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# The Influence of Using Different Types of Risers or Chills on Shrinkage Production for Different Wall Thickness for Material EN-GJS-400-18LT

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## Abstract

In modern times, there are increasing requirements for products quality in every part of manufacturing industry and in foundry industry it is not different. That is why a lot of foundries are researching, how to effectively produce castings with high quality. This article is dealing with search of the influence of using different types of risers or chills on shrinkage cavity production in ductile iron castings. Differently shaped risers were designed using the Wlodawer's modulus method and test castings were poured with and without combination of chills. Efficiency of used risers and chills was established by the area of created shrinkage cavity using the ultrasound nondestructive method. There are introduced the production process of test castings and results of ultrasound nondestructive reflective method. The object of this work is to determine an optimal type of riser or chill for given test casting in order to not use overrated risers and thus increase the cost effectiveness of the ductile iron castings production.

**Keywords:** Ductile iron, Shrinkage cavity, Riser, Chill, Ultrasound

## 1. Introduction

Theory of molten metal feeding – risers designing is important with respect to volume (dimension) changes during the solidification process. In the specific temperature, the volume of metal is constant and in the normal pressure it is function of the temperature. The measuring scale of the increasing volume during the heating is a coefficient of volume expansion, on the other hand the loss of volume is being called [1]:

- Tendency to create shrinkage cavities - during the solidification,

- Tendency to contraction - in the solid state.

A riser fulfils a function of a reservoir filled with molten metal during these volume changes. That is why a riser must solidify after a casting does. Riser must provide enough amount of molten metal to casting as it solidifies. It is also necessary to keep the positively directed solidification - schematic illustration in Fig.1.

During a parallel solidification, the fronts of solid are converging under a null angle at the same time along the entire length of thermal axis. A result of this type of solidification is the shrinkage porosity in the thermal axis. When the fronts of solid

are converging under angle  $\omega$ , which is opened towards the riser, the solidification is called positively directed. This type of solidification allows the riser to feed the entire volume loss and the casting is solidifying without shrinkage cavities or porosity. During a negatively directed solidification is the angle  $\omega$  opened away from the riser and the internal shrinkage cavities in the casting are being created [2].

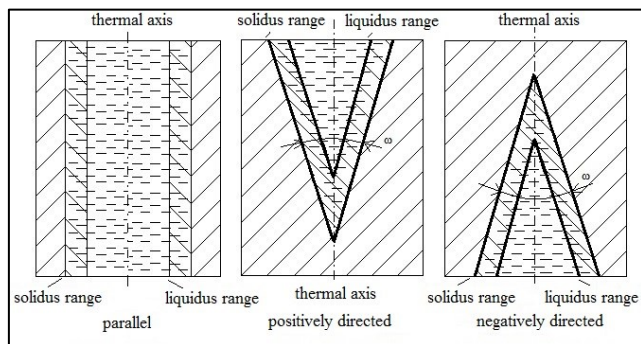


Fig. 1. Schematic illustration of parallel, positively directed and negatively directed solidification [2]

## 2. Work methodology and materials

Moulds for test castings were made using the furan sand mixture. The aim of this investigation was to find out the influence of used riser or chill on shrinkage cavities creation. According to this a following gated pattern was applied:

- 2 patterns - 300 mm height, 250 mm width, 40 mm thick,
- 2 patterns - 300 mm height, 250 mm width, 80 mm thick,
- Risers/ chills - one riser for each casting or a combination of riser and chill,
- Gating system - fireclay tubes, filter and extension pouring basin.

### 2.1. Calculation of the riser size

For the calculation of the riser sizes a several methods can be used:

- Heuver's circle method,
- Přibyl's calculation method,
- Wlodaver's modulus method.

In this investigation, all designed risers were calculated by using of Wlodaver's modulus method. The principle of this method is that a solidification time of the riser must be longer than a solidification time of the casting (or hot spot). These solidification times are calculated by Chvorinov's rule (1) [3, 4]:

$$t = c \cdot M^2 \quad (1)$$

Modulus is defined as ratio of a casting volume to a surface area of the casting (or hot spot). Therefore, the mathematical expression of the modulus is (2) [3-5]:

$$M = \frac{V}{S} \quad (2)$$

In general, according to the Wlodaver's modulus method there must be kept the following ratio (3) [2, 3]:

$$M_r : M_n : M_c = 1,2 : 1,1 : 1,0 \quad (3)$$

First, all of the moduli were calculated using the (2) equation. Then the risers were chosen from a Chemex company catalogue [6]. Each riser was an exothermic type.

