ASSESSMENT OF RISK MANUFACTURING PROCESS THROUGH MODELLING

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Abstract

In a submitted paper we are going to deal with possibilities in using statistical instruments and methods of product quality management and with application of simulation modeling in production and maintenance introducing procedures on examples being solved in mechanical engineering companies. Sustaining competitiveness and increasing a level of provided services requires permanent innovative changes to be made by organizations. Innovation management in mechanical engineering and production takes the commissioning of new processes for granted into organization operation, into quality of products or services in area of organization and processes management, implementation of new /improved/ technologies, innovation of new, improved products and services.

Keywords: statistical instruments, manufacturing process, simulation experiments, machines equipment.

1 Introduction

The innovations require applications of modern management methods and appropriate analytical tools and techniques enabling prerequisites for proper proceeding in problem reviewing. There is a whole range of methods being used, tools, techniques whose classification is non-uniform, as it represents an interdisciplinary issue. In a mechanical engineering practice there are first of all used those based on a quantitative principles, expressed through a mathematical, a stochastic or a logical model. As a rule they need collection, preparation and processing of needed data. A more detailed definition and classification are comprehensive. Methods and techniques of several sciences we want to use aiming to apply partial innovations are overlapping in area of improvement, optimization, process modeling, implementation of new methods of functional or process management, management procedures, motivating approaches, new enhanced manufacturing technologies, commissioning of significantly improved products or services into production and introduction on the market. It may relate general analysis of processes and systems, methods of processes and system management, decision-making methods, methods of statistical analysis, methods of operational analysis, methods of reliability, security and risk analyses, methods of quality analysis, simulation, optimization and forecasting methods. Manufacturing and mechanical engineering systems always involve autonomous variables that are interpreted from a physical view as time. Breakdown effects (of a human factor, machines and equipment) always interfere with a system activity. Combined, hardy predictable causal sequences come into being. External effects of environs become evident in a form of random deviations in amount, structure and quality of material and energy inputs etc. about which we can obtain only statistical characteristics. We cannot predict in particular when, where, on which machine and device a defect will occur, what kind of material is needed. Requirements for a change of technical, technological and organizational processes bring a certain risk. It relates dynamic, stochastic, complex systems. Some occurrences and processes are hardly predictable; some cannot be expressed in a quantitative way. Relations and links among elements and environs are very complicated between several components, causing that effects and probabilities of their occurrence are conditional. Reviewing of impulses and relations in a system is hindered; the possibilities of an experiment are limited or impossible. A system can be described only through a full-range and mathematically complicated model, sometimes it is impossible to do so. When a review level is decreased, a part of a whole might be garbled and misrepresented [1], [2]. We need advanced sophisticated research tools limiting the risks from improper solutions of such generally defined risks so that they enable modeling of working environments and simulating of various variants and consequences of decision before they had been implemented.

2 Assessment of a workshop manufacturing process of fibreglass semi-finished products through modelling.

A foreign company has a sub-company in Slovakia that deals with production of glass fiber semi-finished products for specific purposes in automotive and consumer industries.

Production of a glass fiber semi products is provided in a single-shift operation, while computer-aided controlled by an actual production plan.

A production hall of the company is divided in two parts. Main part of a lamination manufacturing process takes place in the first part. The second part, which is characterized as a past-production part of a manufacturing process is assigned to finish the products into requested dimensions and to reach needed quality; manufacturing processes for glass fiber margin working, glass fiber semi product working through pneumatic equipment is concentrated here aiming to cut out, to bore and to spot-drill specified orifices.
Generally we can specify the production as a work-shop type of production, where mainly manual work of operators of particular operations enters into manufacturing process with a minimum use of machine automatic or semi-automatic technology.

