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THE NEW SYSTEM OF CONTROL AND VERIFICATION IN VIRTUAL SCENE

In the past, and even today the technology of automotive industry operations are in a certain amount performed by man. The advantage and disadvantage is also that the speed of the work of man depends on his skills. Today spot welding is an important technology used in the production of body in white in the automotive industry. With the increase in competition, this technology is increasingly required in automated or robotic form. For its application in practice by current demands must often use computer aided technology. Modern virtual technologies are examined and applied in various sectors of development and production. Body in white consists of more than 300 smaller different shaped parts connected by many welding points (over 4000) [1]. Therefore, the high demands for precise positioning of welding points, the optimal trajectory planning of robot motion and perfect synchronization of robotic workstations cells.

Keywords: planning, virtual design, virtual verification, new production line.

The paper describes one practical implementation of the Digital Factory concept – design of a new production line using modern planning method of virtual testing and control of processes. The project covered graphical facility design, detailed design of operations and material flow simulation. This case study shows facility process planning, commission and in the end finding the optimization rules and corrective actions to increase existing casting line throughput. All phases of the project were carried out using simulation software, duration of the project was 6 months. Simulation software WITNESS has been used for material flow simulation.

Off-line programming robots and manufacturing facilities represent a significant technological and time advantage not only in introducing new products, but also to change the existing production applications. Emulated environment allows program the robot without stopping production well in advance to prepare robot programs, which increases overall productivity. We are able to create realistic simulations using real robot programs and configuration files identical to those used in production. Although currently used simulation tools, such as Robcad, IGRIP or Catia, are unable to solve the problem of optimal robot motion planning [3]. Planning spot welding robot trajectories requires much more experience and subjective decision-making, leading to a continued need for on-line correction of robot programs. The speed of the machine work depends not only on its parameters, but mainly on the ability of humans to learn this machine to work quickly.

Model construction of manufacturing equipment, as well as the establishment of relevant robot programs by simulation system represents a true picture of reality. An absolute compliance with reality cannot be assumed. Ideally, it would be to load the robot program without any adaptation. However, there are essential differences between the computer model used to implement graphical simulation and real environment. Deviations may be caused by:

– errors in position of the workpiece and the environment due to the position of the robot,

– errors in tool precision with regard to the robot flange,

– errors in the relative position of robot axes.

For these reasons, correction of the robot path is required, i.e. adapt the simulation to actual geometric conditions. It is an integrated process of modeling, measurements, numerical identification of robots real physical properties with the implementation of a new model [2].

Virtual Design

Based on the space dispositions and restrictions a unique concept of two robots moving along a shuttle conveyor had been designed. A third robot had been designed to operate under the first two along a parallel bottom shuttle conveyor. A 3D sketch of the system and a 2D scheme together with the system component description is on the following Figures 1 and 2:

Process chain and timing

After layout design it was necessary to define workflow that takes into consideration all process prerequisites and restrictions of the planned line. Timing analysis is performed on operations and their sub-operations. Based on the defined operation sequence, an automatically generated GANTT chart helped to define the beat rate of the whole casting line.

After assigning the cycle times operations are assigned to the relevant equipment and production parts. All these elements (parts, process, operations) can be linked together using a PERT diagram, example shown on the following Figure 4.

Process Description

The process begins with the impulse for core setting robot to start its cycle. Core setter leaves its default position and arrives to core grippers, where appropriate gripper is selected according to the engine type. Then it moves to the manually prepared cores, takes cores, transfers to four available ingot molds and inserts cores to one of them. As soon as the core setting robot arm leaves the mold, pouring robot receives the command to take the flask with the aluminium alloy. In the meantime a worker enters the mold and makes sure the cores are in a good condition and position. Worker leaves the mold and closes the safety door. Robot then pours the alloy into the mold and moves to its idle position. After the solidification time, mold opens and the third robot – extraction robot takes the casting from the mold and places it into the buffer to cool down. After cooling down extractor takes the casting and places it into the manipulation area for further processing on a saw. The fourth, manipulation robot places the casting to a saw, from where it takes the casting to a roller conveyor for the quality inspection.

