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Computer-Aided Design of Steel Casting Taking into Account the Feeding Ability

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Abstract

A new Computer-Aided Design approach is introduced for design of steel castings taking into account the feeding ability in sand moulds. This approach uses the geometrical modeling by a CAD-program, in which the modul "Castdesigner" is implemented, which includes the feeding models of steel castings. Furthermore, the feeding ability is guaranteed immediately during the design by an interactive geometry change of the casting cross section, so that a directional feeding of the solidifying casting from the installed risers is assured.

Keywords: Computer-Aided Design, Casting, Solidification, CastDesigner, FreeCAD, Feeding ability, Riser

1. Introdution

Nowadays the develoment of the mechanical engineering parts processing, including castings, is not conceivable without CAD application for the making of drawings and three-dimensional views. Furthermore, it becomes increasingly more important that the part is constructed taking into account the functional parameters as well as the manufacturing parameters. One of the most important manufacturing properties of steel castings is the volume shrinkage during the phase transition from liquid to solid state. Steel cast alloys have a lower density in the solid state then in the liquid state. This causes a deficit of melt during the solidification of casting alloy. A nonfeeding design of the casting process leads to formation of shrinkage defects: shrinkage cavities, macro- and microporosity and in certain cases also to hot tears. At last this led to the concept of the "Castability" in the scientific usage.
The concept of the „Castability" with regard to the supply feeding of castings ("feeding ability") was formulized already in the 20ties of the last century. There are many scientific publications in the field of the analysis and geometry correction of the castings to reach the feeding ability of castings [1-11]. Currently different systems are used in the foundries for the simulation of the solidification processes of casting, which is very helpful for the examination of the effectiveness of the filling and feeding system to avoid the formation of defects during the casting. Also one can analyse the feeding ability of the casting afterwards. Only the professional experience of the foundryman in dealing with the different filling and feeding systems allows to raise the feeding ability by changing of the casting geometry. The pragmatic realisation of the functionality in the final version of the casting geometry very often causes contradicting opinions between the designer and the foundryman. In the present work the attempt to compile a system-technical method based of the mathematical feeding models [1-8] and modern computer methods for the development of a casting geometry appropriate for feeding system based on the application of such CAD systems, like FreeCAD, SolidWork, CATIA or other is undertaken. The suggested design method includes the introduction of certain restrictions into a conventional CAD-program to provide an "intertemporal" feeding of casting in a way that the final geometry fulfils the conditions of the feeding ability automatically. In this manner the designer is not deflected from his main goal to realise the functional application of the mechanical part. Besides, it is possible to use the geo-

metrical restrictions in a way that the achievement of this principal purpose is not endangered. Using the new design method the designer gets tools in the hand, which help him to select solution of design taking into account the technological parameters independently.

2. The developed methods

The offered approach uses geometrical parameters of casting sections which influence casting feeding.
For using of these methods in the computer program, certain geometrical models of a body casting are required. From this point of view, model of a middle axis has the best potential [12]. It is approximately considered that a feeding of casting occur along a middle axis during its solidification. A triangulation of Delaunay [13] and the diagrammes of Voronoi [14] are also used to estimate the local thickness of walls of a cast detail. The graph theory has a great importance for the description of the feeding path in the casting. A mathematical model of the feeding ability of steel casting based on the works of the authors [6-8] is used in the present work. Important feature of this model is an introduction of casting feeding quality assessment using a quality-value α number. This number is used as a parameter of the required casting density during the assessment of its feeding ability. It is assumed that possible defects of shrinkage in casting correspond to defects in a end zone of test casting from similar steel (Fig. 1). For the description of possible defects density standard is necessary for each steel (Fig. 1). The quality-value α for most steels lies in the interval from 1.01 to 1.4.

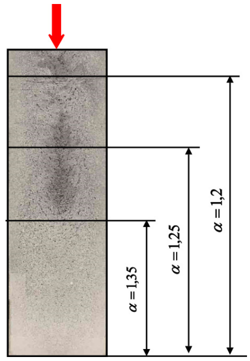


Fig. 1. The density standard for a casting of steel 35 L (GS-52) produced in sand mould

Approach to assess the casting ability to feeding by liquid metal contains three various methods in present work: a) So-called „track curve"-method, b) Cross section analysis, c) 3D-analysis and correction of the casting geometry. The methods are implemented in the computer program module "CastDesigner" which is working together with other modules of "FreeCad"-system.