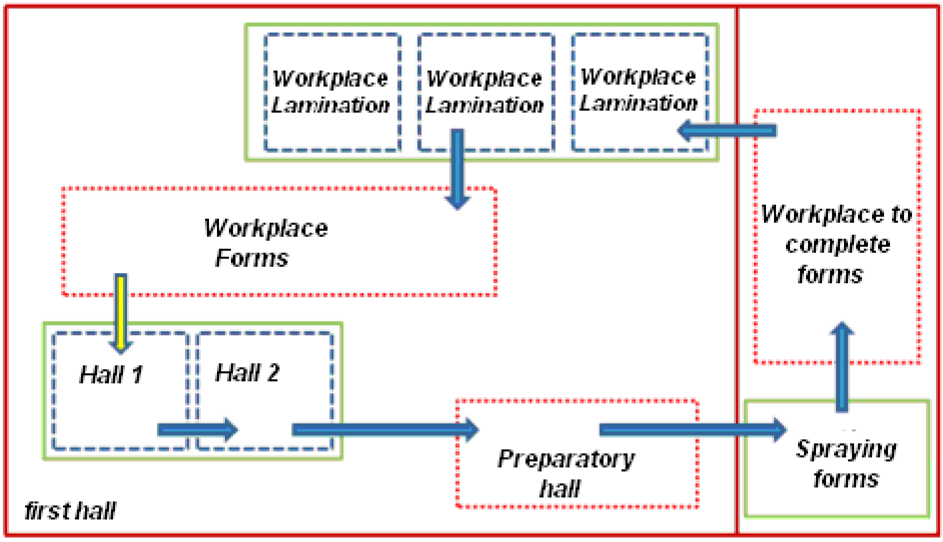

Fig. 1 *Flow chart of an organization of glass fiber semi product manufacturing process*

The problem was an insufficient capacity of a working place for form spraying with a modified resin for the following reasons

1. *Manufacturing operation before spraying is realized quicker*, that is more important in order to observe the production plan than spraying itself. Therefore the forms prepared for spraying are cumulated resulting in:

- Continuous processing of form in sequence is delayed; the room assigned for prepared forms is fulfilled resulted in extension of handling time needed to move the forms into a form spraying working place,
- Each form staying in a queue, which has not been processed within 30 minutes from its preparation is /due to minimum static energy situated on the form surface/ covered with dust from environment in such a rate, that subsequently it must be thoroughly cleaned before spraying.
- Not all forms at a form spraying working place are processed by a production plan on a particular working day.

2. Working place overload.
Spray application of a gel coat is physically demanding work, requiring regular pauses for an operator in series production. When a working place is overloaded, the pauses are minimized, or eliminated, that may cause, that the operator in spraying has a higher failure rate, which shows in a final phase of glass fiber processing of a glass fiber semi product on a quality check point and on a product repair working place. Then it is necessary to devote more time in order to remove surface defects of a particular product.

3. Use of a capacity of a lamination working place is insufficient.
Each form after spraying a gel coat must go through a „drying process „before a direct lamination. It takes 1 hour of a manufacturing time needed so that a gel coat sprayed layer becomes dry. Lamination process is affected in a negative way by an insufficient manufacturing capability, shorter or longer shut-downs occur in a manufacturing cycle.
The operators on a lamination working place work up a sprayed form, if its gelcoat layer is not sufficiently hardened, it causes defects /unconformities/ on a surface structure of a laminated semi product time assigned for lamination production time on a lamination working place is not sufficiently used, use of a lamination working place is loaded by an ineffective overhead (substitute) work due to lack of forms assigned for lamination.

4. Negative economic consequences

Violation of a production plan results in rise of overtime work. Production plan is carried out only during workweek off time or working in weekends. Analysis of technology, spatial and time structure of a process and sub-processes is a starting point to define parameters of a problem being used. General process and each process on a lower level was analyzed and described by a conceptual model, expressed by a block diagram.

