INVESTIGATION OF CASTING DEFECTS IN NIGERIAN FOUNDRY INDUSTRY

(A Case Study of Lagos and Ogun States)

BY

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Abstract

Casting that does not meet the quality standard or agree with the laid down technical specifications is said to contain Cast Defect since it cannot be used directly without necessary corrections. In this work, attempt is made to study the level of cast defects in foundries in Lagos and Ogun States. The study revealed that 35.7% of defects recorded are blow holes; 31% short run, shrinkage 7% and porosity 6% other various types of defects are less than 20%. This high percent of blow holes, which is caused by high moisture content, improper drying and inadequate vent and permeability of the moulding materials, can be attributed to the fact that a large number of our foundries employ sand casting process. Majority of casting without defect are obtained from non-ferrous metals using permanent moulds. Most casting defects are recorded in ferrous metals and alloys (steel and cast iron).

INTRODUCTION

The importance of foundry industry as a vital base for rapid industrial development of a nation is no longer in doubt. What seems to be in doubt is the commitment of the nation to an integrated development of foundry sub-sector. In spite of the fact that the foundry sub-sector is the backbone for the provision of spare parts and components, it has not untill recently received the attention deserves.

In Nigeria today 99% of foundries are of cottage and small scale categories. Foundries in Nigeria produce less than 5% of the cast products needed by the industries in Nigeria [1,2].
Even this 5% comprises predominantly products with simple shapes such as grinding ball and rods (for cement, quarrying and mining industries) grinding plates (for corn and pepper millers), manifold covers and housings (for water supply and drainage).

It is the desire of any foundry practitioner to produce castings without or with less defects. This is still an illusion. Foundries all over the world produce cast products that sometimes contain one defect or the other. Even though foundry are recorded in various foundries across the country. This situation leads to unnecessarily high production costs, lack of confidence in the reliability of the products and consequently low patronage in the face of imported alternatives.

The major focus of this study is to identify and classify defects in Nigerian foundries, and suggest ways by which these defects can be prevented.

2.0 METHOD OF INVESTIGATION

The study was carried out in form of questionnaire coupled with oral interview, visual inspection of cast products and assessment of casting procedures. This study covers Lagos and Ogun States. A total of 31 foundries were visited out of which only 21 responded with analysable data which was used in this study.

3.0 RESULT AND DISCUSSION

The survey revealed that 75% of the foundries are jobbing and they receive all kinds of jobs as requested by customers.

3.1 MANPOWER

The survey revealed that 12 out of 21 foundries visited have Metallurgical Engineers, out of which 9 are Foundry Engineers, 10 have Foundry Technologists, 20 have Foundry Technicians, 13 have Pattern Markers, 16 have machinists and another 13 have other types of Engineers. The survey also revealed that more than 67% of foundries visited are under-staffed, i.e. they lack appropriate skilled workforce. Only 33% of the foundries surveyed has basic categories of staff as required of a standard foundry industry.

The detailed distribution of manpower among the foundry enterprises visited is presented in fig. 1. As can be seen from the figure, Technicians dominate the technical staff in the foundry sub-sector because most foundry industries find it cheaper to employ technicians than employing engineers or technologists. Normally, the technicians are sent on in-house training to acquire skills needed for daily routine jobs. Cases of mal-employment of professionals were observed. For this reason, some simple problems that require technical solutions cannot be solved.

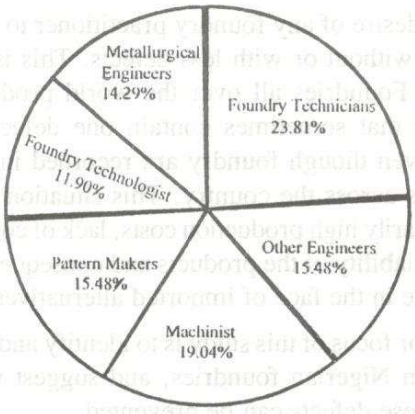

FIG. 1. PIE CHART SHOWING THE STATE OF MANPOWER AMONG FOUNDRY ENTERPRISES IN LAGOS AND OGUN STATES OF NIGERIA.

