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(54) Method for designing feeding systems of cast iron pieces

(57) The invention relates to a method for designing optimized feeding systems of cast iron pieces.

It is based on trying to maintain a thermal equilibrium in different areas of the piece such that metal housings are areas for the actual piece instead of for associated risers or sprues. For such purpose the invention proposes:

- breaking down the piece into areas split by the different sectional jumps produced in the piece;
- measuring the solidification moduli of each area;
- identifying the transfer areas;
- measuring a critical time for the transfer areas;
- measuring the solid fraction that would be reached in the areas after the transfer areas in the previous critical time, and
- comparing the solid fraction reached in the critical time with a certain solid fraction value called minimum solid fraction.

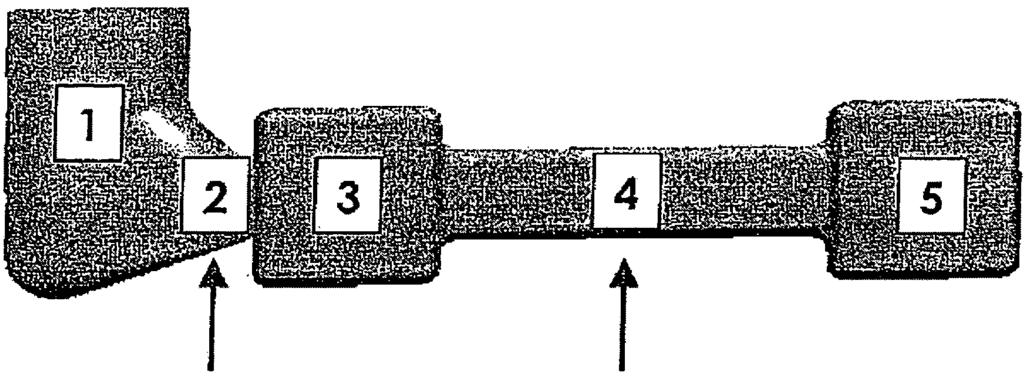

Figure 6

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Description

Field of the invention

[0001] The invention is comprised within the field of feeding methods for pieces obtained by means of a casting process.

State of the Art

[0002] Designing the feeding system in a casting process is one of the basic problems that need to be solved before beginning the manufacture of each piece because it is a determining factor in the final quality of the obtained piece.

[0003] The difficulty involved in producing healthy casting pieces is based on the complex nature of their solidification and of their volumetric changes, from the casting stage to the end of the solidification.

[0004] As a first step in this type of studies, the cooling rate of the piece is evaluated, which rate essentially depends on three elements: the thermal properties of the material used, the properties of the mold (heat conductivity) and the shape and size of the piece (solidification modulus). The following different types of feeding are used today.

[0005] Conventional feeding consists of directing solidification from the cold points through the thicker sections and placing a riser or sprue having a suitable size at the end of each solidification cycle. The shrinkage of the liquid is thus always compensated from the thicker sections, which in turn extract metal from the riser to be fed.

[0006] This feeding type has the huge drawback of an excessive number of risers or sprues in pieces having a complex geometry with a significant drop of the yield of the metal used.

[0007] Force feeding with risers is based on the fact that the liquid shrinkage must be compensated until it almost reaches the solidification temperature, therefore feeding from the riser must be maintained up until reaching the eutectic temperature.

[0008] If the intention is to use the entire expanse of graphite for feeding the piece, it is necessary to avoid reverse feeding from the piece towards the riser. This method tends to generate flaws in the form of a shrinkage hole due to the secondary shrinkage, especially in areas where heat tends to be concentrated because of the difficult ejection thereof.

[0009] Finally, the force feeding method without risers is a particularity of the previous case applied to thin pieces in which the filling system serves as the riser. As the significant solidification modulus of the piece decreases, the solidification modulus of the riser neck also decreases.

[0010] Therefore, for thin pieces the gate can carry out the function of the riser neck. In this case, the sprue and the part of the feeding channels which are located above the highest part of the piece will act as a riser.

[0011] Patents are known which describe feeding systems or processes for pieces or types of pieces or specific components. The following can be mentioned:

Patent document RU2241574 mentions a process with all the steps for feeding mid and large sized pieces including the addition of Mg and the necessary Argon flow. This patent relates to a manufacturing process but is intended for components with a mid-high weight.

Patent document JP20063466723 mentions a feeding method by means of a heated cylinder for the purpose of improving the flow of material through the inside of the mold, preventing the solidification of the outermost part of the material in contact with the cylinder. This patent relates to a system improving the feeding yield but it does not take into account the features of the part to be fed.

