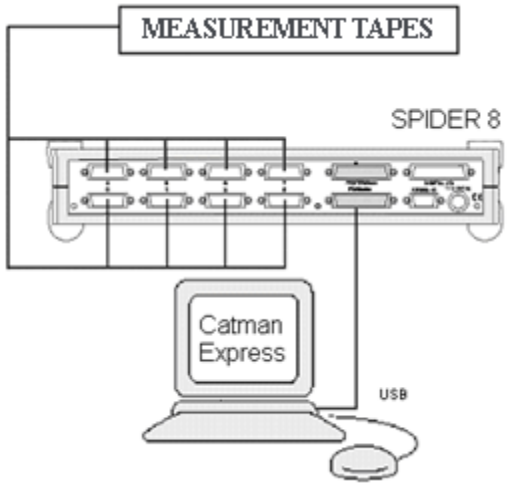

Figure 10: Measurement results of stress on the main girder of the crane trolley

After finished measurement was obtained that deviates from simulation results were less than 0.5%, which is bellow level of statistical error of 5%. According to measurements, validation of the simulation results was made and proposed designed was proved (Figure 11).

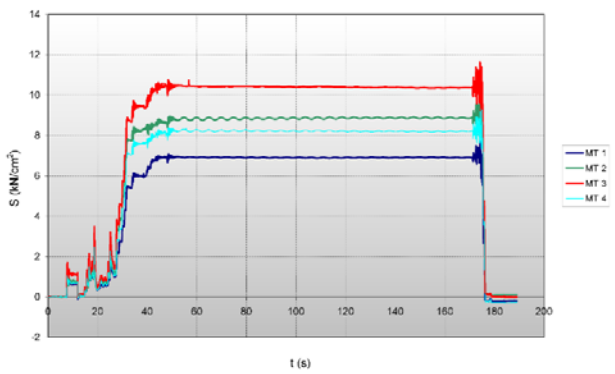

Figure 11: Measurement results of stress on the main girder of the crane trolley

Based on calculation results, results from simulation and experimental research, company applied for CE certification of the product. Final stage in Stage Gate model was delivery and system commissioning (Figure 12). After starting of the system analyses of all system parameters was conduced and it was concluded that new product completely satisfied, by the design and functionality all criteria.

Figure 12: Installation of the equipment

10. CONCLUSION

In the paper was explained innovative approach for development of the new product by using adapted Market-pull innovation model. Basic need for development of new product was market need, which was through R&D department produced as final product.

Classified by nature of the innovation, crane trolley can be fitted in the class of incremental innovation and considering type of innovation it can be fitted in the class of product innovation.

Motive for product development, as concluded is source of competitive advantage, because in existing product pallet such crane trolley doesn't exist. The same situation is with competitors, which alslo dont have such product but they are not in the position to develop it.

For idea generation mind map is used in order to define all steps in product development.

Complete innovation is described by Stage Gate model, which is used later for complete project.

Methodology from system enginieering is used for new product development. Based on proposed methodolgy problem from the real world was transfered to the level of mathematical model, which was used as base for calculation and simulation.

Results from calculation were analysed and trolley structure was dimensioned. Dimensioned model was used as base model for simulation which was used for testing of conceptual structure solution. Based on results from simulation prototype was made which was again used for gathering experimental results from stress analyses as validation of the simulation results.

New product was produced based on proposed methodology for innovation projects. Product was succesfully tested, comissioned and certified, which profeed mentioned methodology used for new product development.

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