

# The assessment of bell casting producibility based on computer simulation of pouring and solidification

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## Abstract

The work estimates the possibility of modification of the traditional production method of bell castings taking into account calculations performed by NovaFlow&Solid simulation program. Changes are evaluated with regard to the arrangement of the shrinkage defects in castings, which are of influence on the acoustic and mechanical properties of castings.

**Keywords:** Bell, Artistic casting

## 1. Introduction

A bell is a unitary and specific casting, and production of bells is considered as a distinct field of casting – the bellfounding. A separate moulding technology was developed, the ‘false bell’ method, invented in the Middle Ages and used until today. This method is applied for production of large bells (over 25 kg), while for small bells the investment casting method using the ceramic shell mould is employed [1, 2]. By centuries, bells were produced according to the almost unaltered technology, shared and bestowed in a narrow circle of people, most often the familiar one. The method, description of which appeared as early as the Middle Ages [3], was slightly modified in Renaissance [4], and in XVIII century was transformed into the procedure of mould making which is still in use [5]. The mould is prepared with the use of templates called ‘strickle boards’ rotated around the bell axis. The elements which are necessary to be accomplished are: the mould core, the bell pattern, the cope, and – most often in another technology, without the use of templates – the bell crown i.e. the element making possible to fasten the bell to the

supporting structure. The structure of a bell is presented in Fig. 1. The moulding operations are laborious and energy-consuming, each of the many subsequent layers of moulding material demands for drying in a temperature of about 80÷90°C. All operations necessary to accomplish the bell mould can last from about 3 to 6 months.

With regard to its application, the bell is a musical instrument which belongs to the vessel idiophone group and is played by indirect striking. Idiophone is an instrument made of naturally elastic material which vibrations are the source of musical sound without the necessity of applying any artificial stress. The shape of a bell profile is decisive for the quality of sound, and the bell head (Fig. 1) constitutes the ‘circular nodal point’ which do not take part in vibrations [6].

The internal defects of the bell waist in the form of shrinkage porosity or cavities can disturb the vibrations of casting by interposing the additional nodal points.

The method of template moulding brings up no objections, but doubts can be raised about the position of mould during the pouring of metal, which should be recognized as incorrect as far as the directional solidification criterion is taken into account. It

seems that there is a lack of the effective feeding of the metal solidifying in the sound bow, which accumulates from about 30% to 50% of metal mass, depending on the type of an European bell, and that a danger of shrinkage cavity occurs. Defects in this element, even in the shape of rather small cavities, can probably significantly deteriorate the acoustic properties of a casting.

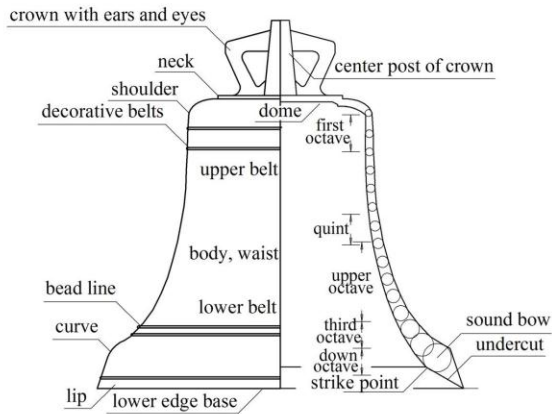


Fig. 1. Elements of a bell

## 2. The method of investigation

The purpose of the work is an analysis of producibility of the bell-type cast structure, the basis for considerations being a bell made in the shape designed according to J.G. Krünitz [7] (Fig.2), cast of B20 tin bronze ( $t_{\text{pour}}=1150^{\circ}\text{C}$ ), the mass of which is equal to about 100 kg.

The fulfilling of the requirements necessary for the proper solidification conditions was assessed taking into account simulation analyses carried out by NovaFlow&Solid program. The assessed factors were the simplicity of production mould making, correctness and perfection of filling the mould with molten metal, prevention of the contraction defects including shrinkage cavitation and shrinkage porosity.

Three optional designs of gating system were selected for the assessment of pouring and solidification: the 1<sup>st</sup> – according to the recognised bellfounding practice (Fig. 2), the 2<sup>nd</sup> – including the crown feeders (Fig. 3), and the 3<sup>rd</sup> – in which metal is poured

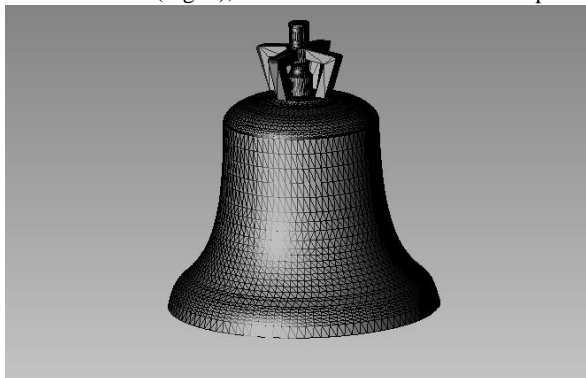


Fig. 2. A visualisation of the bell model shaped according to Krünitz – first option

through one of the open feeders placed along the lip of the inverted bell, and the crown is at the bottom of the mould (Fig. 4).