According to [5] mostly chills made from grey iron are used and the thickness of the chill should be a minimum of the same size as the thickness of the section to be chilled. Adding chills to one side of a section can reduce the modulus by up to 50%. Another authors [7] stated that chills dimensions depend on the thickness of the section to be chilled as the Tab.1 and Fig.2 show. In this examination, the chills dimensions were calculated using the values from the Tab.1 and then the closest available chill (Fig.3) was chosen.

Table 1.  
Chills dimensioning according to [7]

S [mm]	K [mm]	O [mm]
below 20	0,5 . S	S/2
20-40	0,8 . S	S/3
above 40	1,0 . S	S/4

Where S, K and O are illustrated in the Fig.4:

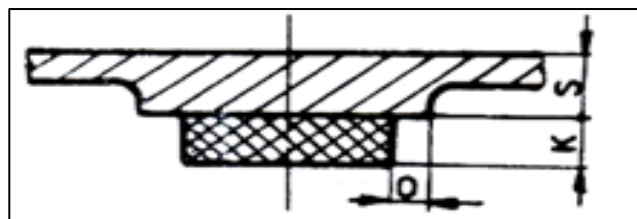


Fig. 2. Chills dimensioning [7]

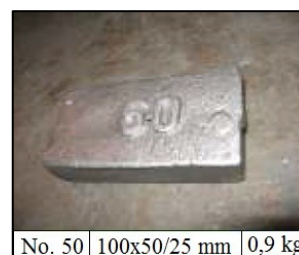


Fig. 3. Designed chill

A thickness of chosen chill is smaller than 0.8 multiple of casting's wall thickness, because the chill was not used for hot spot chilling, but it was used as an end chill. End chill increases the feeding distance by increasing end zone length [8]. Based on feeding distance, which is 4 - 5 multiple of casting thickness are the chills for given test castings thick 40 mm requisite. Since the

gates to casting are situated from the bottom, the thermal distribution inside the casting is influenced by liquid metal flow on the entire height. By using of chill the overheating of lower part of the mould is decreased, which leads to an improved feeding from a riser.

In Tables 2, 3 and 4 is described, which patterns, risers and chills were chosen for particular moulds.

Mould No.1 contained 2 castings 40 mm thick and 2 castings 80 mm thick with cylindrical exothermic risers (Fig.2) and not contained any chills.

Table 2.

Patterns and risers for mould No.1

Wall thickness [mm]	Casting's modulus [cm]	Riser used and its modulus [cm]	
40	1,55	Tele 100-18	1,90
40	1,55	Tele 220-25	2,30
80	2,50	Tele 300-30	3,00
80	2,50	Tele 500-40	3,20

Moulds No.2 and No.3 no longer contained castings 80 mm thick as they turned out to be without any shrinkage cavities. For mould No. 2 were used elliptically shaped risers - also necks were shaped this way. Mould No.3 contained the same risers as mould No. 1 but necks were enlarged compared to necks from mould No.1. These changes of the neck shape/size should prevent premature solidification of casting-riser connection through the neck. Also a combination with chills should support the feeding ability of riser.

Table 3.

Patterns, risers and chills for mould No. 2

Wall thickness [mm]	Casting's modulus [cm]	Riser used and its modulus [cm]	Quantity and type of used chill
40	1,55	Tele 125-32/14	2,00 -
40	1,55	Tele 125-32/14	2,00 3x No. 50
40	1,55	Tele 210-30/20	2,40 -
40	1,55	Tele 210-30/20	2,40 3x No. 50

Table 4.

Patterns, risers and chills for mould No. 3

Wall thickness [mm]	Casting's modulus [cm]	Riser used and its modulus [cm]	Quantity and type of used chill
40	1,55	Tele 100-30	1,90 -
40	1,55	Tele 100-30	1,90 3x No. 50
40	1,55	Tele 220-30	2,30 -
40	1,55	Tele 220-30	2,30 3x No. 50

## 2.2. Moulding and pouring

Fig.4 shows the positioning of patterns and a bottom part of the gating system. Chills were put on the outer side of pattern near the gate. Between the patterns and filter chamber was a 150 mm gap to prevent the mutual thermal influence.

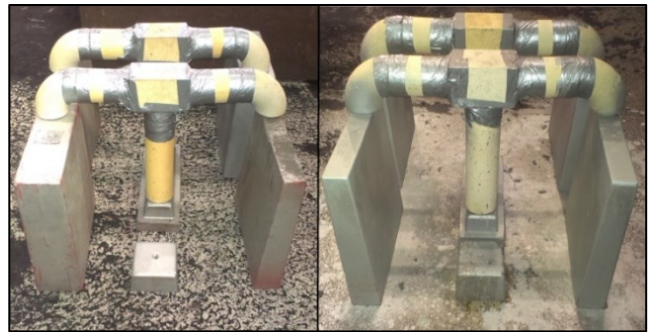


Fig. 4. The positioning of patterns and a bottom part of the gating system - left for mould No.1, right for moulds No.2 and No.3

The upper part of mould No.1 can be seen in the Fig.5 and the upper parts of mould No.2 (left) and No.3 (right) is in the Fig.6.