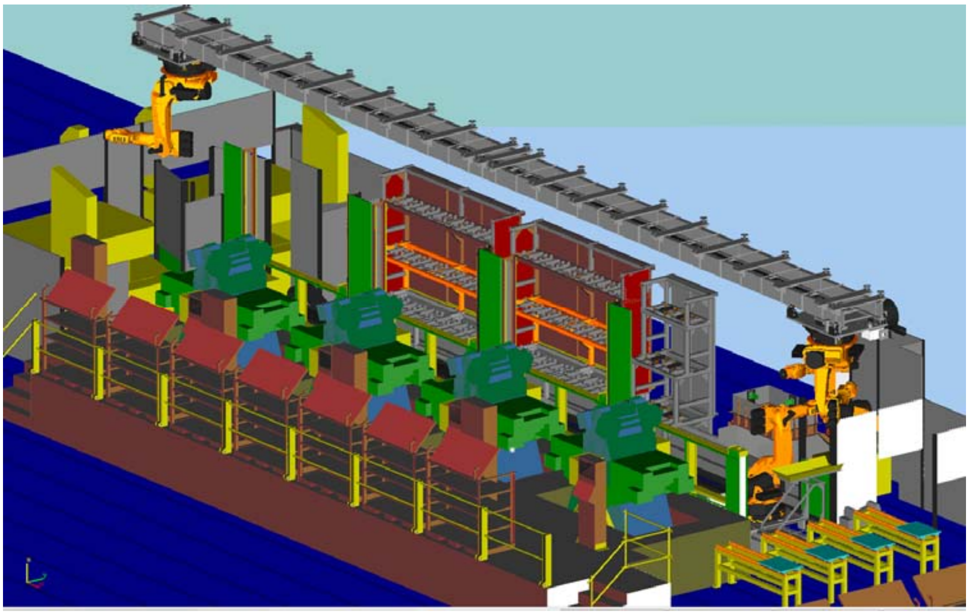

Fig. 1. A 3D sketch of the system

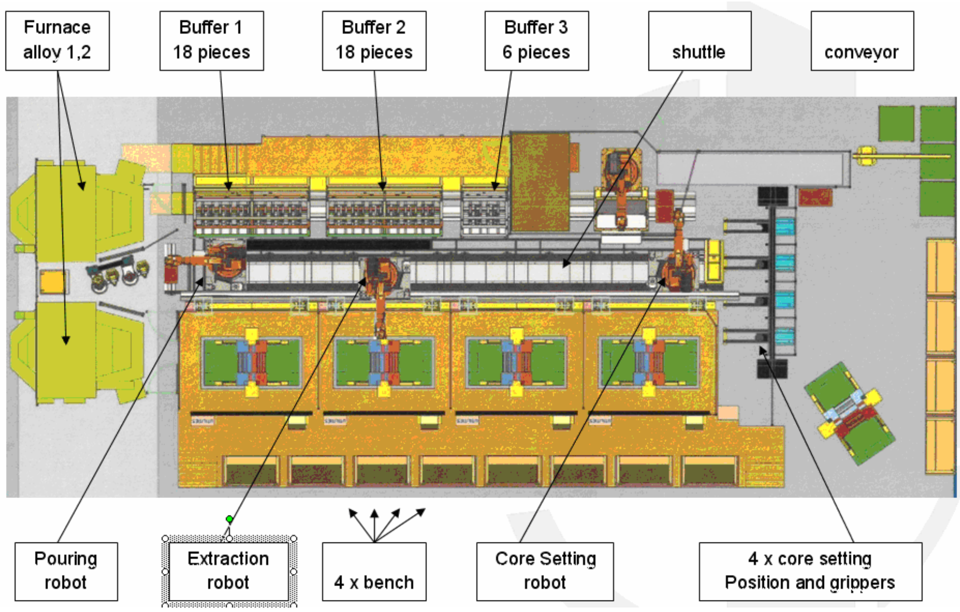

Fig. 2. A 2D scheme together with the system component description

Collision analysis

The casting line consists of the core setter, pouring, extractor and manipulation robots, four ingot molds, buffer with capacity of 42 castings, saw, output conveyor and a team of workers. The line operates with several space restrictions. The main restriction is that the core setter and pouring robot share the same shuttle conveyor without possibility to pass each other. To avoid possible collision, interaction of these two robots played a key role in the system analysis.