2.1. So-called track curve method

To design the feeding ability of casting an adaptation of mathematical models [6-8] to the real possibilities of the CAD is necessary. This method allows both: 1. to apply the model for the development of casting geometry and 2. to analyze this geometry taking into account of feeding ability. One can use the "track curve"-method to design castings with easy cross section contours (Fig. 2).

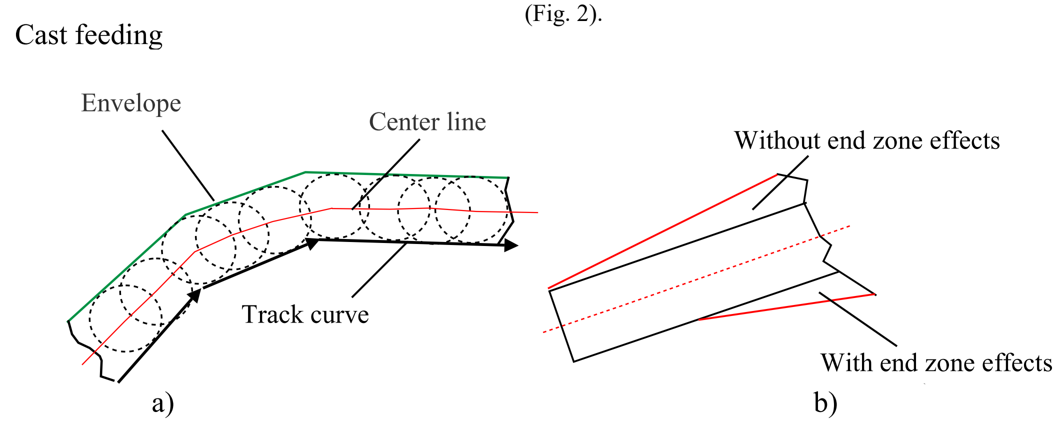
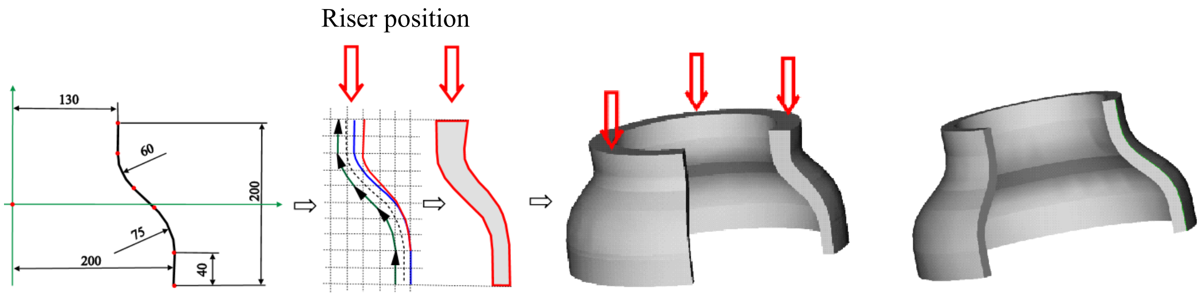


Fig. 2. Presentation of the "track curve"-method
a) Arrangement of the contours with the design of envelope curve and middle axis
b) Design variations without and with consideration of the end zone effect

The "track curve" is that line along "unrolls" the virtual Heuvers-circle [2]. The movement of the virtual Heuvers-circle goes against the feeding path from the farthest place to the riser. The envelope curve of these circles creates an external and internal contour of section of casting. The centre of the movement describes the center line of the section (a middle axis), i. e. the curve of the feeding path.

The design of simple armature part with only one feeding path direction from above down with the help of module "CastDesigner" is shown in Fig. 3. The sequence of design begins with the drawing of a sketch of the casting contour using the standard module "Sketch" of the FreeCAD-system (Fig. 3a). Fig. 3b presents analysis of the casting feeding ability by taking into account the calculated wall thickness and the necessary metal density according to the quality-value α in the module "CastDesigner".

The black arrows show direction of feeding analysis of the casting. The blue contour corresponds to a surface of casting which can be changed. The external contour which takes into account the technologically necessary addition automatically arising by the solution of the mathematical models [6-8] is shown with red colour. Fig. 3c demonstrates the casting part which was developed with the standard module "FreeCAD" and corrections of cross section necessary for feeding ability with the help of the module "CastDesigner". Fig. 3d shows the casting geometry which does not have the feeding ability for comparison.



a) b) c) d)

Fig. 3. Design of the casting using the module "CastDesigner" based on the "track curve"
a) Sketch of the surface contour of the casting which was developed with the module "Sketch FreeCAD", b) Analysis of the feeding ability and geometry change of the casting in the module „CastDesigner", c) Geometry of casting feeding ability calculated by the "CastDesigner“ d) Customary design solution for the casting with the uniform wall thickness which was developed using the module "PartDesign FreeCAD" alone.