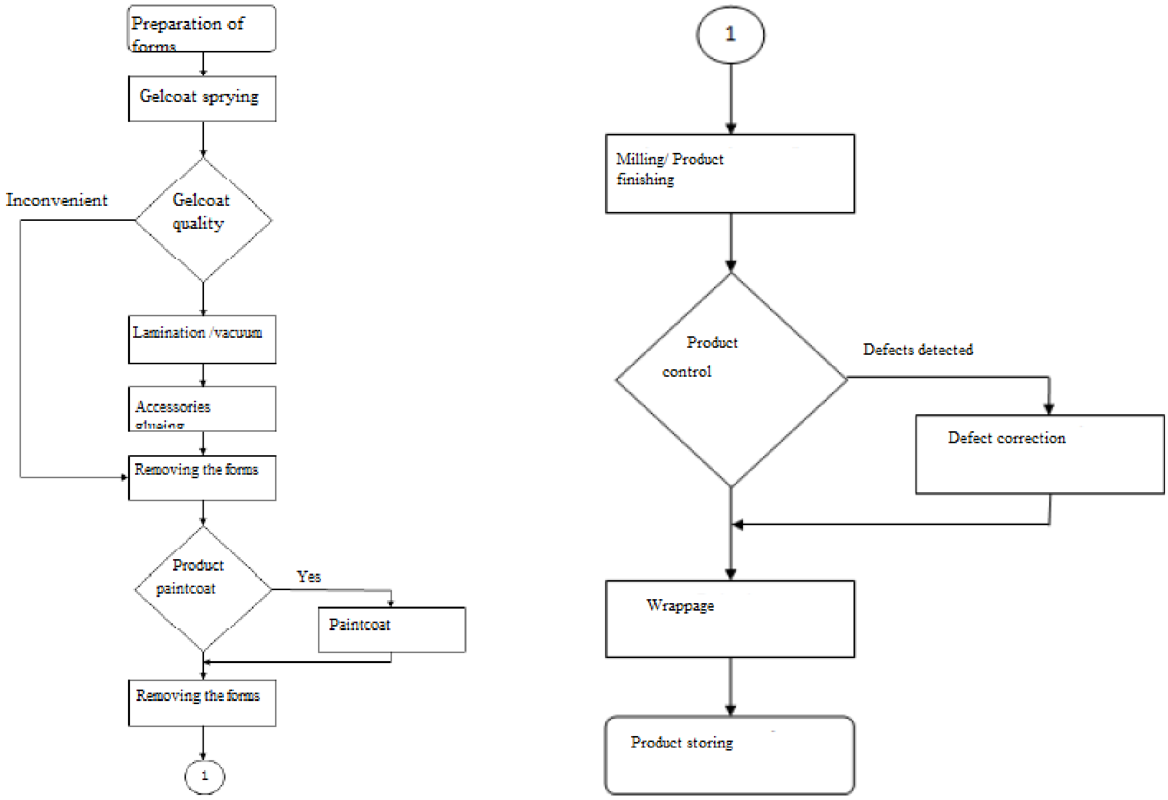

Fig. 2 *Block diagram of a general production process*

The company information system provided for data, which were analyzed, statistically processed for eight month period of a manufacturing process and as used to define input parameters and to assess real conditions by simulation modeling. The problems that had been defined have a negative impact on a total economic result of the company. 3 main parameters were defined through analyses of the assessed data.

1. **Increase of volume of an overhead work** in a monitored period from a total available working time 24 percent that stands for about 8500 EUR spent with regard to payment of wages to employees for a particular overhead time when waiting for a form.

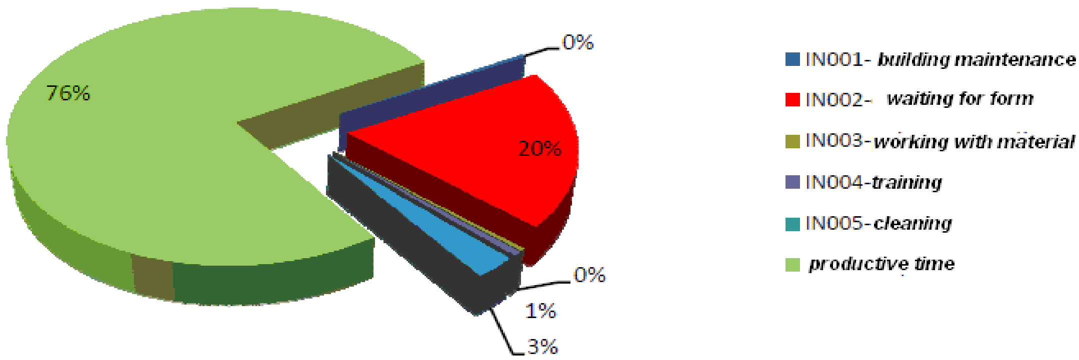

Fig. 3 *Graphical display of the volume of overhead work at working places of a front hall*