3.2. CASTING PROCESS

The study revealed that sand casting is the most widely used process as over 90% of the foundries use this method. The distribution of casting processes in Nigerian foundries is presented in fig. 2. As can be seen, least practised casting process is squeeze moulding which accounts for only about 5%

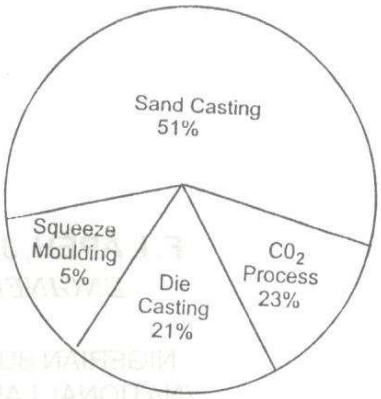

Fig. 2. Pie Chart showing the distribution of casting processes in foundries in Lagos and Ogun States.

3.3 PRODUCTION INFORMATION

Result of the survey carried out showed that about 67% of the foundries have been in practice for more than 20 years, 24% have been in operation for 10 years and 9% of the foundries have been in operation for less than 5 years

9% of the foundries are involved in only ferrous metal casting, while 9% are into non-ferrous metal casting only. About 81% are involved in both ferrous and non-ferrous metal casting.

It was discovered that 98% of the foundries visited do not have facilities to detect internal defects. About 80% of the foundries visited claim to have interest in R & D in various areas which include; (i) die casting; (ii) failure analysis; (iii) intricate casting; (iv) pattern making; (v) crucible production, etc.

20% of the respondents are not into research due to lack of facilities and lack of co-operation from larger foundries.

3.4 CAST DEFECTS

The major types of casting defects, according to the survey carried out, were blow holes, shrinkage, short run, cracks, porosity e.t.c. The pie chart that depicts the types of casting defects commonly found in Nigeria's foundry industry is shown in fig. 3.

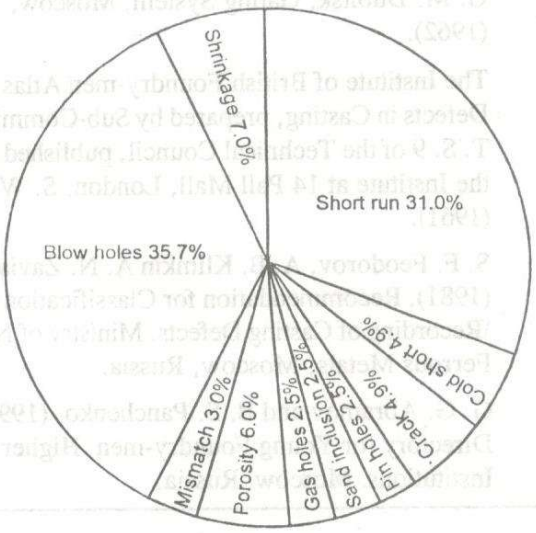

Fig. 3. Pie chart that depicts the major types of casting defects found in Nigeria's foundry industry.

Apart from major types of casting defects depicted in figure 3, the following defects are also present, though not common: incomplete filling, warpage, chipping, burn-on, scab, non-metalic inclusion e.t.c.

3.5 DISCUSSION

Factors that can promote cast defects include level of skill of manpower, temperature, pattern materials, gating system calculation and positioning, type of moulding flask. The results showed that the constraints to the development of foundry in the country as identified in the report of survey by the National Foundry Development Committee published in 1986 remain unchanged today. One of the major constraints identified then, which is still valid today, is inadequacy of experienced and skilled workforce in the sub-sector (Report on Techno-economic Assessment of Enterprises in the Engineering Materials Sector of Nigeria by NBRRI). Non-availability of skilled workforce is one of the factors that promote casting defects in foundry sub-sector [3].

Melting, superheating and pouring temperatures are important parameters in casting operations. However, most of the foundries visited do not have facilities to determine any of this crucial temperature points. Only about 14% have the facilities, many of them are characterized with inaccurate measurement of melt temperature. The is unacceptable because every foundry should have facilities to determine temperature accurately.

Gating systems (sprues, risers, slag collectors and runners) are supposed to be accurately calculated and their positions determined depending on the type of metal, shape, size, etc[4]. The study carried out in this work revealed that most foundries do not adhere to these principles, and, in this case pouring positions are visually determined without much consideration for risers.