2.2. Cross section analysis

The method of the track curve is not very effective for castings with more complicated configuration. The cross section method was developed for these casting parts (Fig. 4). An analog of this method is often used in the manual analysis of feeding ability and in the determination of the necessary geometrical changes of casting. The user has to specify position of risers in this method. Cross section of a contour is divided into a set of areas by means of Delaunay triangulation. The circumscribed circles of Delaunay triangles are aproximations of the Heuvers-circles and the circumferential line of the triangles are approach the cross section contur (Fig. 4a). The approximation can be refined, when the number of the areas of the disassembled contour is raised.

By the use of the Grum-Grshimailo-principle: „… every higher standing area of a casting should serve as a riser for the lying underneath area and the riser should solidify as a last part…“ [1], an automatic orientation of the feeding paths occurs along the center line of cross section. Additionally, the user of the program can change these directions also according to own request. The geometry change suggested by the system (Fig. 4a - 4e) guarantees a metal density to be not lower than in the calibrating casting and it is expressed by the quality-value α. The geometry changes can appear either symmetrically to the center line of casting (Fig. 4b), or shifted to the allowed side as well (Fig. 4c and 4d). The module "CastDesigner" allows to design the feeding paths with the help of the indicate the liquid metal supply direction (Fig. 4b, 4c and 4d) as well as with the help of the definition of the desired feeding zones of riser (Fig. 4e).

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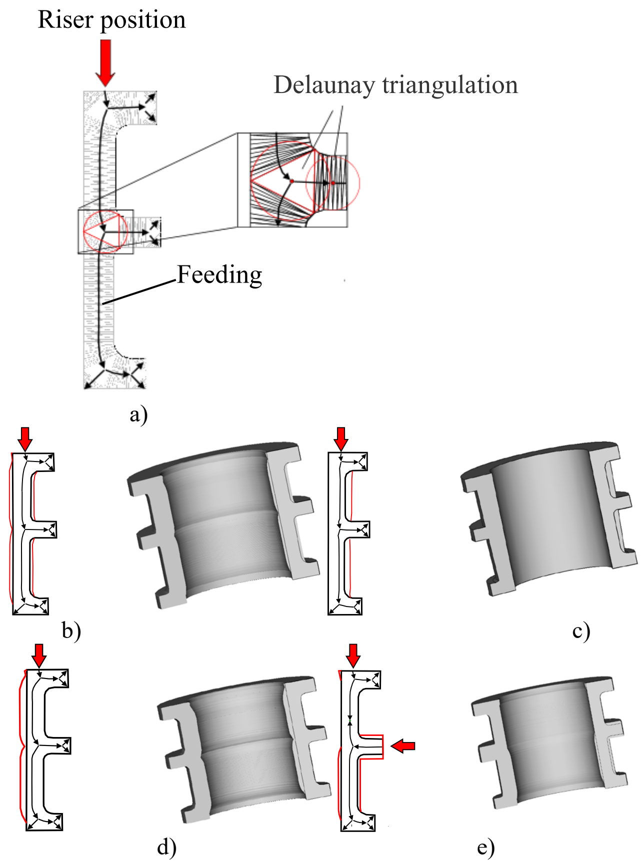

Fig. 4. Design by the cross section method
a) Triangulation of the cross sections, determination of the feeding directions and feeding paths, b) Generation of the geometry change appropriate for feeding ability of the casting with the symmetrical additions and 3D-representation of the generated casting, c) and d) Movement of the geometry change in the machining allowance of the casting, e) Development of the feeding ability geometry of the casting with additional side riser and targeted reorientation of the feed zones of the riser

The developed version of the design solution of the casting part must be in accordance with the conditions of its feeding ability. This is demonstrated with an example of design of steel casting (Fig. 5a).