Patent document RU213861 presents a new feeding method based on splitting the mold in two halves in which the different elements (compartments, collectors, channels, etc.), are communicated by different channels. In this case the patent relates to a general feeding system for all pieces and not customized for the geometry of the piece

[0012] In any case, none of these processes or other similar processes can establish and design the most suitable feeding method for particular and different cases because each one proposes general solutions to be applied in all cases.

Explanation of the invention

[0013] The method object of the invention is based on the objective of trying to maintain a thermal equilibrium in different areas of the piece, so that metal housings are areas for the actual piece instead of for associated risers or sprues. The intention is for the channels to be replaced with the thin areas of the piece instead of with channels specifically designed outside of same.

[0014] In this method for designing the system the typical solidification curve of the casting along with the corresponding volumetric changes calculated by means of the balance between the shrinkage due to solidification of austenite and the volumetric expansion associated to the formation of graphite (Figure 1) is established.

[0015] The areas corresponding to a predetermined solid fraction are established in the solidification curve, in this case 0.4. Therefore one area shows the liquid shrinkage area which, in the event of inappropriate feeding, leads to primary shrinkage holes and the other area in which the metal viscosity increase is progressive.

[0016] This phenomenon forces reaching a moment in which fluidity is not sufficient for the pasty metal to feed the areas with a volume deficit. The viscosity-solid fraction ratio is shown in Figure 2.

[0017] The method for designing the system takes into account that the solidification of an industrial piece occurs heterogeneously depending on the geometric modulus of the piece and of the adjacent areas.

[0018] Different solidifications have been modeled by means of the thermal analysis technique for geometric moduli between 0.38 and 0.81 cm, as shown in Figure 3.

[0019] The proposed methodology for designing systems is carried out according to the following phases:

1. The heat moduli of the piece are established.
2. The transfer areas are displayed.
3. The critical time in which a predetermined critical solid fraction CSF is reached according to the metallurgical quality of the cast metal is calculated for the transfer areas.
4. The solid fraction reached in the areas fed by the transfer areas is verified for this critical time. If this solid fraction is greater than a certain value, called the minimum solid fraction (MSF), the mass feeding time is considered to be reached.
5. The calculation of the feeding time and its corresponding solid fraction is carried out according to a formula such as the following:

$$sf = f(M,t)$$

6. The modulus of the riser or sprue neck must have a minimum opening time assuring that a solid fraction of at least the minimum value referred to as MSF is reached in the fed part.
7. The heat modulus of the riser or sprue must be at least a defined percentage P1 greater than the modulus of the neck deduced from applying this method.
8. The feeding volume is calculated according to the following ratio: volume of the piece by liquid shrinkage (including the deformation due to pressure) to the yield of the riser or sprue.

[0020] The main advantage of this method for designing of the feeding system is that it will allow feeding cast material in each case (each piece) according to the morphology of the piece, the quality of the metal and the evolution of the solid fraction to obtain flawless pieces, assuring proper filling and the absence of flaws in the obtained piece.

Brief Description of the Drawings

[0021]

Figure 1 shows a typical solidification curve of a spheroidal graphite casting and volumetric changes associated to the solidification.
Figure 2 shows the evolution of the liquid iron viscosity with the solid fraction.
Figure 3 shows the solidification curves of spheroidal graphite casting for different geometric moduli.
Figure 4 is the standard piece used in this practical case 1
Figure 5 shows the different areas and its modulus for practical case 1
Figure 6 indicates the transfer areas for the piece of practical case 1.
Figure 7 calculates the critical time of the different areas when the solid fraction of the transfer areas is the critical solid fraction CSF.
Figure 8 shows the cover used in practical case 2.
Figure 9 indicates the different areas considered in the study of practical case 2.
Figure 10 shows the cover of practical case 2 with the initial design leading to internal flaws.
Figure 11 shows the new solution considered for the cover of practical case 2 to prevent the flaws indicated in the previous Figure.
Figure 12 shows the new areas corresponding to the new geometry of practical case 2.

[0022] Finally, Figure 13 shows the piece obtained for practical case 2, once the feeding system has been modified.

Detailed Description of Preferred Embodiments

[0023] Two examples for applying the method for designing feeding systems of casting pieces are described below.

Case 1: Standard piece (Figure 4)
The steps to be followed are the following:

1.- Establishing the solidification moduli of the piece, according to the different marked areas. (Figure 5)
2.- The transfer areas are subsequently defined as those areas feeding areas with a larger solidification modulus than what they themselves have (Figure 6)
3.- The critical time for the transfer areas (for sf=CSF) is measured. See Figure 7.
4.- The solid fraction of the different areas is calculated for the previous critical time.
5.- The feeding system is validated according to the values obtained in the previous phase. If the area to be fed reaches a solid fraction value for the established critical time of at least the minimum solid fraction (MSF), it will be fed accordingly. If not, problems will arise during solidification of the piece.