2. **Work on weekend days** aiming to fulfil a week production plan is due to loss of productive hours organized out of standard working hour fund, planned for a particular working week. „An overtime work „is evaluated with an extra pay to a standard hour rate of the employee amounting + 25% for each hours worked in case of overtime worked during a working week and 50% in case of work in weekend days.
Volume of overtime work performed during the monitored period does not mean only increased costs relating wages for employees, but also increased costs in relation with a hall operation. We can calculate them amounting about 12 000 EUR for the monitored period.
3. **Costs with relation to a non-quality of glass fiber semi products** caused by a problem being solved with a description of defects as laminating into a wet form and removal of dust pollution; an expert assessment of a quality supervisor is amounting. 5000 EUR for a monitored period.

Development of particular elements of a computer-aided model

There has been developed a room layout of a working environment in a simulation software product which is identical with a layout in a frontal part of the company manufacturing hall, from physical elements of particular processes with their description. (Fig.4, Fig.5).

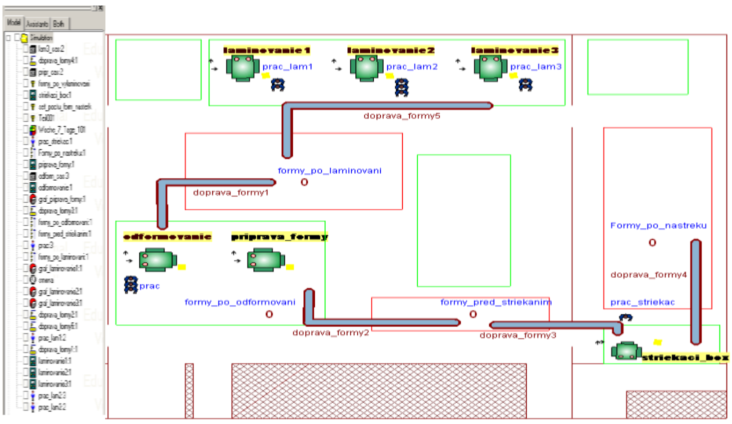

Fig. 4 *Layout of a frontal hall with the elements used*

The following elements of a model have been defined:
1. Attributes for a working shift, needed to keep a real character of simulation with regard to a real course of processed during production. To set a change in an attribute we set the first and the second part of a change, which are separated with a pause.
We had defined the input values needed to start a work (setting of an initial value of number of laminated forms needed to start Works on a form releasing working place). We had set maximum storage capacities assigned to release the forms on particular working places.
2. Variables
In a program environment we had defined 3 variables needed for internal logic of modules, a form release, form preparation and lamination.
Through these variable functions we enabled that a situation behaves on particular working places in such a way as in a real life, i.e. if a software logics of any module will demand a presence of more employees as they are assigned from a base for a given module to perform a particular activity, „ a standardized time“ needed to perform it will be divided in an equivalent way (reduced) with regard to a number of additional employees on a working place.
3. Programming of a behavior logics of particular elements within the model.
For particular elements we had set their behavior through program algorithms with regard to real performance of a simulation. We had implemented into logics of modules adequate number of employees to particular working places to perform a particular activity (Labor Rule), which was set to a variable value using variable function for a form release operation, preparation of a form and lamination.
4. Connection of particular modules through an instrument for a conveyor.
Aiming to interconnect the working places, as well as to define transport routes, we used in a simulation environment of a simulation program such container, that creates needed interface for flow of forms in a process, in which we had defined time needed for handling among particular modules, whereby we also established a flow of material as well, in our case a flow of forms in a circular flow of a manufacturing process.