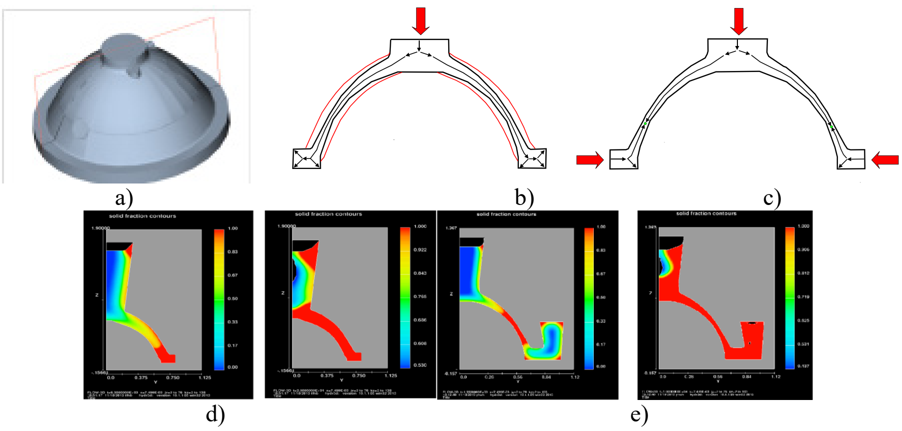

Fig. 5. Feeding analysis and generation of the necessary geometry change of the casting with two versions of feeding system under application of the module "CastDesigner". a), b), c) and the comparison with the results of a solidification simulation by Flow-3 program d) and e)

Using Fig. 5 one can determine very easily the preferential feeding version and the necessary geometry changes of the casting in order to achieve the necessary metal density. Of course, the presented methods include a check of solidification simulation. The

Fig. 5d and 5c show the simulation results. The sequence of analysis of the feeding ability of casting and the determining of a riser position in the 3D-model of the casting is shown in Fig. 6.

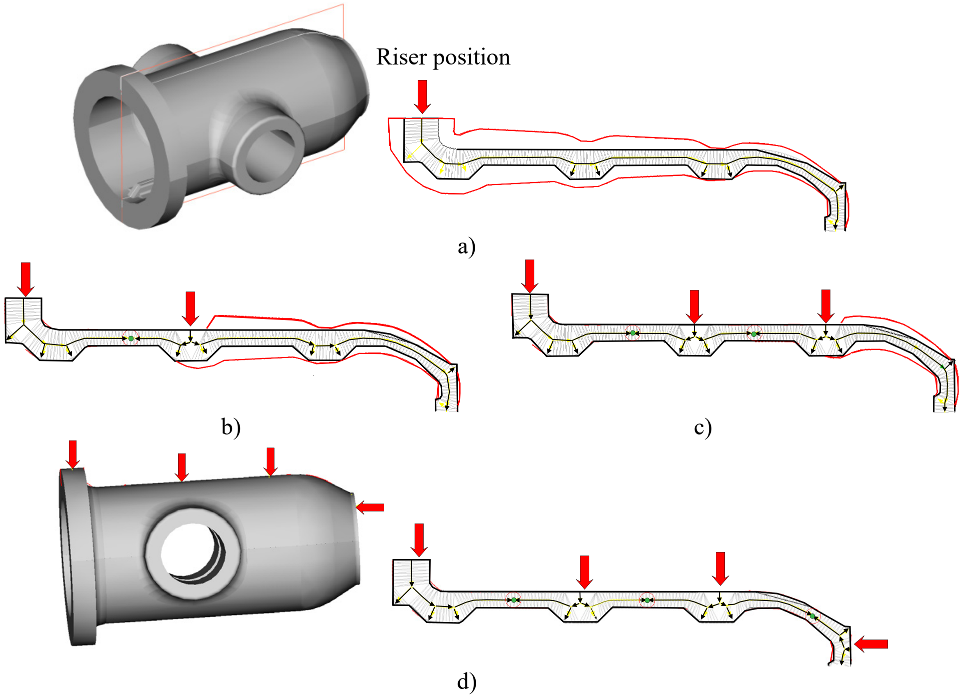

Fig. 6. Determination of a feeding system for the casting by the application of the module "CastDesigner"
a) Choice of the cross section for the analysis and the first concept of the feeding system, b) and c) Analysis of the version of the necessary geometry changes of the cross section, adding of the second and third risers, d) Suggested solution appropriate for feeding ability of the casting cross section
b)

The result of such an analysis the optimal system of the feeding with a minimum of risers, the riser position and the technological geometry change of the casting for the achievement of a required density are obtained.

2.3. 3D-analysis and correction of the casting geometry

This method gives the possibility to analyse local feeding paths. Answers the question is: „If it is possible to realise a continuous feeding from the point "A" up to the point "B" (Fig. 7a and 7b). The desired feeding path should be designed by the user.

If the feeding path is "free", a change of the geometry is not necessary.

If this is not the case, the minimal necessary geometrical changes are indicated on the screen for the realisation of the "checked" feeding path.

This method is based on an enlargement of the "track curve" where every point of the casting surface corresponds to a certain enrolled ball.The surface colour of the casting corresponds to the radius of the ball. One can check the final geometry with the geometrical changes and the feeding system with the help of the thermal knots within the shortest time with the help of the module "CastDesigner" (Fig. 7d). This method is very suitable for the cast technological preparation directly in the foundry and can serve as an additional intellectual aid for the user before the solidification simulation.

