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Simulation based CAD/CAM model for extrusion tools

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ABSTRACT

The specifics of tool making companies are that one can state if a tool is adequate only after it had already been made. The irregularities that have been found, lead to repairs of the already existing tool or even to making a new tool, which causes extensions of order delivery terms and additional expenses. This deficiency should be eliminated or at least reduced by introduction of computer simulations into the tool constructions for extrusion process. A new optimizing circle in the construction section is presented in this article. A comparison between old and new construction process is shown schematically. The applied value of simulations is shown on a practical example – based on the calculated results we optimized the shape of the tool for extrusion. It is proved that simulation results are comparable to experimental results.

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1. Introduction

Unsteady velocity distribution of material flow in profile cross-section area is a major problem of profile extrusion [1-3]. Tool design is mainly utilized by traditional methods – based on experience of the designer (so-called "trial and error" method). To improve velocity distribution of material flow and shape of extruded profile, technological simulations will be introduced to tool design process. Based on the results of simulations, tool geometry will be optimized. Software platform called HyperWorks is used for simulating material flow of aluminum alloys.

This paper describes the current design process from accepting an order to final tool testing. Further on a suggestion for new model of design process is presented, which includes simulations. The paper also illustrates the use of technological simulations in a tool-making company on the example of a real tool.

2. State of the art

Various scientists have already worked on introducing numerical simulations into process of designing tools for extrusion – there has been presented a process for modeling components, required for simulation [4, 5], tool optimisation based on simulation results [5], and simulation results for trial examples [4-7]. Stebunov has presented a special-purpose program for aluminium profile extrusion simulation and described special modulus of that software [8].

Netherland's scientists have present a case study about optimizing die design and process parameters for extruding a complex solid profile with large differences in wall thickness. They predicted effects of die bearing length and extrusion speed on extrudate temperature and extrusion pressure. Results showed that a longer die bearing allows more heat to dissipate from the extrudate to the colder die and leads to a greater extrudate dimensional accuracy. Authors concluded that 3D FEM simulation is a viable predictive tool for both die design and process optimization and the approach is applicable to the extrusion of other alloys for any other extrudate shapes [9].

Scientists from Yantai University (China) simulated tools for extrusion using software HyperWorks. To balance the local metal flow velocity, four different methods were tested – resizing portholes, adding bosses, chamfering mandrels, and adjusting the length of the bearings [10].

3. Software package Hyperworks

Software package includes several programmes which are designed for different type of industry. Three different tools are used for simulating material flow of aluminum alloys: HyperMesh, HyperXtrude and HyperView (as shown on Fig. 1) [11, 12].

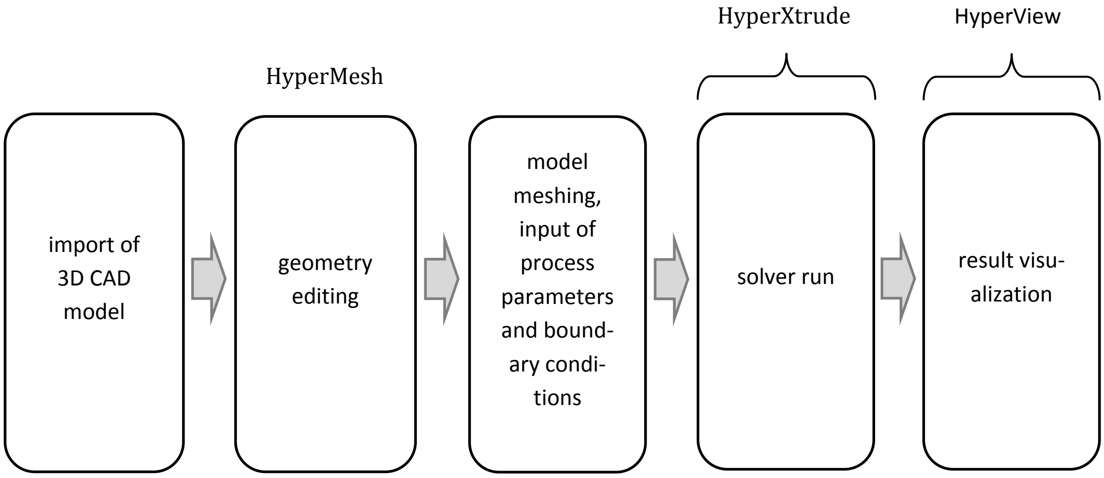


Fig. 1 Typical HyperWorks workflow

Numerical model is prepared in HyperMesh. HyperMesh is a preprocessor and enables interactive data input. At the beginning 3D CAD model is imported and meshed, followed by entering process parameters such as extrusion velocity, die, billet and ram temperature etc.