Case 2: This case relates to a cover and the steps to be followed are the same as in the previous case (Figure 8).

1.- Moduli are measured according to the different marked areas (Figure 9), and the moduli.

Area A: Modulus = 0.48
Area B: Modulus = 0.44
Area C: Modulus = 0.64

2.- The critical time is measured in the different areas.

Area A: Tc = 48.4 sec
Area B: Tc = 41.4 sec
Area C: Tc = 81.0 sec

4.- The solid fraction of the different areas is calculated for the critical time of the area on which its feeding depends.

Area B: sf(Tc = 48.4 sec) = 0.63
Area C: sf(Tc = 41.4 sec) = 0.13

5.- In this case, since area C does not reach a minimum solid fraction of P1, it will cause internal flaws as shown in Figure 10

[0024] In order for area C to be able to reach a solid fraction that is identical to or greater than the minimum solid fraction MSF, the geometry of the piece is modified as shown in Figure 11, and the viability of the new system is again checked.

1.- Measuring the moduli according to the different marked areas (Figure 12), and the moduli.

Area M: Modulus = 0.86
Area A: Modulus = 0.58
Area B: Modulus = 0.61
Area C: Modulus = 0.61

2.- The critical time is measured in the different areas.

Area M: Tc = 137.6 sec
Area A: Tc = 67.9 sec
Area B: Tc = 74.3 sec
Area C: Tc = 90.3 sec

4.- The solid fraction of the different areas is calculated for the critical time of the area on which its feeding depends.

Area A: sf(Tc = 137.6 sec) = 0.91
Area B: sf(Tc = 67.3 sec) = 0.53
Area C: sf(Tc = 74.3 sec) = 0.41

[0025] In this case all the areas have a solid fraction above the minimum solid fraction (MSF); they will have no internal problems and the piece will be sufficiently fed (Figure 14).

Claims

1. A method for designing optimized feeding systems of cast iron pieces **characterized in that** it comprises:

   a) breaking down the piece into areas split by the different sectional jumps produced in the piece;
   b) measuring the solidification moduli of each area;
   c) identifying the transfer areas as those areas feeding areas with a larger solidification modulus;
   d) measuring the critical time for the transfer areas, defined as the time it would take to reach a certain solid fraction value called critical solid fraction;
   e) measuring the solid fraction which would be reached in the areas after the transfer areas in the previous critical time, and
   f) comparing the solid fraction reached in the critical time with a certain solid fraction value called minimum solid fraction.

2. A method for designing feeding systems of cast iron pieces according to claim 1, **characterized in that** the critical solid fraction is a value between 0.37 and 0.51.

3. A method for designing feeding systems of cast iron pieces according to claim 1, **characterized in that** the critical solid fraction is a value between 0.55 and 0.67.

4. A method for designing feeding systems of cast iron pieces according to claims 1, 2 and 3, **characterized in that** the minimum solid fraction is a value between 0.13 and 0.41 so that designing the feeding system assures proper filling and the absence of flaws in the obtained piece.

5. A method for designing feeding systems of cast iron pieces according to claims 1, 2 and 3, **characterized in that** the minimum solid fraction is a value between 0.45 and 0.65 so that designing the feeding system assures proper filling and the absence of flaws in the obtained piece.

