# THE EXPLOITATION OF PARALLEL PEDAGOGICAL MODEL FOR LECTURES OF CONTROL OF THE METALLURGICAL AGGREGATES

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**Abstract**

Quality of lectures and possibility for students after graduation, which is related to that is significantly dependent on level of closeness to the current techniques and technological practice. Along with the excursion to the specialized companies has important role the possibility to get known better with studied technique and technologies through models. Models could be physical or mathematical. The new type of models is introduced in this paper. It is so called parallel model. This model conveniently combines the advantages of both types of models mentioned above. In this paper is the parallel pedagogical model represented by technology of control of the oxygen converters in steelmaking factory. The correct physical realization of the pedagogical models of some technologies, for example steelmaking processes, cannot possibly include the real chemical and thermal processes, but it can represent precise all mechanical operations. These and others necessary technological operations can have parallel realization in the mathematical form in computer. Computer provides synchronous parallel operation of both models and through computer visualization significantly increases pedagogical value of otherwise irreplaceable physical model.

**Keywords:** parallel model, pedagogical model, simulation, lectures model

## 1. INTRODUCTION

Each subject of study has it's the specifics. Specializations that are linked to metallurgy are characterized by extremely huge technological aggregates and extensive technological units, which usually work with products of high temperatures while consuming extremely large amounts of energy. Now the diversity and complexity of these technologies requires for their control to exercise deep knowledge of the processes that run through them. They appear here demanding mechanical operations, which are accompanied by complex chemical and physical plots.

Students should be familiar in detail with these units both through field trips and practice, as well as using models that were used in the teaching process in the laboratories of the school. The nowadays trend, which significantly helped rapid development of computer technology, represents an effort on modelling and simulation of metallurgical as well as other technologies on computers with support for various simulation programs. This trend is of vital importance in research, but in terms of understanding the work of individual metallurgical aggregates would be more appropriate physical models, for their physical clarity. Our experience shows that students remember more experiments on physically existing facilities than the simulation results.

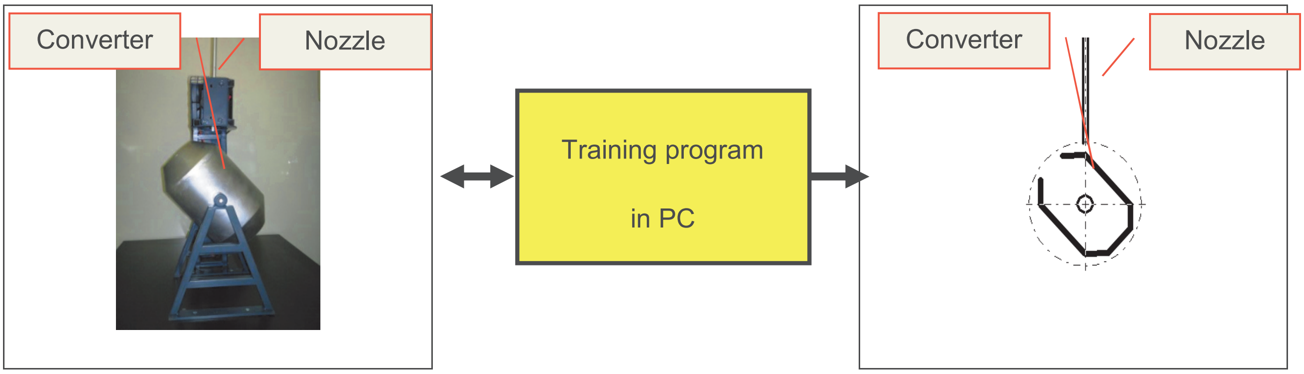
But most of metallurgical processes is of such a nature that it is impossible their realization in the form of complex physical models of teaching, and therefore the idea to create a qualitatively different type of models that have been identified as the so-called parallel models. These can be combined and how the benefits of physical models (clarity) and mathematical models that are implemented by a computer program.

The exact physical implementation of most of pedagogical models of metallurgical technologies can include real chemical and thermal processes, but rather can closely mimic the basic mechanical operation, which senses the students perceived most intensely. These mechanical operations here due to synchronization in parallel running around on the computer, but are supplemented by the necessary technological processes (in mathematical form), which cannot be implemented due to technical reasons by the physical model. The computer then provides synchronous parallel operation of both models by means of computer visualization significantly improves the educational value of otherwise irreplaceable physical model.

To demonstrate the application of parallel pedagogical model was selected control technologies oxygen converter steel plant (LD technology).

## 2. OPERATING PRINCIPLE OF THE PARALLEL PEDAGOGICAL MODEL

The principle of work of parallel pedagogical models is synchronous parallel operation of the model implemented physically reducing metallurgical or other technology or unit, and expansions in form of a mathematical model which allows to calculate and through simulations with cooperation of visualizations they effectively represent the instantaneous state of the modelled device. As an example, the parallel pedagogical model of steelmaking using LD process can be used (see **Fig. 1**).