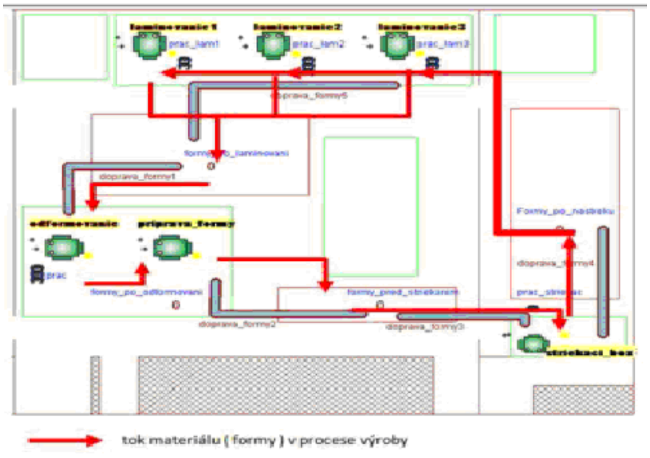

Fig. 5 *Flow of material through a model*

5. Setting of graphical outputs aiming to monitor a course of simulation

After having adjusted a general simulation with regard to its identification with a real course of a manufacturing process for a frontal part of a company hall, we included the graphical outputs into simulation environment (Fig. 6) in order to monitor main indicator related to simulation aiming to control behavior of simulation of real conditions, i.e. a condition for a simulation of a problem, when there is insufficient capacity of gel coat spraying, whereby given graphical elements (a pie chart for monitoring a working load of particular working places) we used later on in experimenting with an established model, for verification of results of experiments from a point of view of a practical applicability of a chosen model in a manufacturing process of laminated semi products.

2.1 Verification of a developed production model

Programming in the first step resulted in development of a model of manufacturing process focusing on a problem occurring on a gel coat spraying working place and a reality of simulation behavior aiming to assess simulation characteristics from a point of view of credibility to real conditions of manufacturing processes.

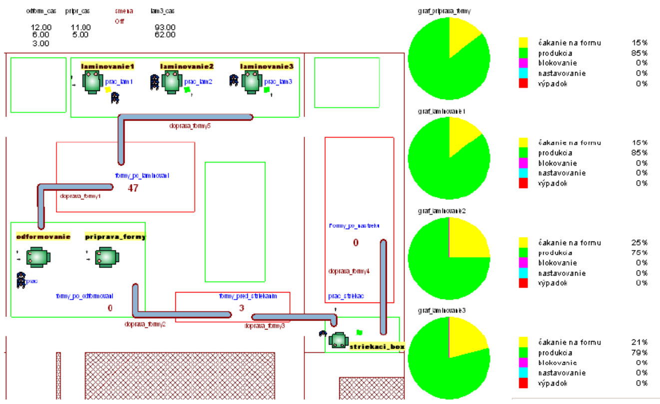

Fig. 6 *Verification of a model of real conditions and results from simulation experiment*

Through monitoring of a manufacturing process in a simulation interface of the Witness software we concluded, that a developed model of production truly conforms to real behavior of a manufacturing process in production of laminated semi products. Resulting statistical indicators expressed graphically approximate really to parameters of a defined problem.

Total number of processed forms during a working shift is 50, as minimum as by 5 forms less entered into a manufacturing process than expected by a standard production plan.

The employees on the laminating working place processed all forms after a gel coat spraying, it means, that at the beginning of a working shift next working day there will be no form ready for laminating sooner than in 2 hours after its beginning. So a downtime occurs and a relating rise of a subsidiary or overhead labor.

There was unceasing downtime during simulation of a manufacturing process on particular working places from 15% up to 25% from a total working time. These downtimes used to be organized in a real process through organizing of a substitution work, usually an overhead work.

2.2 Implementation of simulation experiments

Aiming to assess a possible solution of a problem in a manufacturing process, the simulation experiments were implemented. The experiment plan has been chosen from a view of possibilities, which could positively influence a manufacturing capacity of a spraying working place.

1) Division of the gel coat spraying working place into two working places, whereby at a new one the second employee will use a spraying gun.

2) Division of a gel coat spraying working place into two equal working places using a spraying technology with a spraying pump by two employees.

3) Equipment of an actual working place with a gel coat spraying robot.