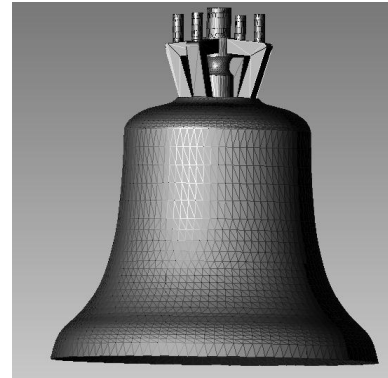


Fig. 3. A visualisation of the bell model – second option

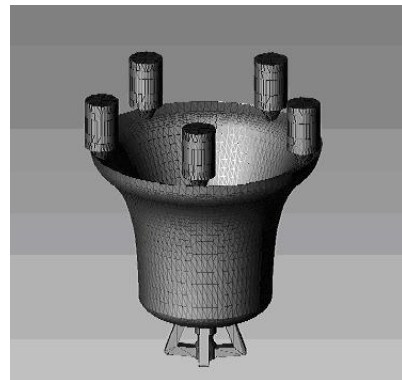


Fig. 4. A visualisation of the bell model – third option

## 3. The description of the obtained results

The simulation of pouring and solidification of casting carried out by NovaFlow&Solid program according to the 1<sup>st</sup> option gave the results in the form of graphs representing the arrangement of shrinkage defects within the volume of the bell casting (Fig. 5) and over the selected cross-sections (Figs 6 and 7).

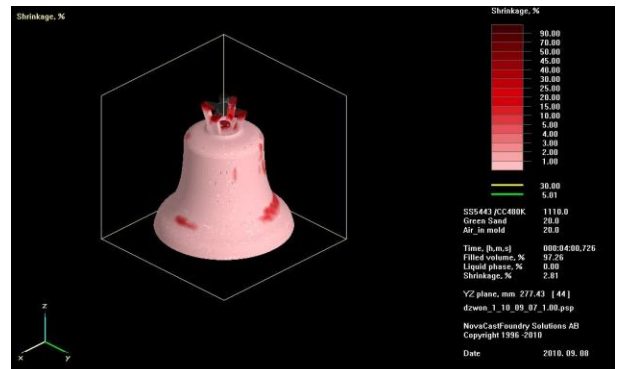


Fig. 5. Shrinkage of a bell casting, a view – 1<sup>st</sup> option



Fig. 6. Shrinkage of a bell casting, longitudinal cross-section – 1<sup>st</sup> option



Fig. 9. Shrinkage of a bell casting, longitudinal cross-section – 2<sup>nd</sup> option



Fig. 7. Shrinkage of a bell casting, transverse cross-section – 1<sup>st</sup> option

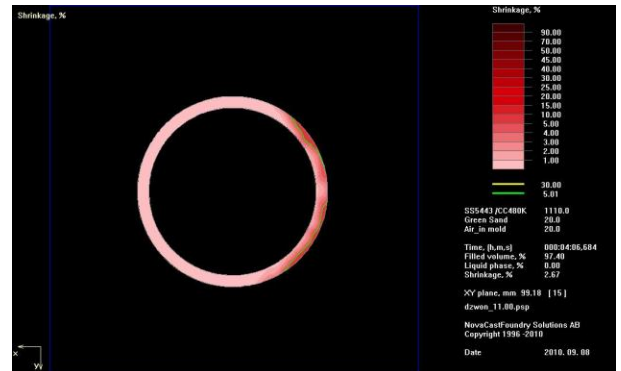


Fig. 10. Shrinkage of a bell casting, transverse cross-section – 2<sup>nd</sup> option

The simulation of the 1<sup>st</sup> pouring option revealed defects of the bell waist within the whole casting volume, and the misrun in the upper part of the crown.

The simulation of solidification according to the 2<sup>nd</sup> option gave the resulting arrangement of shrinkage defects within the volume of a casting presented in Fig. 8, while Figs 9 and 10 show this arrangement in selected cross-sections of a bell casting.