***The physical model of the oxygen converter model*** ***Computerized mathematical model of oxygen converter*** ***Computer visualization model oxygen converter***

**Fig. 1** The principle of parallel pedagogical model (Example of the LD process)

**Fig. 2** shows a general scheme of parallel pedagogical model. This can be vertically divided into the physical area, presented its own reduced model of physical process, which is interesting of the real possibility of monitoring the work of a physical model of the process from the point of an observer (a student). This area also includes an interface that enables mutual data communication between the physical model and computer. The second area is the area of a computer model visualization process. It includes reduced mathematical model of process 1, which is a true mathematical copy of mechanical parts and processes of the physical model and expanded mathematical model of the process 2, which simulates the real process aggregates that can be implemented in a reduced physical model (this includes, for example, high-technological processes of iron, steel and hot forming processes).

Results obtained with the reduced and the extended mathematical models of the process are handled and a time-synchronized and visualized with an appropriate graphical output device of computers. Here the synchronization means that the results of calculations on computer models are passed through a suitable interface to the actuators (mostly actuators) of the physical model. In some cases, certain data from the physical model sensed and fed via an interface to a computer realizing the mathematical models. The goal of synchronization is to ensure absolute fidelity simulated visualization with real visual manifestations of the physical model. The concept of parallel teaching model is also based on the fact that the primary process is running on the computer simulations; the secondary is the behavior of the physical model.

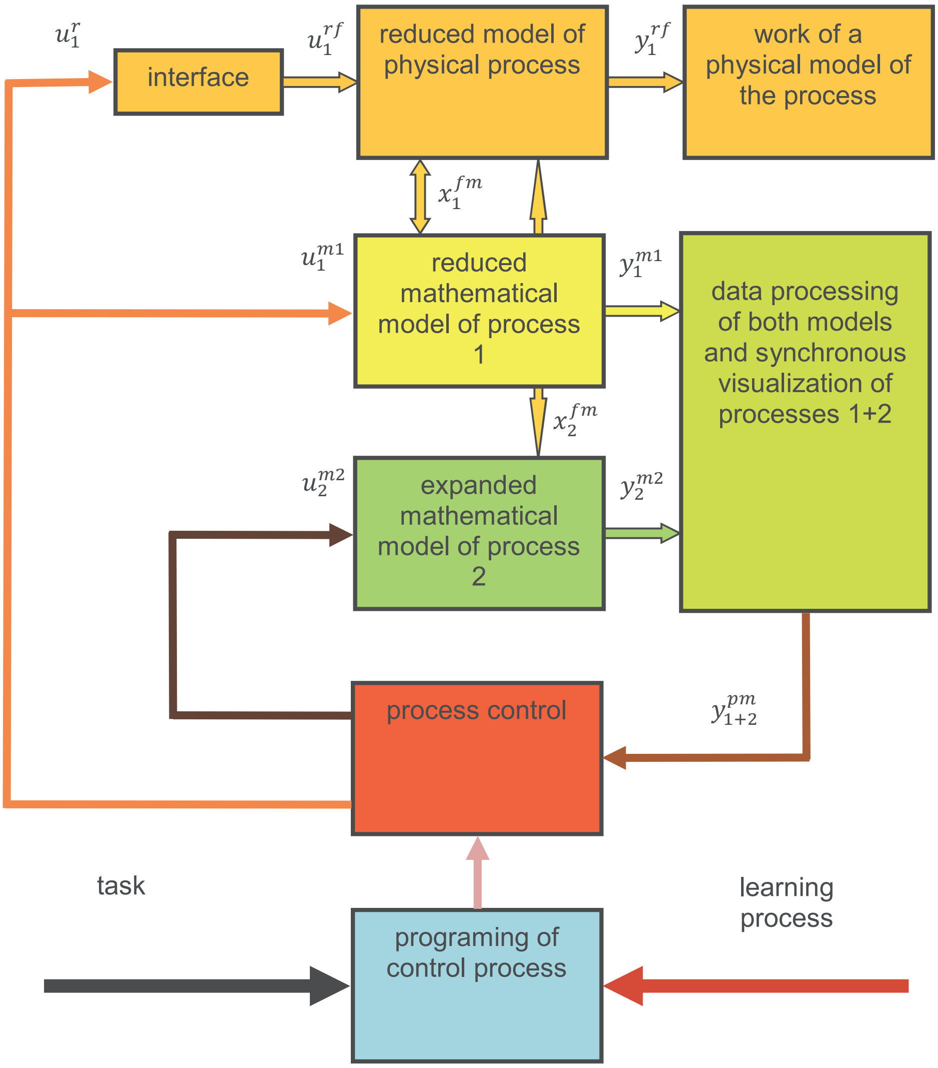



**Fig. 2** General scheme of parallel pedagogical model

The third area we might call process control. It can be implemented using a computer (PC) or programmable logic controller (PLC).