HyperXtrude is a CAE tool that runs a simulation – this is a virtual press, which simulates how material flows through the tool. The method used for calculation is a finite element method (FEM).

HyperView is a post-processor and enables results visualization.

4. Extrusion tools design – analysis of the current process

Main designers' goal is a tool with optimised characteristics that will meet all requirements given. That is achieved with correct geometrical and technical properties of a tool.

Extrusion tools design is currently based on designers' experiences. The results are unseen until the test tool is produced. Given the tool does not meet all the requirements, corrections are needed. Main disadvantages of the existing process are production delays and additional costs. Current tool design process is schematically presented on Fig. 2.

The process begins with an order, which includes requirements and specifications of the desired tool. The company then prepares the instructions for design. If un-clarities occur, they are resolved in a dialog with the customer. Next step is performed by design teams, where the design and modelling begins in order to meet the given requirements. 2D construction is still used more often than the more complicated, space oriented, 3D modelling. As the modelling is done, a review of the completed activities is performed in order to look for errors. It is subjective as it all depends solely on the experience and qualities of the designer. Adjustments are possible, however rare, because the designer has no objective scale or tool to evaluate the solution. At this point the design phase is concluded, preparation of NC programme begins and the tool goes into production. Manufactured tool is provided to the customer, who performs the test extrusion and the produced test profile is submitted to a series of tests, which show, if the product provided meets the initial requirements.

At this point the whole process can be objectively evaluated for the first time since the placement of the order. All the previous evaluations were only estimations based on experience and assumptions. In case deviations from the requirements occur, corrections are needed:

- small deviations are corrected during production.
- larger deviations require design correction and geometry changes and production of a new, improved tool.

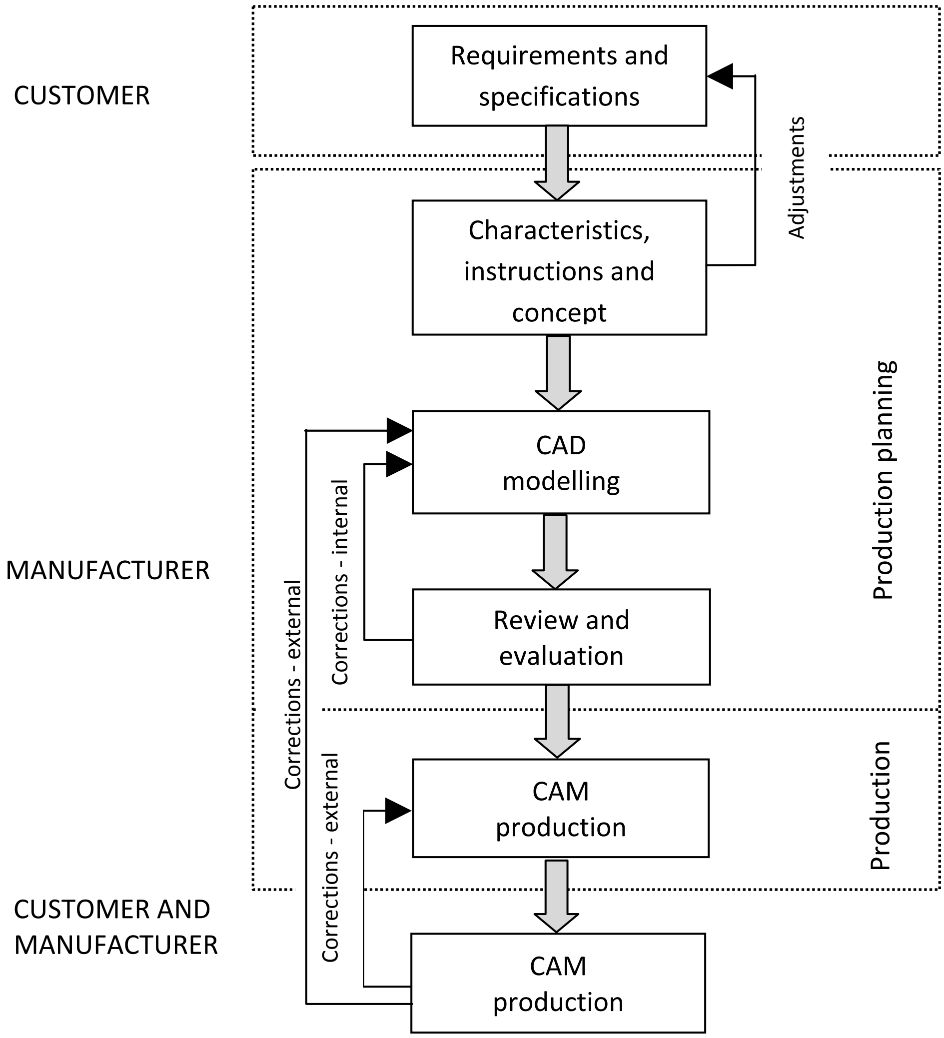


Fig. 2 Current design process

The Fig. 2 shows the connection between CAD and CAM. The design phase is CAD based and the production is fully computer supported (CAM).