There are standards for selecting flasks of all kinds of casting depending on size, weight and type of metal. The study carried out in this work revealed that only about 20% of the foundries under study adhere to this. Others use any available moulding flask.

It was revealed in this study that 65% of the patterns are made from wood just because of its affordability and availability. In choosing wooden pattern, they do not necessarily consider size, weight, and the configuration of the casting as required technically.

In this study 35.7% of defects recorded are blow holes, 31% short run, 7% shrinkage, and 6% porosity. Other defects are in the neighbourhood of 20%. This large percentage of blow holes agree with the fact that a large number of our foundries adopt sand casting process without paying much attention to sand processing before it's usage.

Despite the abnormal condition under which most of indigenous foundries operate, it is worthy to note, from the study carried out that over 40% of casting were obtained without defects. Most of the casting without defects are obtained from non-ferrous metals using permanent moulds. Most casting defects are recorded in ferrous metals and alloys (steel and cast iron) which are basically blow holes and shrinkage.

Some casting defects, their likely causes and possible ways of their prevention are listed in annex 1. The casting defects in annex 1 are not peculiar to ferrous metals alone, they can be found in non-ferrous metals. Annex 1 serves as a guide to foundry engineers and technologists.

CONCLUSION

The study carried out in this work revealed that most defects in the Nigerian foundries can be attributed to lack of basic facilities for testing moulding materials and for analysing molten metal. Inadequate trained manpower also contributed in no small measure to most of the defects recorded in Nigerian foundries.

The possible causes and prevention of cast defects published in this work can serve as a general guide for all foundry men.

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ANNEX 1

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION [5,6,7]

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
1.	**SHORT RUN** - Defect inform of incomplete filling of the Mould with molten metal during pouring	1. Low pouring temperature 2. Not holding down the chemical composition of some elements in the alloy during melting. 3. Inadequate vent and permeability. 4. Low pouring speed 5. Incorrect calculation of the gating system 6. Wrong position of pouring. 7. Inadequate molten metal in the ladle	1. Increase pouring temperature of the molten metal to the specified technological procedure 2. Hold down the chemical composition of silicon, phosphorous and carbon in the molten metal to deoxidize (for steel alloys) 3. Decrease the degree of ramming and increase the number of vents on the mould. 4. Pouring should be done faster without breaking. 5. Re-calculate the gating system 6. Change the construction of the gating system and pour the metal through the thinner part of the cast item, if possible additional riser can be used. 7. Proper calculation must be done on the quantity of metal required to fill the cavity.
2.	**INCOMPLETE FILLING**- Defect inform of a hole in arbitrary form which occurs as a result of low fluidity during pouring.	1. Not holding down the chemical composition of the alloy in the molten metal. 2. Lack of adequate venti-lation and permeability of the mould (pre-ramming of the moulding mix) 3. Low pouring temperature 4. Low pouring speed 5. Wrong calculation of the gating system	1.Hold the composition of silicon, phosphorous and carbon in molten metal, use deoxidizer when melting steel. 2. Increase the degree of ramming and holes in the mould 3. Increase pouring tempe-rature to the specified standard. 4. Pouring should be done quickly without breaking. 5. The calculation for the gating system and its cross sectional area should be done properly