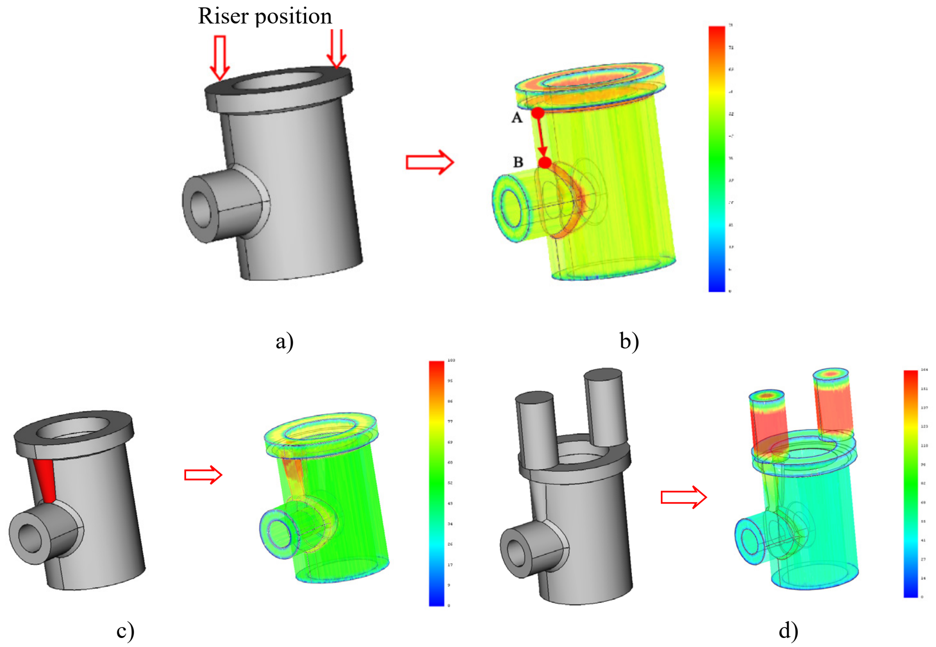

Fig. 7. Construction of the additional feeding path in the connection of the thermal knots
a) Determining of the feeding direction, b) Inquiry of two thermal knots with the help of the 3D-analysis, c) Inquiry of the geometrical change to the union of both thermal knots taking into account of α – value, d) Inquiry of the riser and final check

3. Conclusions

A computer program was developed to support a designer in the casting development and a foundryman for a quick analysis of the feeding ability of casting. The system is acting within the scope of the compiled module "CastDesigner" in the "FreeCAD-program ". The application of the program shortens the preparation time for the casting production and decreased the casting defects. It allows an objective selection of constructive solution with the technological solutions and leads to a rise of the casting quality. Casting yield can be also raised.

References

[1] Groem-Grzjimajlo, V.J. (1933). *Steelmaking*, Moscow, p. 408.
[2] Heuvers, A. (1943). *Giesstechnik, Die Giesserei, Vol. 30*, 201.
[3] Chvorinov, N. (1940). *Giesserei, 27*, 177-186.
[4] Pellini W.S. (1953). *Trans. AFS,. Vol 61*, 61-80.
[5] Namur, R. (1958). *Giesserei Technisch-Wissenschaftlich Beihefte, N. 20*, 1077-1087.
[6] Balandin, G.F., Tschebotarev, A.S. & Tschikunov, J.M. (1976). *Casting*, 21-23 (russ.).
[7] Polaykov, S. N. (1985). *Casting*, *N. 11*, 7-9. (russ.).
[8] Polyakov,S.N. (1989). *Casting, N. 10, 18-19*. (russ.).
[9] Hartmann, R., Poliakov, S., Popkov, V. & Martin A. (1998). *Konstruieren+Giessen 23*, 4.
[10] Korovin, V.M., Polyakov, S.N., Korotchenko, A.J., Polyakov, D.S. & Bast J. (2012). *Russ., Foundryman 2*. 29-35 (russ.).
[11] Tschebotarev, A.S., Tschikunov, J.M., Sladkova, L.A., Porozkov V.N. *http://www.ruscastings.ru/work/168/2130/2984/6312.*
[12] http://en.wikipedia.org/wiki/Medial_axis
[13] http://en.wikipedia.org/wiki/Delaunay_triangulation
[14] http://en.wikipedia.org/wiki/Voronoi_diagram