Currently used design has proven un-sufficient in many aspects. The weaknesses of the current design model are:

- Undefined, problematic, time consuming and often unclear process of input variable defining to match the client's requests.
- In the process of geometrical modelling 2D construction is used more often than the preferable 3D modelling.

- Design and development of the tools is mostly based on skills and experiences of the designer.
- Control analytic calculations are performed, but not in extend of complete, integrated solutions.
- Simulation techniques are not used in the design level.
- The required geometry adjustments of the tool are rarely performed in the design period.
- Only the prototype testing gives feedback and guidelines for improvements to designers.
- A lot of information about the design of the product during the production are doubled and repeated.
- Error discovery is difficult.
- Errors are repeated often in the process of design, construction and production of the tools, even if a similar production was already ongoing without interruption.
- Cost control is limited.
- Ability to repeat construction and production is low due to un-transparent process.
- Adjustment to buyer demands is difficult.
- Company is unable to adjust to new demands for complicated tools of larger dimensions.

5. The new model of design process

Section 4 showed many flaws in the currently used design process. Main disadvantage is lack of objective evaluation ability, which would help predict the results already in design phase [13].

Simulations help designers predict material behaviour during extrusion before extrusion itself. A tool can be evaluated and tested before it is even produced. In comparison with the previous one the new model uses an additional primary optimisation circuit in design phase (marked black on scheme on Fig. 3).

The tool geometry is designed in 3D array. The 3D model has to be compatible with HyperWorks simulation package. Designer uses previous experiences to prepare the first model which is then simulated and the results give improvement guidelines for the new 3D model. This is repeated until we are satisfied – this makes it the new primary optimisation circuit in design process. The product has to meet geometrical requirements and the material flow has to be as laminar as possible.

Process continues the same as before. Final model of the tool is prepared based on the simulation results and previous experiences. After evaluation NC programming, tool production and customer testing are performed. Additional corrections are done if needed, but it is more of an exception than a rule, because faults are detected and resolved in the primary optimisation circuit.

Presented model would be ideal, but it is rarely achieved completely in praxis. The reasons for that would be other factors, which affect the production, such as alloy structure, operational parameters of the extrusion, process stability and others. The goal is to come as close as possible.

Previous model consisted of CAD and CAM, but here we introduce also CAA (Computer Aided Analysis).