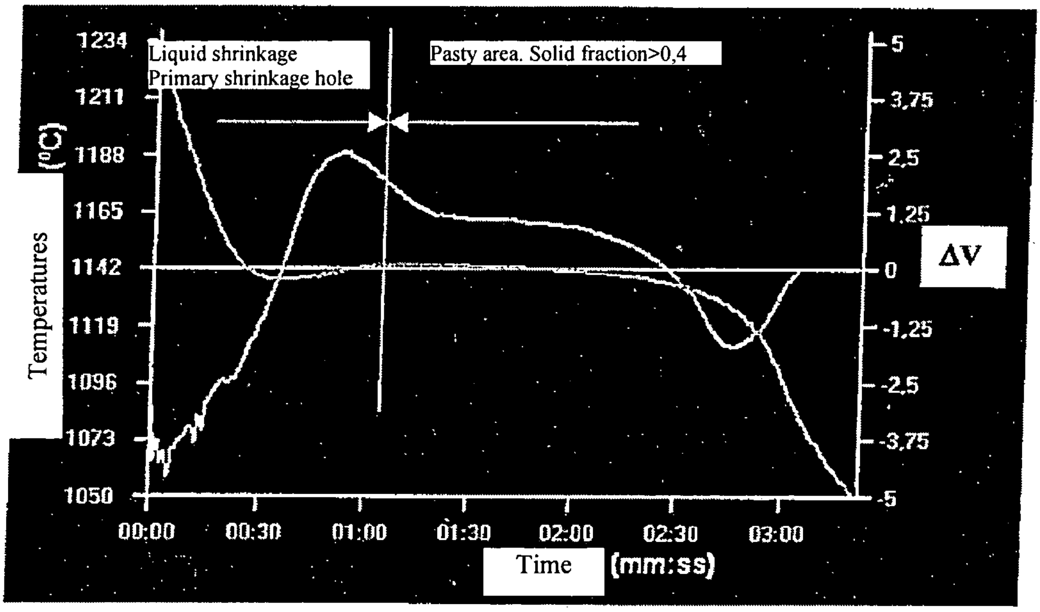

Figure 1

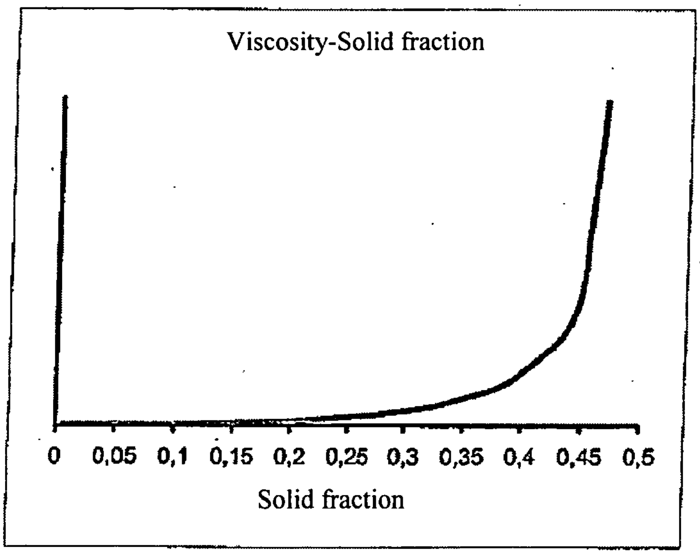

Figure 2

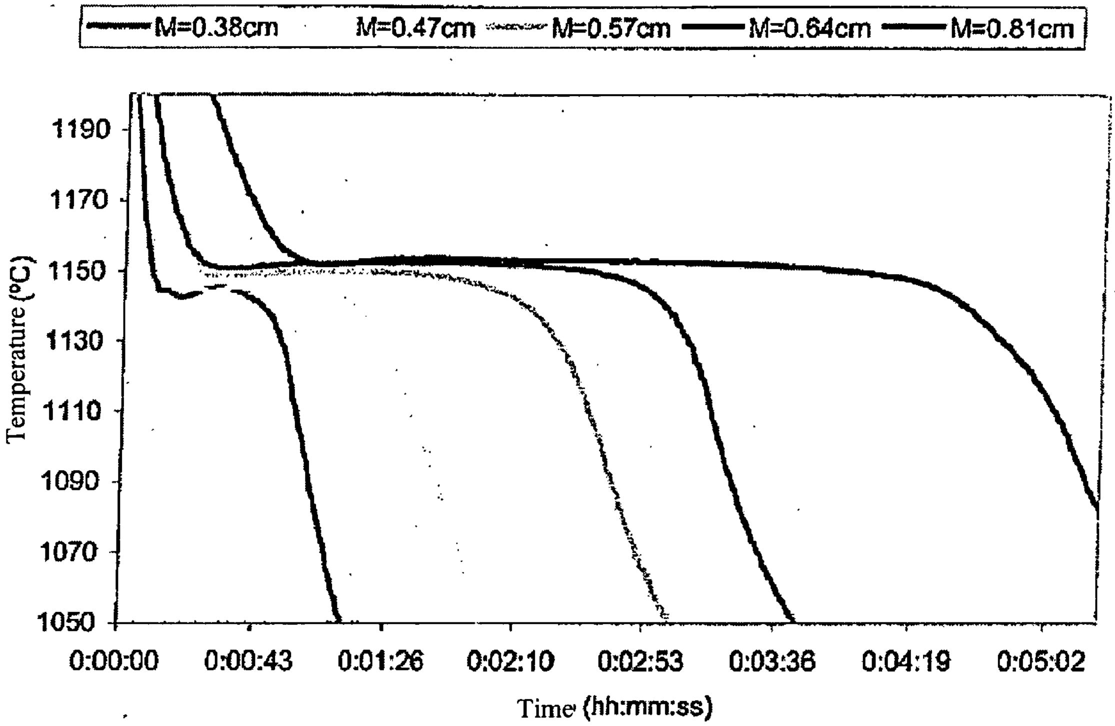

Figure 3

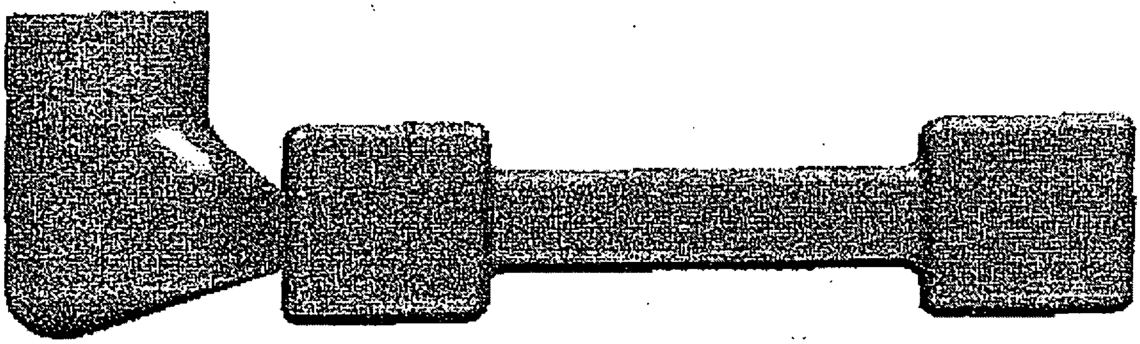

Figure 4

Area	Modulus
1	0.94
2	0.76
3	0.90
4	0.65
5	0.87

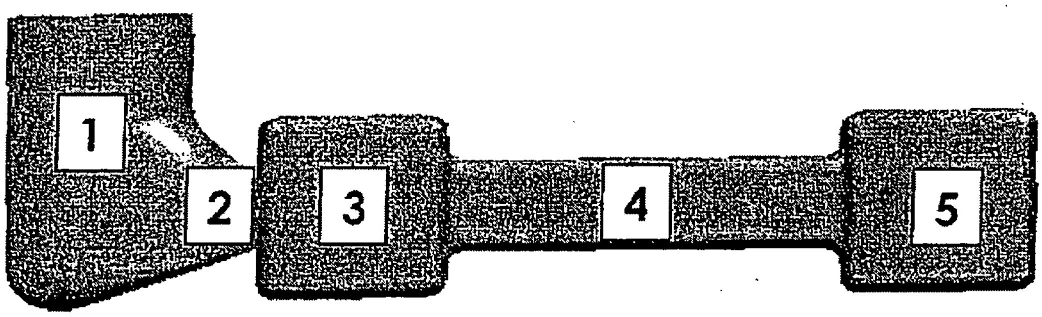

Figure 5

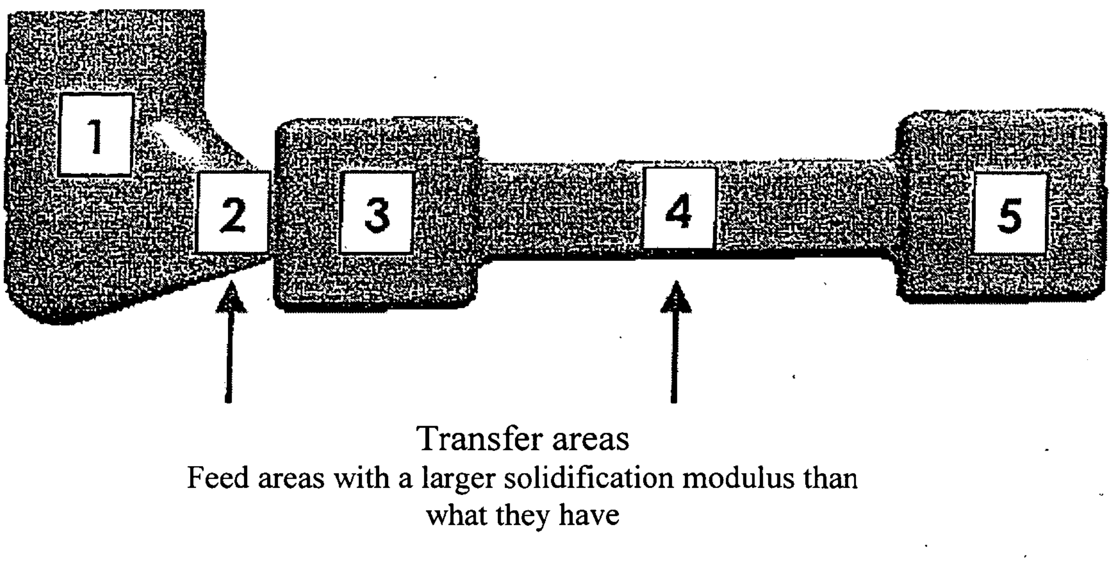

Figure 6

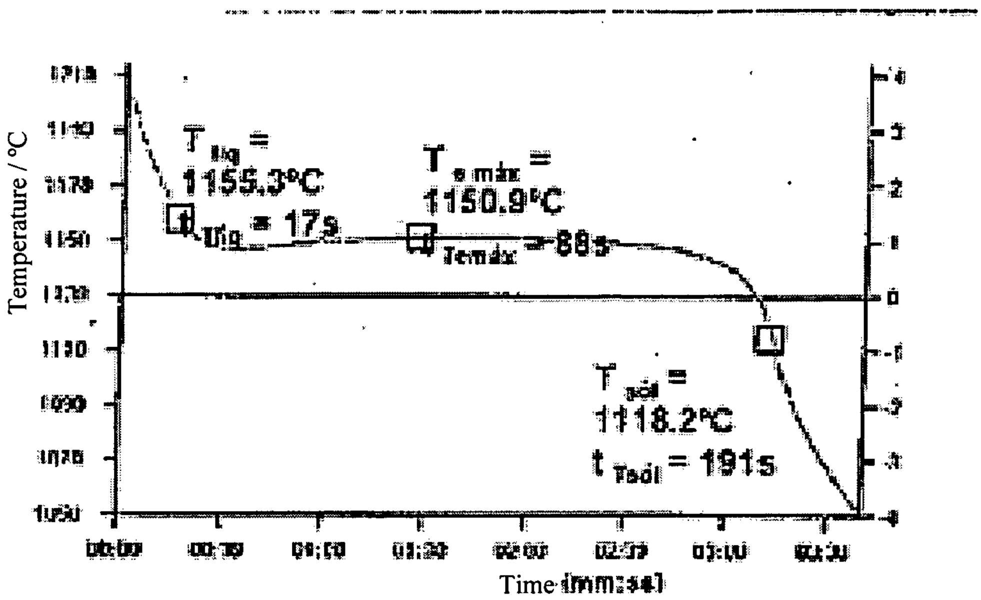

