

# Virtual Prototyping in the Field of Die-casting

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## **Abstrakt**

*V předložené zprávě je uvedena metodika návrhu pracoviště pro tlakové lití za využití moderních softwarových prostředků umožňujících 3D simulaci celého pracovního cyklu pracoviště. Metodika je demonstrována na studii plně automatizovaného pracoviště tlakového lití. Jsou rovněž představeny možnosti 3D simulací poskytované v rámci použitého CAD systému. Uvedená metodologie zajišťuje rychlou reakci na změnu zakázky prostřednictvím zkrácení návrhu pracoviště, optimalizaci rozmístění pracoviště, odhalení možných kolizí a vad již ve fázi návrhu a optimalizaci pracovního času. Tímto se docílí rychlého zavedení nové výroby na pracoviště, zvýšení jeho efektivnosti a flexibility. Rovněž se dosáhne snížení nákladů, což se pozitivně projeví na konkurenceschopnosti slévárny.*

## **Klíčová slova**

*Virtuální prototypování, tlakové lití, optimalizace, simulace, automatizace*

## **Abstract**

*This paper describes a methodology of die-casting cells' design using sophisticated software package allowing 3D simulations of the whole die-casting process. The methodology is demonstrated on a study case of a fully automated die-casting cell. Shown are possibilities of a selected CAD package. The methodology provides a reduction of the time-to-market stage by shortening of the design stage, layout optimizing, predicting and eliminating of potential components' collisions already in the design stage, working schedule optimizing and therefore acquire fast new product introduction, increasing efficiency, flexibility, cost reduction and ensuring the competitiveness of the factory.*

## **Key words**

*virtual prototyping, die casting cell, optimization, simulation, automation*

## **1. Introduction**

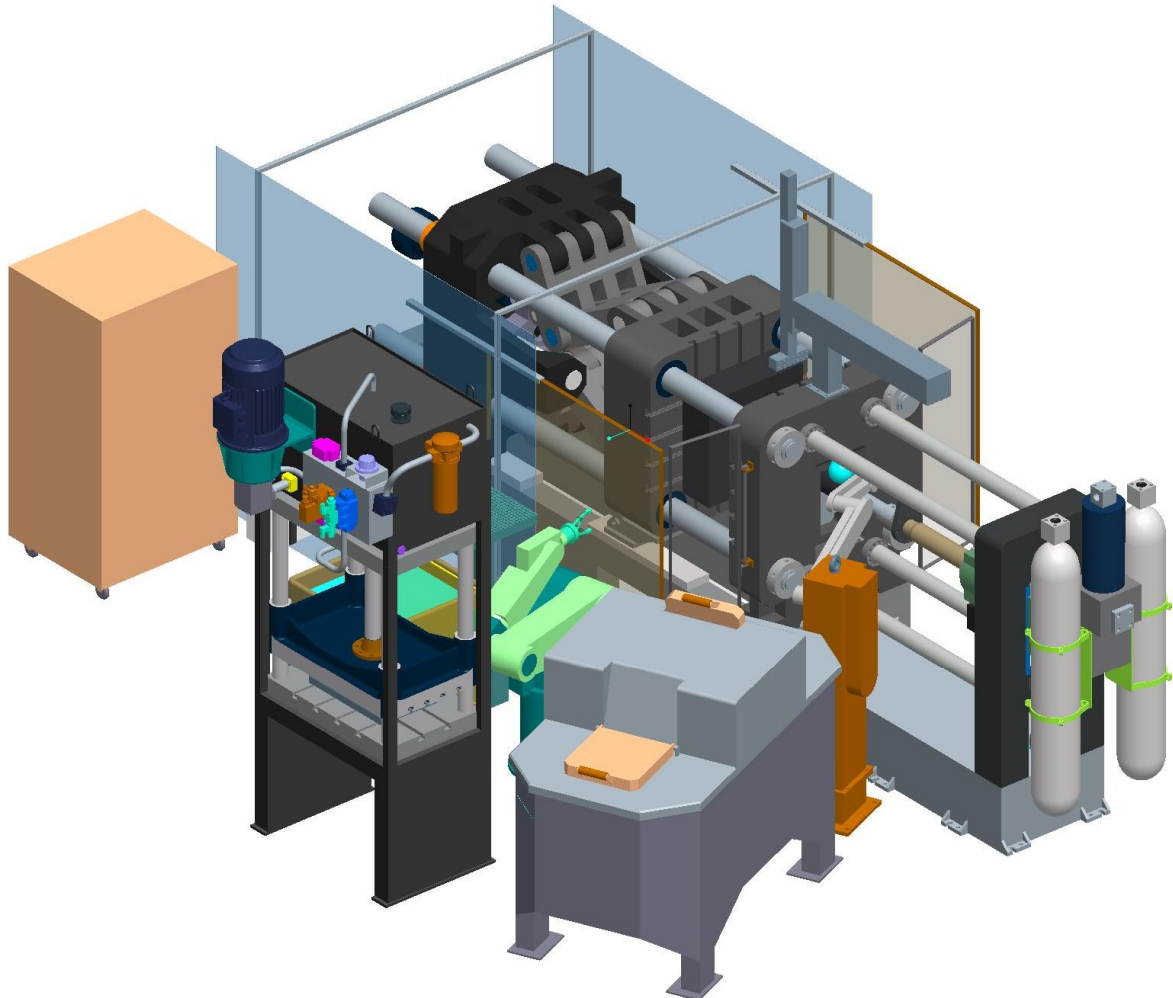
Fast developing hardware and software technology enable us to perform more sophisticated analysis in shorter time. This advantage is exploited when designing fully automated die-casting cells using 3D CAD environment. The design of the die-casting cells starts with establishing the correct requirements of the final product based on customer specifications which allows us to select the right die casting machine. Next step is deciding on the level of automation depending on the production volume, lead time, etc. Knowing all requirements and deciding the cell architecture it is possible to proceed to build the virtual prototype. This model provides a floor plan layout and a process schedule optimization and also moving components collision check. Used methodology and created model can reduce time-to-market stage and increase the overall process efficiency. This leads to cost reduction, higher profitability and flexibility [1].