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
3.	**OVERSIZE OR SWELL-** Defect inform of increase in size as a result of irregular ramming or lack of enough strength of the moulding sand.	1. Inadequate moulding strength or core materials (Not taking to the mix formula) 2. Weak ramming of the core and the mould. 3. High metalostatistic pressure on the wall of the mould and core	1. Increase the amount of additive (clay) into the moulding or core materials to specification. 2. Increase the degree of ramming to the specified standard. 3. Decrease the heights of the sprue in the cope pouring into a very high component should be at an inclined position.
4.	**DIFFERENTIAL IN THICKNESS -** Defects inform of increase or decrease in the thickness of cast item as a result of deformation or displacement of the core in the mould.	1. The use of defected flask or pattern. 2. Poor coupling of the flask 3. Non uniform ramming of the moulding materials	1. The pattern has to be corrected and only fit pattern is to be used. 2. Coupling should be done by tightening the cope and the drag with bolt and nut or key designed for such work. 3. Ramm as appropriate
5.	**OVERLAP-** Defect of cast item as a result of displacement in between the cope and the drag. This gives a different shape to the cast item after solidification.	1. Using defected pattern (improper setting of the pattern on the pattern plate (Table) 2. Incorrect coupling of the moulds.	1. Pattern should be properly fixed unto the pattern plate before working on it. 2. The cope and the drag should be joined with pin or key in order to centralize the flask before pouring.
6.	**WARPAGE-** Defect inform of wrist on the body of the cast item which occurs under the influence of forces as a result of cooling and the use of improper mould	1. Early knocking-out of the cast from the mould 2. Non-uniform cooling rate of the cast item in the mould.	1. The cast should be removed only when it has attained the knocking-out temperature, which agrees with the technological procedure in the foundry shop. (For casting, steel and non-ferrous metals). 2. The construction of the gating system should be changed so that it can take care of uniform cooling of the different part of casting, and pouring should be done through the thinner side of the cast component; use cooler as well.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
7.	**CHIPPING-** Defect inform of loosing some parts of the cast item during knocking-out, cleaning and during cutting out the of risers, sprue and runner and during transportation.	1. Chipping off cast item during the process of knocking out, loading, transportation and off loading. 2. Wrong calculation of the gating system (chipping during cleaning occurs only in cast iron)	1. Knock-out of the casting should be according to the technological procedure and transportation should be done with extra-care. 2. The calculation for the gating system should be done appro-priately and the cross-sectional area of riser should be less than the area where it serves.
8.	**CORE FILLING-** Defect which occurs as a result of the molten metal filling the wrong area of the mould where the core suppose to serve.	1. Inadequate strength of the moulding sand for the core. 2. Poor coupling of the flask to the core	1. increase the amount of additive to the maximum according to the technological procedure and the baking procedure be checked properly. 2. The core should be fixed into the mould supported by the use of chaplet, pin or stud.
9.	**RUN OVER METAL-**Defect inform of an empty hole inside the cast component and it creates a protruded point at the joint.	1. Weak coupling or inadequate load on the flask.	1. Asbestors fibre or clay can be used in between the parting line of the flask with additional load on top of the flask.
10.	**BURN-ON-** Defect inform of a hard layer on the body of castings as a result of the influence of physical and chemical reactions in the mould	1. High pouring temperature 2. Using wrong moulding sand for the mould and the core. 3. Low heat resistance of the moulding sand and the mix. 4. Weak ramming 5. Using low quality facing additive on the surface of the mould or core	1. Check the temperature before pouring the metal into the mould, leave the metal in the ladle till the required pouring temperature is obtained. 2. Increase the quantity of the medium grain size of the sand in the fraction of the mix. 3. Addition of Zirconium and chromo-magnesite as facing materials can be used to improve the heat resistance of the moulding Sand. And it should be applied on the surface of the mould or core in conformity with technological procedures. 4. Increase the degree of ramming according to the laid down technological procedure