Fig. 5. The upper part of mould No.1



Fig. 6. The upper parts of mould No.2 (left) and mould No.3 (right)

In the Fig.7 there is a completed mould No.1 and pouring. The pouring temperature of all moulds was set on  $1360\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ .



Fig. 7. The completed mould No.1 and pouring

### 2.3. Ultrasonic testing

Defects inside the casting can be detected by using X-ray or ultrasonic method. Both methods are non-destructive [9]. Ultrasonic reflecting method, which uses direct or angle probes can cover most of applications [10]. A probe applied to a casting's surface sends thanks to a piezoelectric effect repeatedly impulses of given frequency to a casting. When the probe is not sending impulses it is in a receiving mode. An acoustic signal goes through a binding medium (oil, water) to a casting. Receiver waits for a signal reflected from a defect inside or from a rear side of casting. Reflected waves are shown on the device's display as a defect or an end echo [11]. Ultrasound can be also used for the determination of graphite shape [12]. The following Fig.8 shows a principle of the ultrasonic nondestructive method.

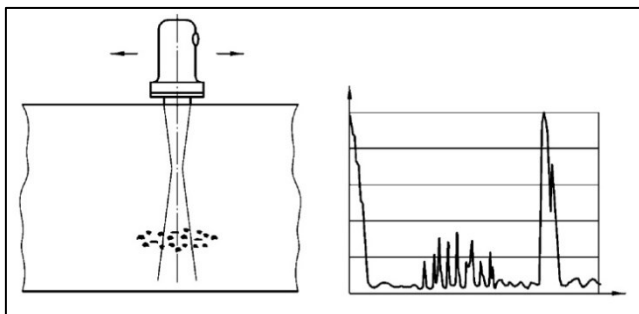


Fig. 8. The principle of ultrasonic nondestructive method [13]

After the moulds were poured and cooled down the risers and gating system were removed. The castings were grinded off and then polished. The technical standard DIN EN 12680 - 1 regulates the surface roughness for ultrasonic testing to  $RA \leq 12,5 \mu\text{m}$  [13]. In the Fig.9 there can be seen castings prepared for ultrasonic testing.



Fig. 9. Polished castings prepared for ultrasonic testing

## 3. Results

Tab.5 presents the results of ultrasonic testing of castings from mould No.1. It can be seen that the casting 80 mm thick solidified without any shrinkage cavities using both smaller and larger riser. On the other hand, in the castings 40 mm thick shrinkage cavities had appeared.

Table 5.  
Results of mould No.1

Wall thickness [mm] / Modulus [cm]	Modulus of used riser [cm]	Shrinkage area [mm <sup>2</sup> ]	Shrinkage thickness [mm]
40 / 1,55	Tele 100-18	1,90	80x20
40 / 1,55	Tele 220-25	2,30	90x20
80 / 2,50	Tele 300-30	3,00	0
80 / 2,50	Tele 500-40	3,20	0

In the Fig.10 there is as an example shown a position of shrinkage cavity on the casting 40 mm thick poured with smaller riser. Shrinkage cavity appeared in one third of the casting's height from riser's side.



Fig. 10. The position of shrinkage cavity

In the Tab.6 are the results of testing mould No.2, which contained only castings 40 mm thick with elliptical shaped risers and their combination with chills. As the ultrasonic tests had shown, the shrinkage cavities in castings poured without chills were significantly smaller than in the previous mould No.1. In addition, shrinkage cavities in castings poured with chills were established as acceptable by standard.



Table 6.  
 Results of mould No.2

Wall thickness [mm] / Modulus [cm]	Modulus of used riser [cm]	Used chill	Shrinkage area [mm <sup>2</sup> ]	Shrinkage thickness [mm]	KSR value [mm]	
40 / 1,55	Tele 125-32/14	2,0 0	-	20x20	4	3,7
40 / 1,55	Tele 125-32/14	2,0 0	3x No. 50	10x10	3	2,7
40 / 1,55	Tele 210-30/20	2,4 0	-	20x20	5	4,3
40 / 1,55	Tele 210-30/20	2,4 0	3x No. 50	20x20	4	3,8

A KSR (Kreis-Scheiben-Reflektor) value stands for substitution size of the defect. If the cavity had a shape of sphere, the KSR value would symbolize its diameter. The KSR value gives an information about a size of cavity and whether the cavity must be additionally examined. After this examination, where the cavity surface to examined surface ratio is calculated, the examiner can evaluate whether the cavity is acceptable by a standard or not [14]. It means, that a higher KSR value can refer to an acceptable cavity, because the cavity does not have to be compact - for example shrinkage porosity.