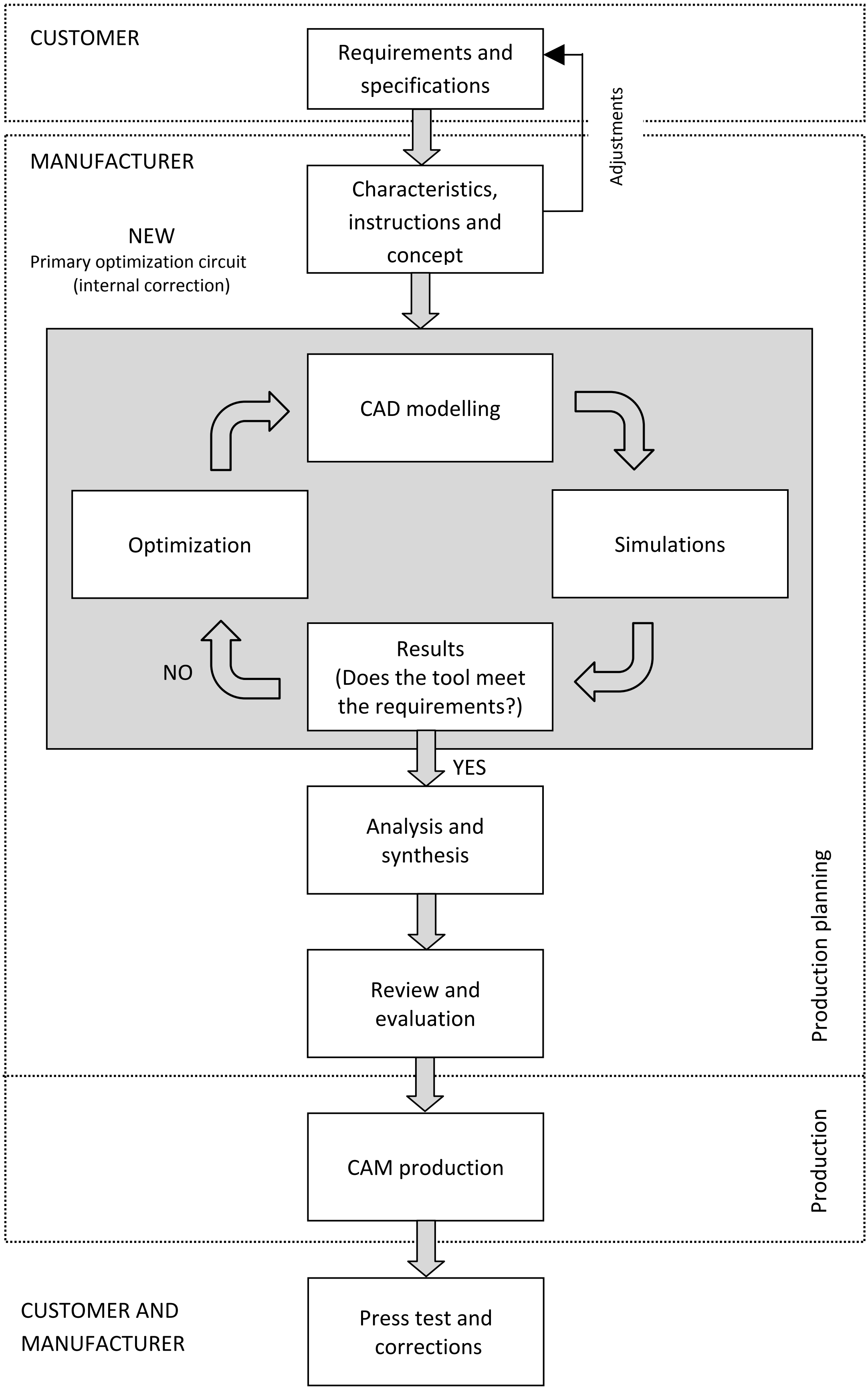


Fig. 3 The new model of design process

5.1 Advantages of the new model

The new model of extrusion tools design process has many advantages, among others [14]:

- The whole process enables designing and production of extrusion tools for complicated shapes of larger dimensions.
- The design process is fully 3D modelling based, which excludes multiplying geometry information about the tool in production preparation phase.
- Design process relies on numerical material flow simulation inside the tool. The result of the simulation gives the bests geometry of the tool, so that these conditions are met:
  - equal speed profile in the reshaping area
  - temperature distribution as equal as possible inside the tool and product
  - pressure distribution in the reshaping areas.
- Data transfer between the design system and production preparation is fully automated and is based on common information.
- Proper demands recognition and determine the specifications is simpler, it's faster and more reliable.
- Geometry design errors are fixed in the design phase of the process.
- The demand for product testing is significantly smaller.

6. Industrial example – results and discussion

A real industrial problem is presented in this section. Drawing of a test profile is shown on Fig. 4.

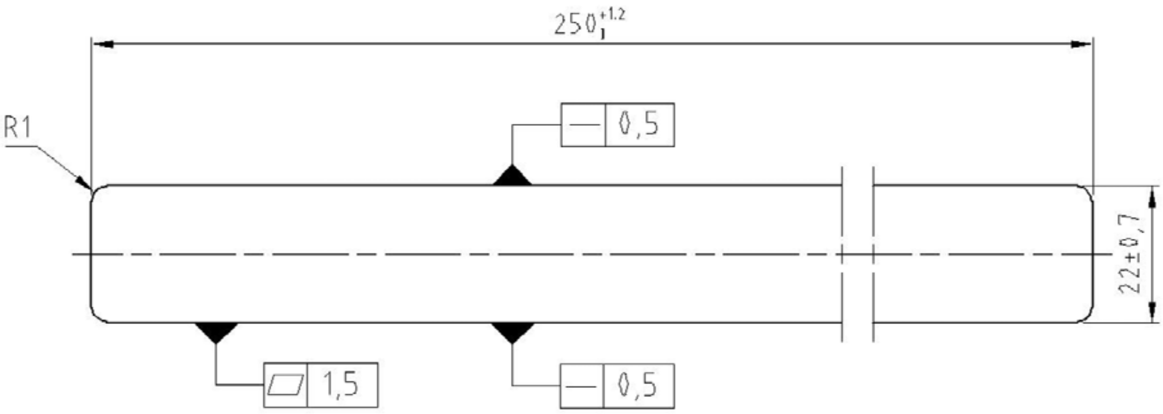


Fig. 4 Profile drawing

That kind of profiles have typical shortcomings – there are cracks on the sides of the profile (those areas show a lack of material). To reduce material flow in the center of cross-section, a special tool shape will be developed with the use of numerical simulations.