## 2. Model creation

For the model creation it was necessary to use a suitable 3D package enabling us to perform all required simulations and analysis, in our case it was used ProEngineer package. The model was created from a library of peripheral appliances, see Fig. 1. When building the assembly, series of checks were performed to verify whether all moving peripheral equipments are able to access the required positions.

## 3. Trajectory creation

The trajectory is driven by set of points in the CAD assembly, through which the manipulator's end point has to pass. These points are defined in an external spreadsheet by  $x$ ,  $y$ ,  $z$  location and  $\xi$ ,  $\psi$ ,  $\zeta$  orientation. Points' positions are being updated automatically by a script created in ProEngineer.



*Fig. 1: Die-casting cell*

## 4. Animation creation

There are two modules in Pro/Engineer for creating motion simulations:

- Pro/Engineer / Animation
- Pro/Engineer / Simulation

### 4.1. Animation module

Design Animation is a tool which can be used for creating animations based on motion sequences of parts, individual assemblies and mechanisms. When entering the Animation



## 4.2. Mechanism in Pro/Engineer

To create any motion simulation in Mechanism module it is necessary to use “drivers”. These drives take place of actual drivers and behave accordingly. It is possible to choose from a selection of drivers with various characteristics. An example motion analysis composition is shown in Fig. 4.

Motion parameters must be specified and therefore calculations had to be performed - basic calculations for linear drivers, sophisticated calculations performed for the manipulator with 6 degrees of freedom. The inverse kinematics was applied for motion planning of the manipulator to follow the required trajectory. Joint angles were calculated for each point of the trajectory. To get from one point to another, an iteration of each drive velocity is performed to get to the next position in the shortest time while having even motion. Drivers can be applied in animations as well.