In the Tab.7 are results of the last mould No.3, where the same risers as in the mould No.1 were used, but the necks were enlarged and the combination of these risers with chills. In castings, where chills were not used, the small shrinkage cavities had appeared. In casting poured with riser Tele 100 - 30 and also with chills an acceptable shrinkage cavity was created. Casting where larger riser Tele 220 - 30 and chills were used was completely without any shrinkage cavities or porosity.

 Table 7.  
 Results of mould No.3

Wall thickness [mm] / Modulus [cm]	Modulus of used riser [cm]	Used chill	Shrinkage area [mm <sup>2</sup> ]	Shrinkage thickness [mm]	KSR value [mm]	
40 / 1,55	Tele 100-30	1,90	-	20x20	5	4,2
40 / 1,55	Tele 100-30	1,90	3x No. 50	10x10	3	3,1
40 / 1,55	Tele 220-30	2,30	-	20x20	4	3,3
40 / 1,55	Tele 220-30	2,30	3x No. 50	0	0	0

In the Fig.11 there is a position of shrinkage cavity in the casting poured with riser Tele 210 - 30/20 without chills from mould No. 2. Shrinkage cavity appeared in one third of the casting's height from riser's side.

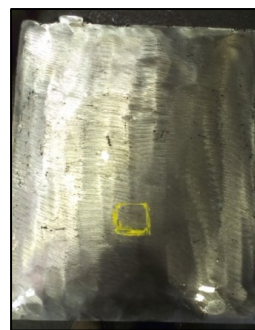


Fig. 11. The position of shrinkage cavity

## 4. Conclusions

From the results mentioned in Tables 6 and 7 it can be seen, that in the castings, where the chills were not used, a shrinkage cavity was always produced. It means that the change of the riser type or the neck enlargement itself was not effective enough. Nevertheless, the shrinkage cavity size reduction was significant. In the castings where also chills were used, smaller shrinkage cavities were created. These smaller shrinkage cavities were evaluated as acceptable by standard.

Casting completely without any shrinkage cavities or porosity was poured using the riser with enlarged neck Tele 220 - 30 with chills. The modulus of this riser is not 1.2 multiple of casting's modulus as the Wlodaver's method states, but almost a 1.5 multiple.

By the casting's with 80 mm wall thickness modulus ratio according to Wlodaver's method was kept and it was sufficient for reaching the required casting's inner quality. So, there is an obvious impact of faster solidification of thinner walls and therefore a reduced riser's feeding ability. In this case it is required to support feeding of molten metal from a riser by using chills.

## References

- [1] Michna, Š., Nová, I. (2008). *Technology and processing of metal materials*. Děčín.
- [2] Gedeónová, Z. (1990). *Theory of foundry processes*, 2nd edn. Bratislava: Alfa.
- [3] Karsay, S.I. (1976). *Ductile Iron Vol. 1 - Production*. QIT - Fer et Titane Inc.
- [4] Wlodawer, R. (1966). *Directional solidification of steel castings*. Pergamon Press.
- [5] Sorelmetal. (2000). *Ductile Iron The essentials of gating and risering system design*.
- [6] Chemex feeder systems. Retrieved March 14, 2015 from [http://www.metkoha.com/en/chemex/feeder\\_systems/index.html](http://www.metkoha.com/en/chemex/feeder_systems/index.html)
- [7] Malik, J., Futáš, P. (2006). *Technical preparation of castings production*. Košice: Elfa s.r.o.
- [8] Steel Founders' Society of America. (2001). *Feeding & Riser Guidelines for Steel Castings*. Retrieved October 11, 2015 from

- <http://user.engineering.uiowa.edu/~becker/documents.dir/redbook.pdf>
- [9] Kriedel, M. (2011). *Ultrasonic testing*. Praha: Starmans electronics.
- [10] Deutsch, V., Platte, M., Vogt, M. (1997) *Ultraschallprüfung - Grundlagen und industrielle Anwendungen*. Berlin: Springer.
- [11] Skrbek, B. (2001). Ultrasonic testing of internal defects of castings from spheroidal graphite cast iron - comparison with radiographic methods. *Slévarenství*. 7-8.
- [12] Belan, J. (2010). Identification of cast iron type with using of NDT methods. *Archives of Foundry Engineering*. 10(1), 103 – 106.
- [13] DIN EN 12680-1. (2003). *Gießereiwesen, Ultraschallprüfung*.
- [14] Krautkrämer, J., Krautkrämer, H. (1990). *Ultrasonic Testing of Materials*. 4th edn. Berlin: Springer.