Velocity distribution of the material flow in the profile and a profile shape were not adequate in the past since the profile did not meet the geometrical requirements. To eliminate those imperfections, tool geometry was changed. Since we need more material on the edges of the profile, two main changes are made:

- feeder's cavity is enlarged on the edges.
- in the center of feeder is a solid bridge, which reduces material flow in the center of the profile.

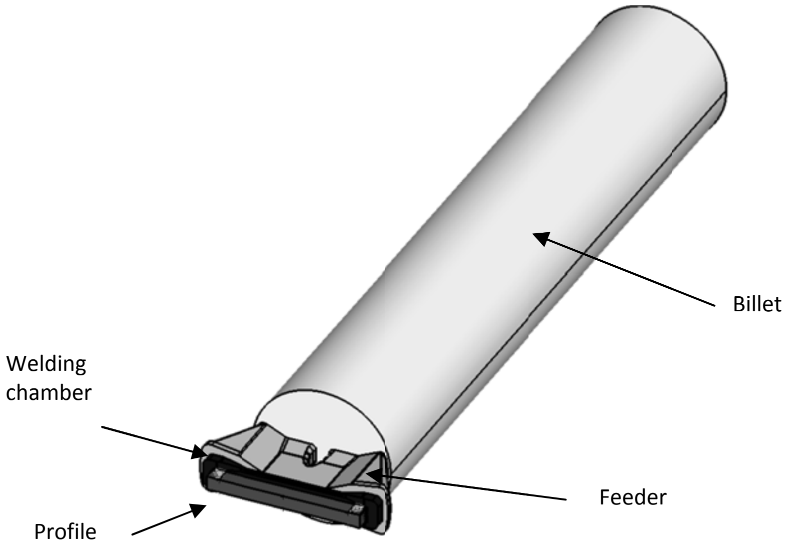
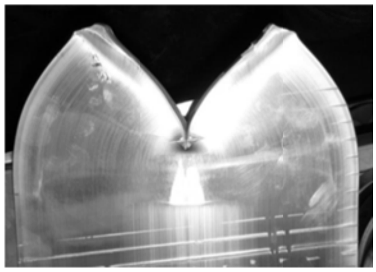
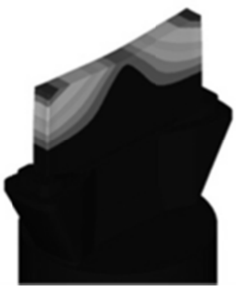
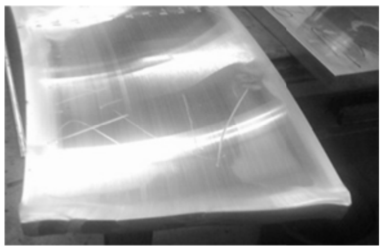


Fig. 5 Tool A – 3D model for simulations

Designers prepared three different versions of the new tool. The main difference between them is in the bridge size – tool A has the largest bridge, tool B has a smaller one, and tool C is without any bridge. All three feeders are shown in Table 1.

Table 1 Different feeder's geometries, simulation results and experimental test results

	Feeder	Simulation results	Test results
Tool A			
Tool B			
Tool C			

On the left-hand side in the table 2 are 3D models of feeder, where can be clearly seen differences between them. In the middle are simulation results – displacement profiles are shown. On the right-hand side are photos of experimental results.

Comparison shows that simulation results are comparable to the real test results. Simulation matches experimental result in all three cases.

According to results, tool C is the most appropriate – velocity distribution of the material flow is almost uniform, and the difference in displacement between center and edges of the profile is minimal.

7. Conclusion

Software platform for numerical simulations HyperWorks is presented. Purpose of individual programs which are used for simulations are schematically presented. The whole process from an order to the final tests is shown. Basic tool-making principle is clearly seen in the scheme – the tool can be objectively evaluated not earlier than at test extrusion.

With the introduction of additional primary optimisation circuit in design phase, correction costs were reduced, geometrically complicated profiles were optimized, and velocity and temperature profiles are more uniform. Longer tool's lifetime is also expected.

Numerical simulations cannot be fully relied on since they are still not developed enough. They can only be a guideline for the designers. However, results presented in this article showed that, for a simple profile, simulation is a very good approximation to the actual situation. With the use of simulations, an extrusion tool was successfully improved.

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