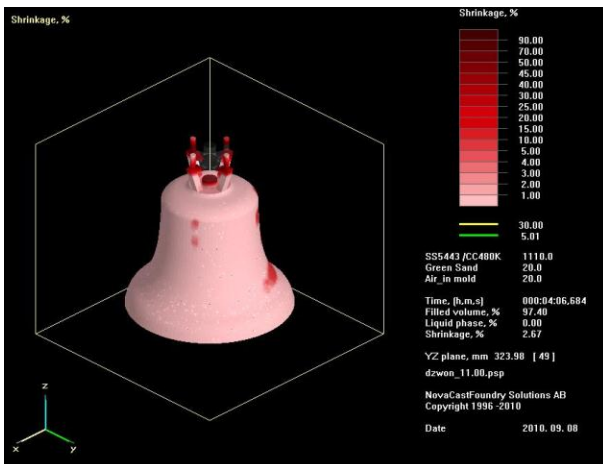


Fig. 8. Shrinkage of a bell casting, a view – 2<sup>nd</sup> option

The shrinkage porosity observed in Figs 8÷10 resulted from the lack of proper feeding. Figs 8 and 9 reveal that the full crown of casting is not achieved and the casting compactness is weakened over the bell waist, the latter can be also seen in Fig. 10. The internal defects of bell waist can affect the bell tuning, thus making it unfit for use. Attention should be paid to the fact that though a bell is a solid of revolution, defects are not arranged uniformly along its waist circumference, but concentrated at one side of the casting (Figs 8, 10).

Considering the 3<sup>rd</sup> option of the bell casting design, the shrinkage defect arrangement was obtained as visualised in Figures 11÷13. Here the shrinkage of a casting for the inverted casting equipped with open feeders can be observed. Application of feeders gives an evident result of restraining the shrinkage defects for this case, and the change in the casting position is advantageous with respect to the directions of metal pouring and solidification of a casting.

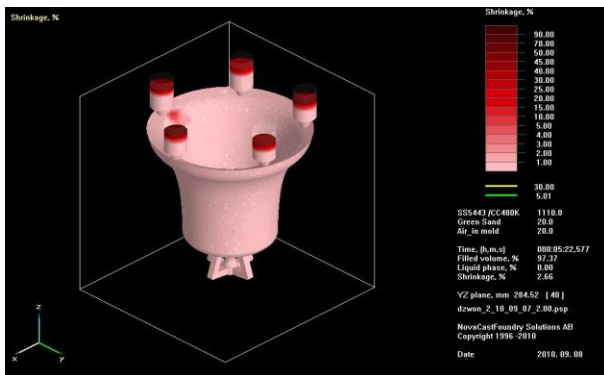


Fig. 11. Shrinkage of a bell casting, a view – 3<sup>rd</sup> option

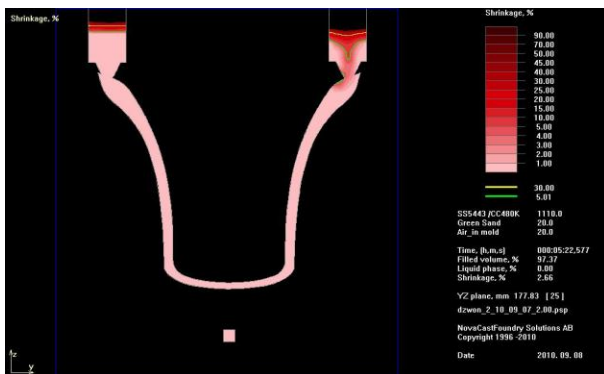


Fig. 12. Shrinkage of a bell casting, longitudinal cross-section – 3<sup>rd</sup> option



Fig. 13. Shrinkage of a bell casting, transverse cross-section – 3<sup>rd</sup> option

Unfortunately, the proposed solution demands for applying the suspended core of large weight and being difficult to keep stable inside the mould. Despite this inconvenience, however, it should be stressed that the lack of internal defects in a produced casting is worth making the effort, since it should provide for high acoustic quality, uninterrupted by any discontinuities within the bell lateral surface.

## 4. Conclusions

The performed analyses of producibility of the bell-type casting allow us to state that:

1. The considered 1<sup>st</sup> option do not provide for the advantageous solidification conditions of a bell casting in the mould, for there occur internal defects of the bell waist within its entire volume after the solidification, and moreover the misrun is observed in the bell crown in the upper part of the bell. The advantages of this method are: the core 'standing' on a stable basis and the possibility of applying hand moulding with use of two cores for the reproduction of the bell crown.

2. The 2<sup>nd</sup> option also do not provide for the advantageous solidification conditions of a casting in the mould. It results from the lack of feeding, the irregular pouring, and the way of solidification of a bell-shaped casting. Due to this factors, there occur internal shrinkage defects.

3. The investigations carried out by means of the NovaFlow&Solid simulation program indicate that there is a possibility of modification of the traditional method of casting bells. The modification of moulding technology by applying the one proposed in the 3<sup>rd</sup> option allow to obtain the high quality bell castings, as is confirmed by solidification analyses carried out by means of the NovaFlow&Solid program, and to reduce the laboriousness of the moulding operation.

## References

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