The fourth area is a link to the model of the pedagogical process. It may therefore be called the area of the educational process. Based on giving the task under the guidance of their teacher students will think out a program on PC or PLC.

The significance of individual variables in **Fig. 2**:

$u_1^r$ - action variables for process control (digital outputs from a computer)

$u_1^{rf}$ - control variable for the process converted to an continuous signal (continuous inputs of actuators)

$u_1^{m1}$ - control variable of the process as inputs of the reduced mathematical model 1

$u_1^{m2}$ - control variable for process control as inputs of the reduced mathematical model 2

$y_1^{rf}$ - continuous outputs of the reduced physical model - real state of the process

$y_1^{m1}$ - calculated outputs of the reduced mathematical model 1

$y_1^{m2}$ - calculated outputs of the extended mathematical model 2

$y_{1+2}^{pm}$ - processed outputs of the reduced and extended mathematical model 1+2

$x_1^{fm}$ - transfer of necessary information between the physical and the mathematical models 1 (via interface)

$x_2^{fm}$ - transfer of necessary information between the physical and the mathematical models 2 (via interface)

## 3. MODEL OF THE OXYGEN CONVERTER

The production process in the oxygen converter using the LD process is a complex technological task, in which you have seen the synthesis of mechanical, thermal and mainly chemical processes. Roughly speaking, the input for batch production of steel is usually composed of steel scrap, molten iron with a high content of carbon and other elements (made in blast furnaces), and various additives. The aim of the production process in an oxygen converter is to reduce the carbon to the specified value, remove unwanted elements and eventually enrich the steel of other necessary elements (depending on the desired type of steel). In addition to the ingredients, which are deducted from the final chemical composition of the steel, the principle of converting iron into steel using the LD process based on the oxidation of the melting by technically pure oxygen fed under pressure over the bath by the cooled working nozzle (oxygen lance). Here, there is a vigorous chemical reaction accompanied by the development of gas and heat.

In terms of automation of the steelmaking process implementation of the pedagogical model we can simply divide the different operations into three parts:

1. Supply converter by necessary inputs, which includes handling processes of charge-mechanical angle converter, transport and insertion into the converter.
2. The process of its own steel production - working nozzle height control (or control the amount of oxygen blown).
3. Tapping and pouring steel slag - mechanical steering angle converter.

The principle function of the parallel pedagogical model can be expected that the mechanical operation of landfill, positioning the converter to basic working position and casting will be realized also by the physical model, the chemical and thermal processes just through the model on a computer. The instantaneous state of the process is visualized with details on the PC. On the computer can be generated additional effects such as sound and light effects associated with different phases of the process. These can be of applied on the physical model.

## 4. THE SOFTWARE IMPLEMENTATION OF THE PROCESS WITH PARALLEL PEDAGOGICAL MODEL

The physical oxygen converter model was produced under the project SP 2014/81 and his picture is on the left in **Fig. 1**. It allows positioning of the converter itself and the control of positions of the working nozzle. As actuators miniature multi-turn actuators are used.

Within the project the computer program simulating the process of making steel with graphical visualization simultaneously controls the actuators of the physical model was developed (see **Fig. 3**).For the realization of models have been used algorithms based on the literature [1] to [6]. Whereas it is a pedagogical model, the transport of a charge from the store to input of the converter was implemented using a robotic hand (students must be referred that in fact it is not a real solution, which is in practice carried out using high-capacity overhead cranes).