Another restriction, and the argument for a thorough spatial analysis, was in transfer of casting from the mold into the cooling buffer. The buffer is divided into three vertical sections, 3 floors each. If the manipulation robot places the mold into the upper floor, no robot from the upper shuttle can be within 2 m distance. This restriction leads to the need for a suitable loading / unloading logic. This analysis has been performed using simulation tool WITNESS by Lanner Group.

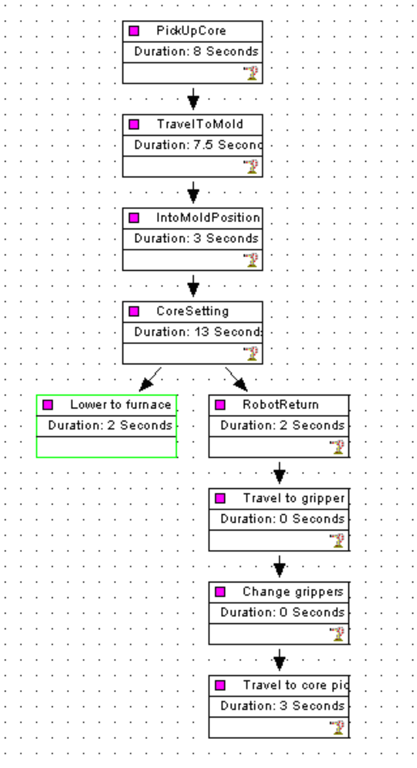

Fig. 4. PERT and GANT chart
describe the material handling operation

Note: The aim of the research is to investigate and develop a new combined inertial navigation system based on electronic gyroscopes, magnetic and barometric sensors. The mentioned system will ensure the accuracy which is necessary for example for the calibration of robotic workplaces and thereby the necessities of utilizing the calibration agents will be limited. A big advantage of the INS is also its autonomy in comparison with methods used nowadays. This leads to the essential simplification of calibration and it even carries big possibilities with it in the field of control and measuring, for example, avoiding the accidental collisions of robots etc. To solve a problem of ensuring the required accuracy is a basic problem. The integration of more measuring devices (INS) is one of the possibilities. The integration of navigation information represents the topical issue of achieving greater accuracy of required navigation parameters. The crucial activity is focused on three basic fields:

– The first goal is to analyze accelerometer and gyroscopic sensors and their possibilities of utilization for inertial navigation. The simulation of the effect of sensors with different metrological parameters and their effect on the properties of the proposed combined navigation system.

– The second goal is to optimize a specialized processor system for processing the data from the defined sensors in connection with controlling items of an industrial robot [5]. The proposal of an algorithm of combined navigation with respect to the used processor system.

– The third goal is to verify experimentally the proposed inertial navigation system in real conditions of the industrial robot operation.

Determining the casting line throughput

NEMAK decided to verify the throughput of the new production system, again with the use of WITNESS simulation. A typical scenario of producing engine castings for two OEMs has been selected for the test. Furthermore, one of the engines is manufactured in both left- and right-handed variant. This requires certain assignment of ingot molds. Production of engines XL, XP and Y had been tested. Some operations and their timing is specific to the given engine type. As an ideal case it is considered to serve the ingot molds in the sequence 1,2,3,4,1,2,3,4,..., which was the target for the control system. Many variants have been tested in the frame of the simulation experiment. The use of WITNESS has been confirmed as a good decision, as the tool flexibility allowed the consulting firm SimPlan Optimizations to make the necessary adjustments to the simulation model based on the input from NEMAK during the project.

The main issues solved wit the help of simulation were:

– Optimization of communication between the core setter and the pouring robot

– Pre-emption analysis and priority analysis for labor

– Number of the workers needed to prepare cores

– Number of the workers for ingot mold checking and cleaning

– Finding the most productive extractor idle position

– Extractor task priorities based on the cooling buffer level

– Testing of the FIFO cooling buffer loading / unloading logic, its dependency on the current position of robots on the shuttle

– Modeling the space restrictions of the third floor of the cooling buffer

– Information flow logic between extractor, ingot molds and buffer

An example of the simulation model implemented in WITNESS is on the following Figure 5.

Simulation analysis has shown that under the current conditions the line is capable of producing only 70 % of the tested production scenario.