Experiment Nr.1 –completion of a spraying working place by an employee and a technology of spraying with a spraying gun

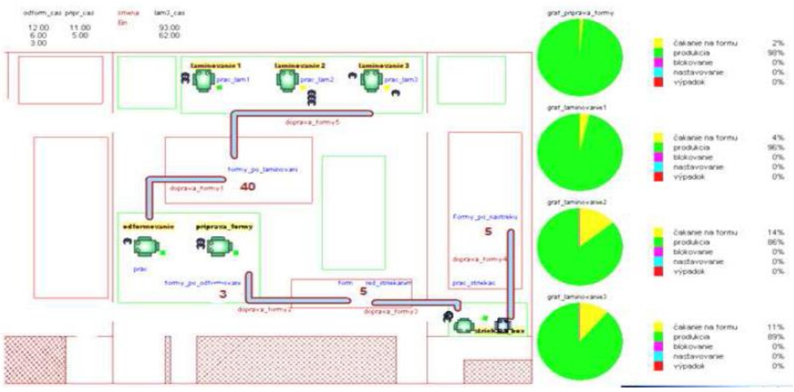

Fig.7 *Model and results of a simulation experiment Nr. 1*

Evaluation of the experiment Nr. 1.

Based on achieved results from a simulation of an experiment we can note a partial improvement of a problem being monitored relating an insufficient capacity of gel coat spraying.

Proposal for a problem solution represents a certain possibility how to improve a manufacturing process of laminating semi products. However the outputs from simulation indicate shortages of a proposed solution – rise of downtimes when waiting for a form.

Experiment Nr.2 –Division of a spraying working place into two working places through a spraying pump with two employees.

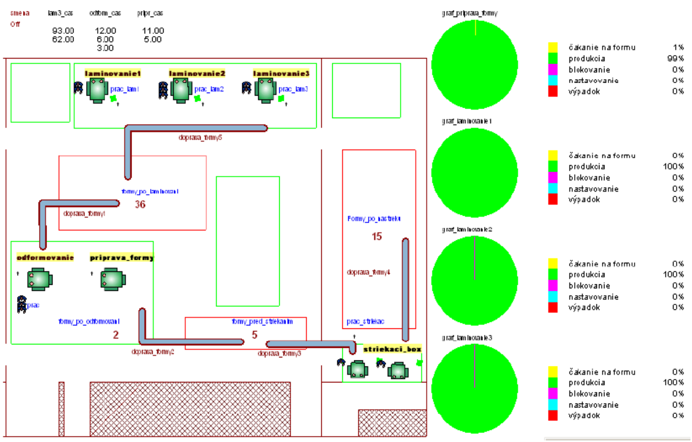

Fig.8 *Model and results from experiment Nr.2*

Evaluation of the experiment Nr.2

A proposed solution of a problem provides a general improvement of a manufacturing process. There were processed 58 companies in a manufacturing cycle as it is supposed by a daily production plan. After having completed a working shift, there is sufficient amount of processing forms available for a shift on the following day. Outputs from simulation – pie charts indicate a quick reduction of downtimes at particular working places, tending to a zero loss of working time (working capacity), or more precisely, remaining downtime is practically negligible for a total cycle of a manufacturing process (a downtime of a working place for a preparation of a form 1% from a working time fund).

Experiment Nr.3 – equipment of an actual working place with a gel coat spraying robot

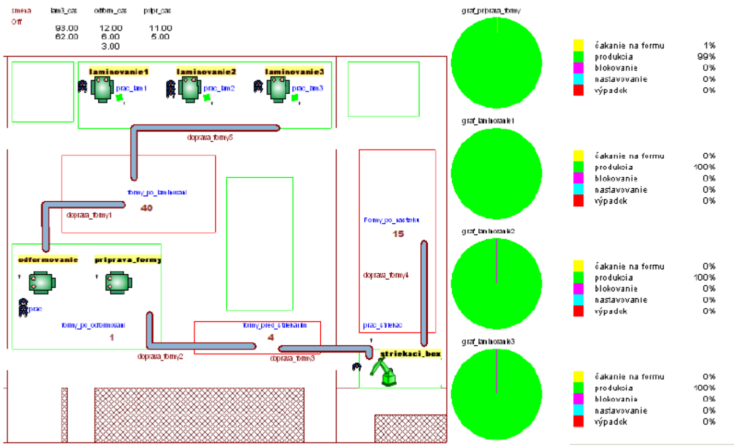

***Fig.9** Model and results from a simulation experiment Nr. 3*

Evaluation of the experiment Nr.3

By simulating an experiment Nr. 3 we conclude that the results of a proposed solution are practically identical with results obtained at experiment Nr. 2, whereby we can deduce a statement, that comparing with experiment Nr. 2 the number of forms being processed has been minimally improved during a working shift in a production cycle, as in total 60 forms have been processed in a production process, i.e. by 2 forms more than at the experiment Nr. 2.