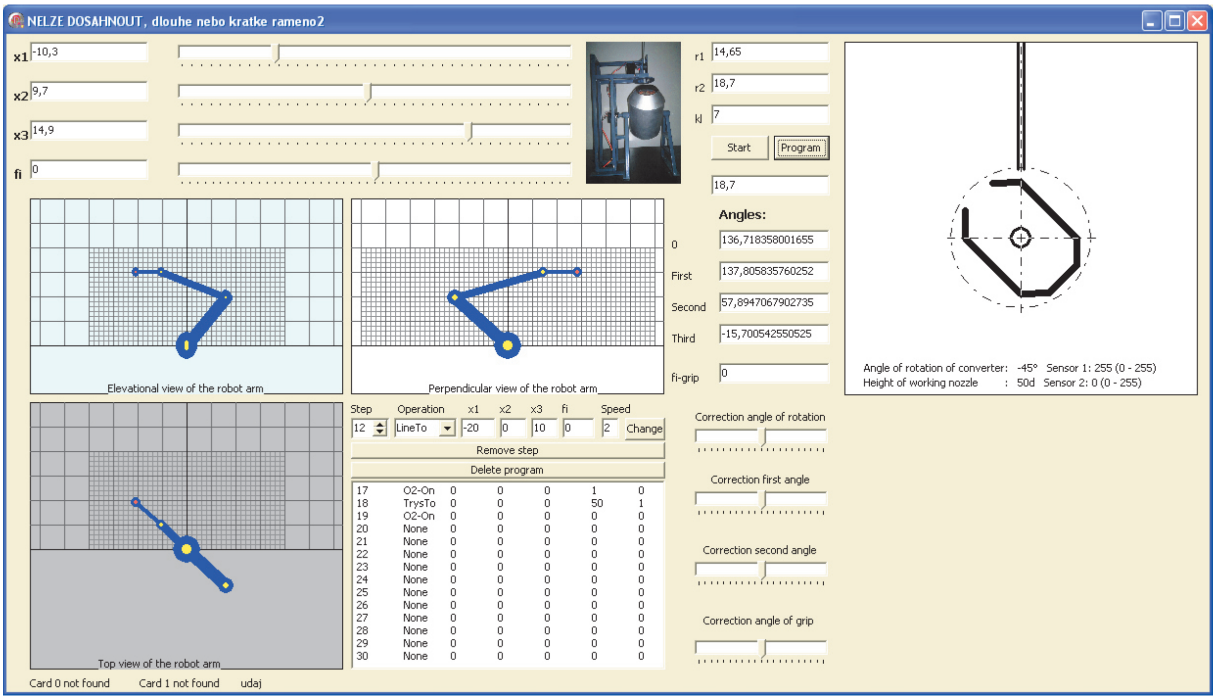



**Fig. 3** Design of the tutorial of the converter control and robot operator

The program not only includes models of the converter with the visualization, but is equipped with a simplified programming language for controlling the position of the converter as a working nozzle and the utility for control the robot with spatial visualization. Program allows students to detect errors in computer simulations (for example bad positions of the robotic arm are indicated). Furthermore, it allows custom motion control of the converter and nozzle, as well as motion control of individual robot arm and the clamp in the process of transporting charge.

## CONCLUSION

In the range of the project SP 2014/81 was created parallel educational model in oxygen steelmaking converter, which can be extended to a wide range of metallurgical technologies for which there is already a physical model. The indisputable advantage of parallel pedagogical model is a multiple increase options and clearness comparing to physical or mathematical models using separately. The PC in which the model is implemented enables easy implementation of control algorithms. However, it is possible to use for the control of specialized equipment such as PLC, allowing 'own' pedagogical process even closer technical practice.

## ACKNOWLEDGEMENTS

***The work was supported by the specific university research of Ministry of Education, Youth and Sports of the Czech Republic No. SP2014/81.***

## REFERENCES

[1] HEGER, M., ŠPIČKA, I. Simulations of Heat Processes into Matlab Program. In PROCESS CONTROL 2008. Pardubice: Univerzita Pardubice, 2008, pp. 1-7. ISBN 978-80-7395-077-4.

[2] HEGER, M., ŠPIČKA, I., FRANZ, J., SCHINDLER, I. Predikce času chladnutí kovových vzorků malých rozměrů, využívající umělé neuronové sítě. In Forming 2008: Sborník konference Forming 2008. Brno: Sinaia, 2008, s. 21-21. ISBN 978-80-248-1795-8.

[3] ŠPICKA, I., HEGER, M., FRANZ, J. The Mathematical-Physical Models and the Neural Network Exploitation for Time Prediction of Cooling down Low Range Specimen. Archives of Metallurgy and Materials. 2010, Vol. 55, No. 3, pp. 921-926.

[4] HEGER, M., ŠPIČKA, I., BOGÁR, M., STRÁŇAVOVÁ, M., FRANZ, J. Simulation of Technological Processes Using Hybrid Technique Exploring Mathematical-Physical Models and Artificial Neural Networks. In METAL 2011: 20th Anniversary International Conference on Metallurgy and Materials. Ostrava: Tanger Ltd, 2011, pp. 324-330. ISBN 978-80-87294-24-6.

[5] JANČÍKOVÁ, Z., ROUBÍČEK, V., JUCHELKOVÁ, D. Application of Artificial Intelligence Methods for Prediction of Steel Mechanical Properties. Metalurgija, Vol. 47, No. 4, 2008, pp. 339-342, ISSN 0543-5846.

[6] SEIDL, D., KOŠTIAL, P., JANČÍKOVÁ, Z., RUŽIAK, I., RUSNÁKOVÁ, S., FARKAŠOVÁ, M. Modal analysis - Measurements versus FEM and Artificial Neural Networks Simulation, Communications in Computer and Information Science, Digital Information Processing and Communications, 2011, Vol. 188, pp. 170-175, ISSN 18650929, ISBN 978-364222388-4.