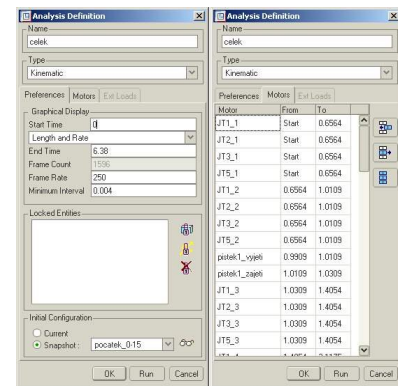


Fig. 4: Motion Analysis

## 5. Collision check and envelopes creation

Both above mentioned methods were used to perform a moving components collision check. The system can be set to either to notify us about a collision or stop the simulation in the event when collision occurs. As a result 3D envelops can be created and exported as a new solid part or in another exchangeable formats i.e. *vrml*, etc. They can be used for “offline” collision check without recalculating the simulation. This can be used when modifying the cell layout, adding extra equipment, safety check, etc. When changing the manipulator trajectory the simulation and envelopes need to be calculated again though. 3D envelopes of the casting extractor and ladling unit presented in the cell assembly are shown in Fig. 5.

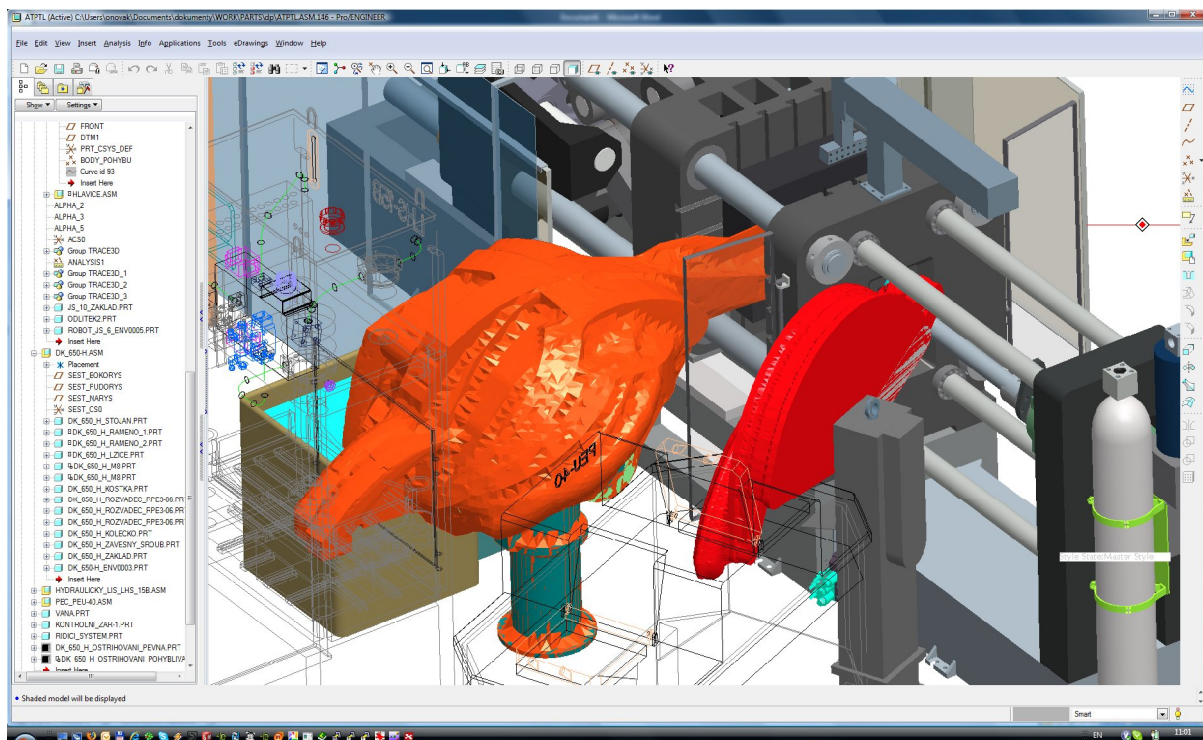


Fig. 5: Casting extractor's and ladling units' envelopes

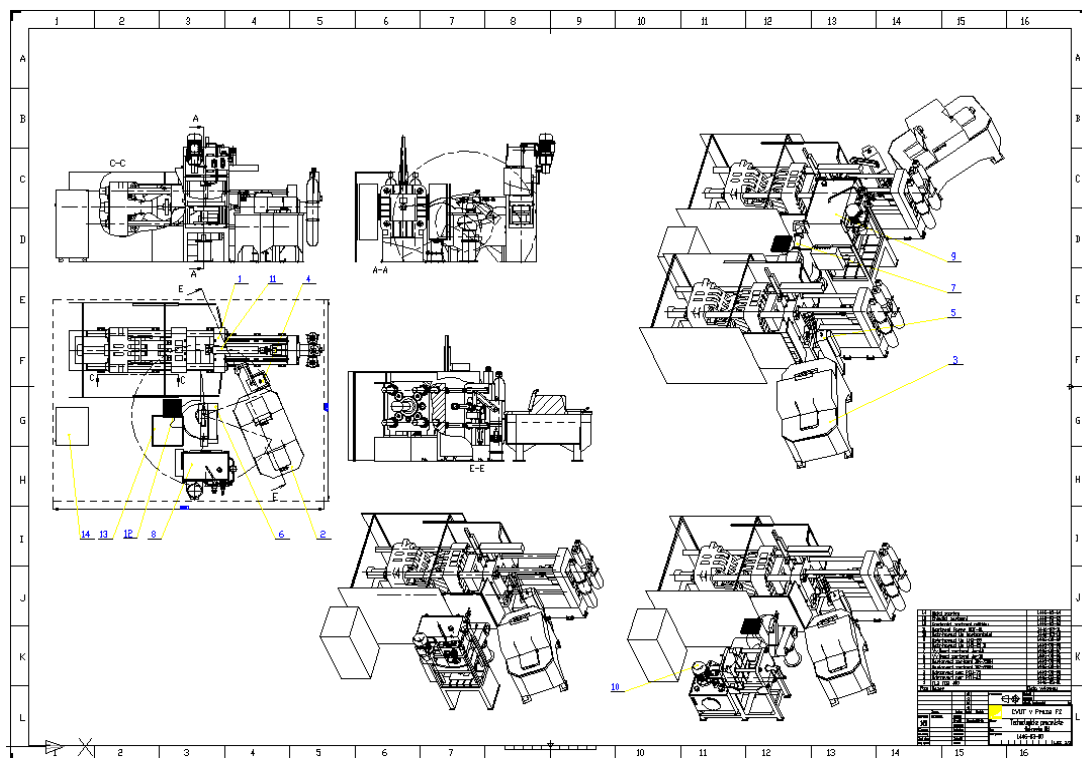
## 6. Summary

Followed was a methodology which could be divided into next phases:

- Phase 1: Die-casting machine selection based on the casting's requirements.
- Phase 2: Cell composition selection based on automation level.
- Phase 3: Die-casting cell architecture selection and layout optimization.
- Phase 4: Process schedule and time optimization - develop a sequence diagram.

This methodology can be further extended by:

- Phase 5: Economical evaluation.
- Phase 6: Automatic die-casting cell technical documentation generating (assembly drawings, bill of materials, etc.), see Fig. 6.