Figure 7

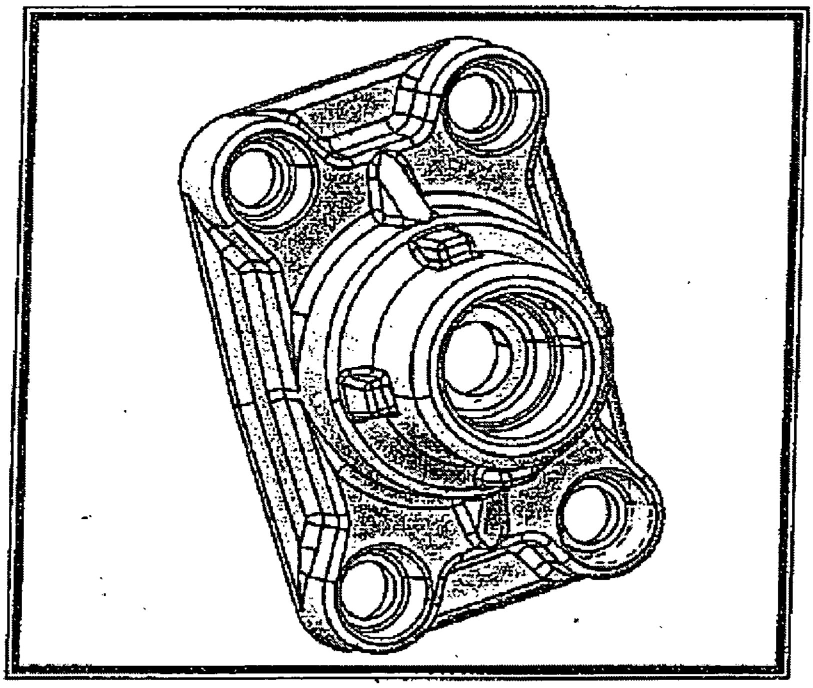

Figure 8

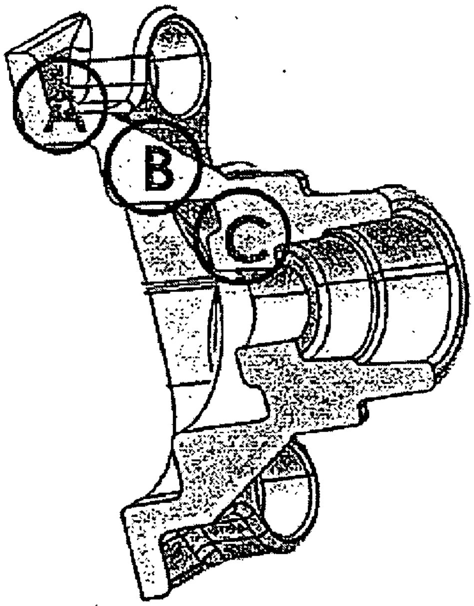

Figure 9

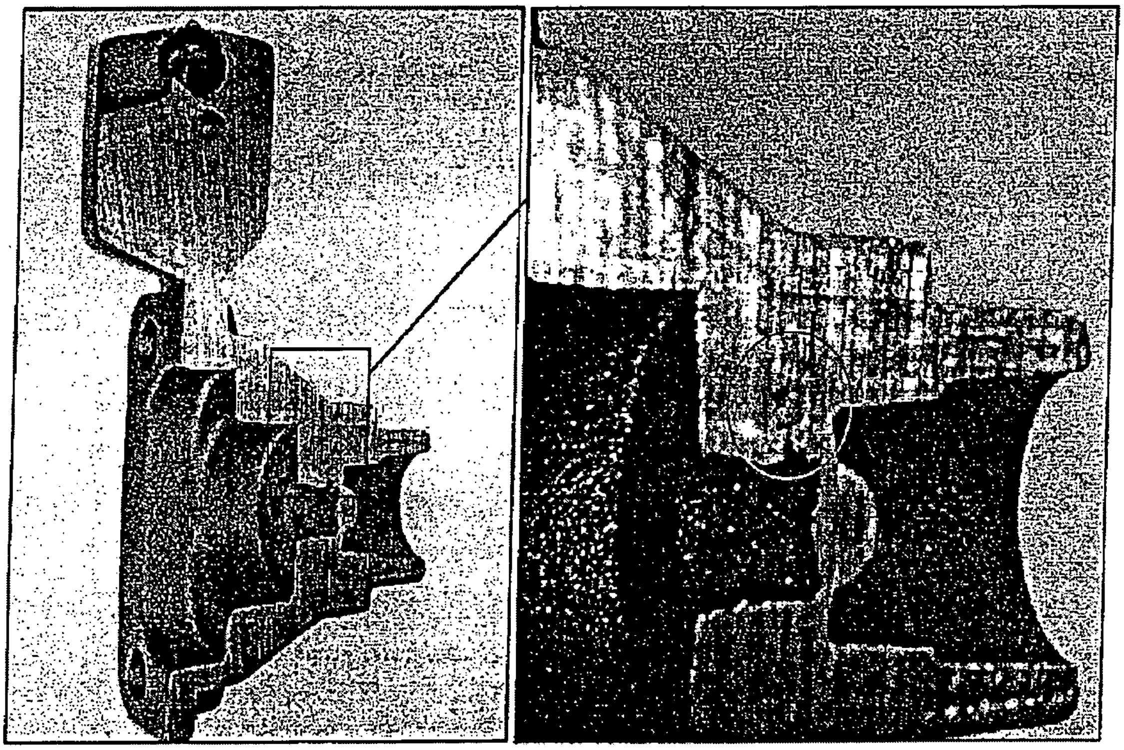

Figure 10

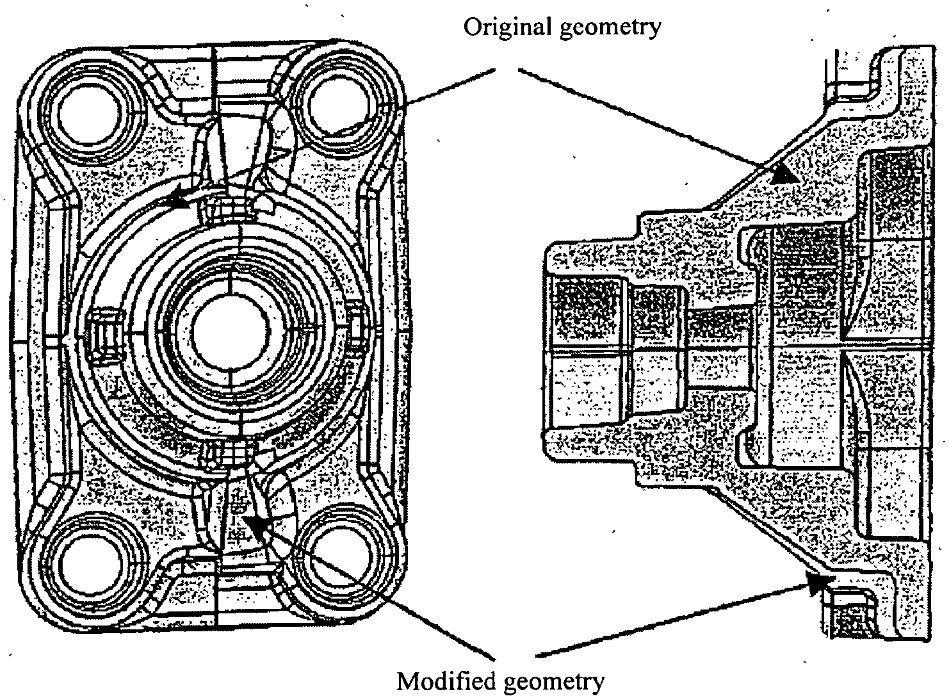

Figure 11

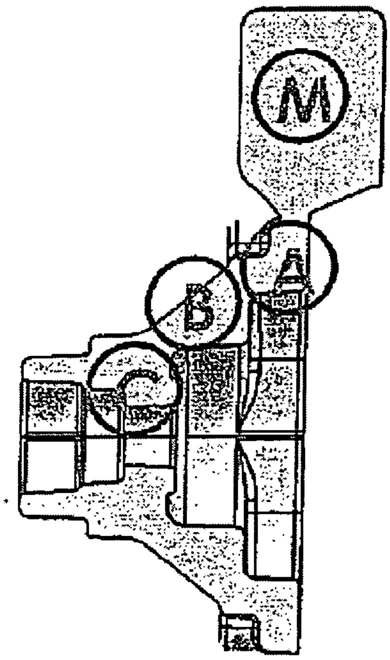

Figure 12

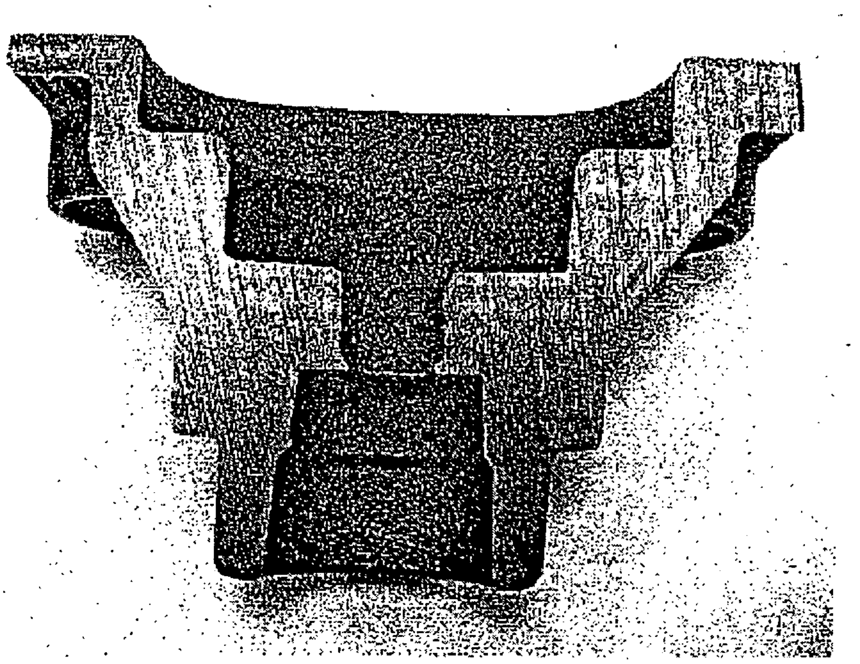

Figure 13

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 38 0333

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	2001, STEEL FOUNDER'S SOCIETY OF AMERICA , CRYSTAL LAKE, IL , XP002473304 * the whole document * -----	1-5	INV. B22C9/08
D,A	DATABASE WPI Week 200510 Derwent Publications Ltd., London, GB; AN 2005-087622 XP002473305 & RU 2 241 574 C1 (SEVERSTAL STOCK CO) 10 December 2004 (2004-12-10) * abstract * -----	1-5	
D,A	DATABASE WPI Week 200038 Derwent Publications Ltd., London, GB; AN 2000-440179 XP002473306 & RU 2 138 361 C1 (METALLURGISTS & INVESTORS ASSOC) 27 September 1999 (1999-09-27) * abstract * -----	1-5	TECHNICAL FIELDS SEARCHED (IPC)
D,A	JP 2006 346723 A (RIMUTEKKU KK) 28 December 2006 (2006-12-28) * abstract * -----	1-5	B22C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	18 March 2008	Baumgartner, Robin

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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RU 2241574 C1	10-12-2004	NONE	
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JP 2006346723 A	28-12-2006	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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- JP 20063466723 B **[0011]**
- RU 213861 **[0011]**