3 Description of achieved results

It results from experiment Nr. 1 that achieved results are not satisfactory in order to remove a problem of an insufficient capacity of a gel coat spraying, creating downtimes on the working places.

An advantage of a chosen solution is establishment of a new working place, where a spraying gun issued at low costs related to the implementation of a given solution into practice. Experiment Nr.1 can be characterized rather than an „emergency strategy „for a temporary application in practice.

Experiment Nr.2 and 3 bring an expected solution of an insufficient capacity of a gel coat spraying into a process. The results obtained from simulation of these experiments indicate almost identical improvement of a manufacturing process. A way of solution with a robot developed in experiment Nr. 3 has in very small rate a better result in number of forms being developed in a manufacturing process as creation of a duplicate working place, as was considered for experiment Nr. 2.

When selecting a suitable solution for practice we considered financial costs related to application of such solution into practice.

We suppose very high primary costs related to implementation of a robot into a gel coat spraying process and high following financial costs related to maintenance, so a profit-cost ration of a solution presented in simulation of the experiment Nr. 3 is inapplicable into an environment of a low-series production of a company.

We consider a proposal for a problem solution in experiment Nr.2 as applicable. A resulting simulation confirmed correctness of a chosen variant in the laminate semi product manufacturing process. Chosen parameters ensure an expected flow of forms during a manufacturing process, therefore we expect a continuous fulfillment of a defined production plan. Minimizing of production downtimes connected with waiting for a form on particular working places fully uses the working time available during a working shift.

4 Conclusion

Aiming to apply the results of simulation in the practice, the implementation steps relating definition of needed costs are to be carried out that can be divided in the following points:

1. Separation of a gel coat working place into two separate rooms through a wall established with strips of a hard foil anchored on a steel console. Similar solution is at several working places in a production hall. The costs related to a separation of a working place can be estimated based on costs that had been performed in other solutions in other working places, so the investments would by about 4000 EUR.

2. Equipment of a working place with needed devices. In particular, it relates to additional equipment with three specified gel coat spraying pumps. Total costs related to three devices and their installation would be about 24 000 EUR.
3. Separation of air intake and air exhaustion into rooms of a newly developed part of a gel coat working place. In particular slight building adjustments with needed investments up to 2000 EUR.

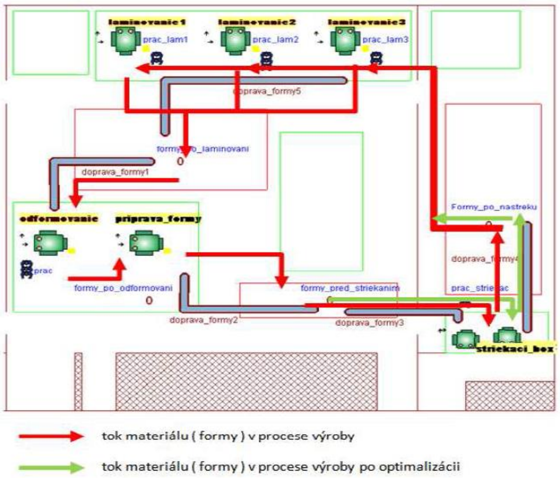

***Fig. 10** Flow of material in a production process after optimization*

Based on above mentioned implementation steps of investments to meet the terms of the proposed variant Nr. 2 we can calculate final costs for about 30.000 Euros. In a monitored period we could deduce a financial loss related to a problem with a low capacity of a gel coat spraying working place amounting about 25 500 EUR.
After having compared a needed investment and a determined financial loss during a monitored period we concluded, that a proposed variant 2 of a manufacturing process of laminated semi products aiming to remove a problem with a low capacity of gel coat spraying, is applicable in practice from a view of investment payoff. Feasibility of a proposal is confirmed by an implemented simulation.

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