**Fig. 6:** Layout drawing, multiple variations shown

Comparing the two modules, the Mechanism module provides more complex motion analyse results, however more sophisticated calculations need to be performed to support the analyse. The Animation tool is mainly created for motion visualization and its limitations are compensated by relatively quick motion demonstration and collision check.

### 6.1. Benefits

Such virtual model provides us several benefits, such as:

- Design time reduction and flexibility.
- Immediate feedback about the process feasibility.
- Moving components collision check.
- Final documentation creation

Usage for this model can be further extended to:

- Multiple die-casting machine cell design and optimization, see Fig. 6.
- Robots trajectory offline programming.

Furthermore this design can be incorporated into whole die-casting plant process planning such as the power supply, raw material supply, castings path, stock and shifts planning, etc.

## **7. Conclusion**

Automation in die-casting is very important. By automation the productivity of die-casting machine can increase over 20 % [2]. Following such methodology as described above provides a powerful and flexible tool for designing and planning die-casting cell. This model provides floor plan layout and process schedule optimization and also moving equipment collision check. Such design can reduce the design time and increase the overall design and cell production efficiency. This leads to cost reduction, higher profitability and flexibility. It provides all advantages of virtual prototyping: It is quicker and cheaper to uncover and modify potential design errors in virtual prototype than in real model.

## ***References***

- [1] Novak O. '*Technologické pracoviště tlakového litého*', *Diploma work*, Praha, 2004
- [2] Manas S., 1997, *Automatizace při lité pod tlakem. Seminář České slévárenské společnosti*, Praha