Optimization measures

The following measures have been suggested based on the results of the simulation experiment, with some measurable benefits in terms of increasing the casting line throughput:

– Identification of the production system bottleneck

– Optimal control logic for loading / unloading of cooling buffer (6 to 9 %)

– Improved communication between the core setter and the pouring robot (10 to 15 %)

– New gripper (3 %)

– Optimization of the core setter arm movements (13 %)

– Optimization of number of workers

– Optimization of information flow during parallel operations on ingot molds

Implementation of suggested measures in cooperation with equipment supplier KUKA Roboter GmbH took 3 to 4 months.

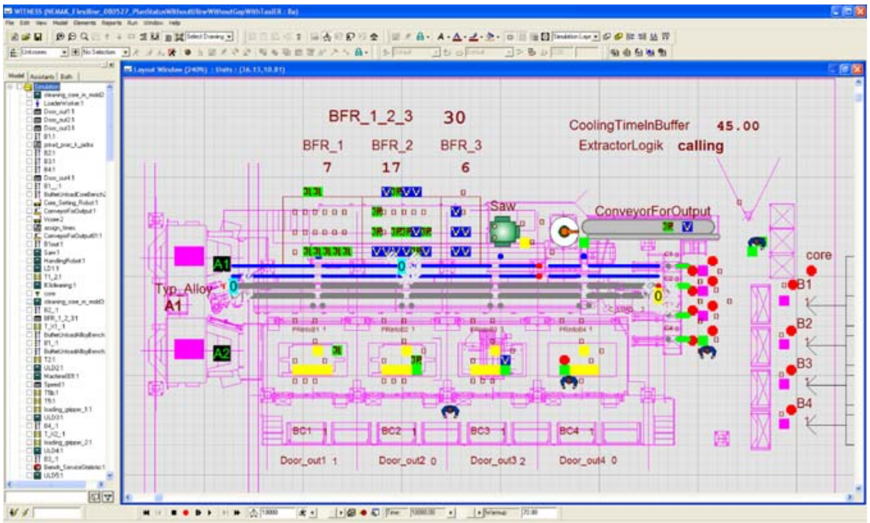

Fig. 5. The simulation model implemented in WITNESS

Summary

During the project, NEMAK purchased WITNESS license, WITNESS became also a tool for operational capacity planning. The model used in the design phase, after few interface modifications, is now used for testing production plan variants depending on the current demand. Regular simulation analysis results in weekly updates to the shift patterns and number of labor needed in the process. The following figure shows data interface for the operational use of the simulation model. MS Excel is used for data input and presenting the simulation results to people that typically don't need to have a process simulation background.

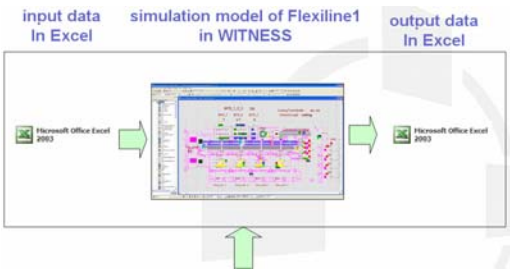

Fig. 6. The final scene in Witness

People from several NEMAK plants (Czech Republic, Mexico, Canada, Germany and U.S.A.) contributed to the project. Simulation study and project coordination had been carried out by SIMPLAN Optimizations Slovakia. Duration of the whole project was 6 months, May to November 2008. Continuation of this project is another project, where a new line with independent movement of core setter and pouring robot is analyzed.

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Новая система управления и контроля в виртуальном пространстве

В прошлом и даже в настоящее время некоторые технологические операции автоматизированного производства частично выполняются человеком. Здесь преимуществом и одновременно недостатком является тот факт, что работа человека зависит от его навыков. Сегодня точечная сварка является важной технологией, применяемой в производстве неокрашенных кузовов в автомобильной промышленности. С ростом конкуренции повышается потребность выполнения такой технологии в автоматизированном или роботизированном режиме. С учетом современных требований, эта технология может применяться на практике с использованием средств компьютеризации. Современные виртуальные технологии изучаются и применяются в различных областях проектирования и производства. Неокрашенный кузов автомобиля состоит из более чем 300 деталей меньшего размера различной формы, соединенных множеством сварных точек (более 4000) [1]. Таким образом, требуется точное позиционирование сварных точек, разработка оптимальной траектории движения робота и идеальная синхронизация ячеек роботизированной станции.

Ключевые слова: планирование, виртуальное проектирование, виртуальный контроль, новая производственная линия.

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