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
11.	**SCAB-** Defect inform of protrusion on the body of cast item as a result of using wrong moulding materials and technique	1. Low strength of the moulding or core sand 2. Inadequate ramming of the mould or core	1. Increase the quantity of additive in the moulding sand, according to the technological procedure; and use moulds with key or clamps for effective coupling. 2. Increase the degree of ramming in the mould and the core to the technological specification.
		3. Incorrect coupling of the flask.	3. Coupling should be done with the aid of directing drift and avoid heating the flask after mould.
		4. High flake off of the surface of mould or core.	4. The moulded flask should be painted with painting apara-tus; for steel with solution of surphide with the relative density of about 1.1 should be used and for cast Iron - solution of black tar dissolved in white spirit relative density of about 1.1. The core is to be painted with anti-burn-on paint.
12.	**HOT CRACKING-** Defect inform of breakage on the body of a cast item as a result of temperature interval of the alloys during cooling. **NOTE**: Hot cracking always occur by the grain boun-dary of the cast pieces which have different oxidizing surface on which dendrite is always seen.	1. Inadequate permeability of the moulding or core sand. 2. High pouring tempe-rature of the molten metal. 3. Non castability of the cast item.	1. Decrease the quantity of additives in the moulding sand or core sand. 2. Before pouring the tempe-rature has to be checked with thermocouple, if nece-ssary hold the temperature till the desired degree is attained as required for such technological process. 3. The original construction of the cast pieces has to be changed in order to take care of the condition of uniform cooling of the whole parts involved, cooler or elbow bar for the corners in the cast pieces can be used.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
		4. Early knockout of the cast item from the moulds.	4, Cooling or knockout temperature should be observed according to the specification.
		5. Wrong positioning of the sprue.	5. Change the position of the sprue in such a away that it can take care of uniform cooling. Use shrinkage stiffen rib and cooler.
13.	**COLD CRACKING-** Defect inform of breakage on the body of a cooled casting which occurs as a result of internal force or mechanical influence on the casting. NOTE: Cold cracking have clean colour grain looking on the surface.	1. Wrong positioning of metal runner to the cast item in concern.	1. The construction of the runner has to be changed in order to take care of uniform cooling of the whole part of the cast component.
		2. Lack of heat treatment of cast piece or incomplete heat treatment.	2. Heat treatment should be applied agreeing with the demands and technological specification.
		3. Early knock-out of the cast from the mould.	3. Leave the cast piece in the flask to attain knock-out temperature before such operation is being carried out.
		4. Wrong packaging of cast pieces during heat treatment.	4. The cast pieces should be packed with supporting stand during heat treatment operation.
		5. Breakage of cast pieces during knock-out, loading and transportation.	5. Collision during loading transportation and off loading of the cast items should not be allowed.
		6. Non compliance with the technology of preparing the raw materials needed for the melt.	6. Check and ensure that raw materials and it's technological process are in accordance with the specification.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
14.	**GAS HOLES-** Defect inform of emptiness formed as a result of gas liberating from the molten metal.	1. Lack of adequate ventilation in the mould	1. Ramming operation should be minimal and the number of vents in the mould be increased to specification.
		2. Wrong calculation of the gating system.	2. The calculation for the gating system be done according to the laid down technological procedures. The gating system should be able to trap down all the impurity in the molten metal and take care of uniform cooling.
		3. Low pouring temperature	3. Increase the pouring temperature of the molten metal to specification.
		4. High pouring rate of the metal into the mould's cavity	4. The time and the speed calculated for pouring operation should not be altered.
		5. The use of poor quality coolers.	5. Clean the cooler from all dirty substances, like oil, grease before use.
		6. Incomplete baking/heating of the mould and core.	6. The time for heat treatment of the mould or core should not be exceeded or be reduced.
		7. High gas concentration in the melt.	7. Deoxidize the alloy or preferably heat the raw materials to reduce the moisture before using it.
		8. Putting hot core into cold mould or vise versa.	8. Putting hot core into cold mould or vise versa is not allowed, both of them should be of the same temperature.
15.	**SHRINKAGE HOLES-** Defect inform of an opening or closed hollow with wrough surface. This occurs due to shrinkage of the metal during cooling	1. Non-castability of the cast pieces.	1. Changes have to be made in terms of the thickness that can accommodate uniform cooling of the cast pieces. Shrinkage webs can be used to control the defect.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
16.	**POROSITY-** Defect inform of concentrated small shrinkage holes on the body of castings. **NOTE:** Porosity of this type are always found during machining or with the aid of flaw detector.	1. Non-uniform cooling of the cast pieces in the mould. 2. High pouring temperature. 3. Non-castability of the cast pieces.	1. Use both inside and out side cooler for uniform cooling. 2. Hold the temperature to the specified degree before pouring. 3. Change the construction of the cast pieces to be produced, such that the thickness chosen should be able to maintain or accommodate uniform cooling of all parts of the castings.
17.	**GAS POROSITY-** Defect inform of pore formed in cast pieces as a result of gas liberation from the metal during cooling.	1. Inadequate ventilation and permeability of the mould or core sand. 2. Violation of the schedule of baking the core.	1. Decrease the degree of ramming, increase the number of vent in the mould according to the technological procedure. 2. Hold the temperature and the time for baking operation of the mould and the core to specifications.
18.	**SLAG HOLES-** Defect inform of hollow fully or partially filled by slag.	1. Filling the cavity mistakenly with slag into the mould cavity when pouring the molten metal 2. Wrong calculation of the gating system. 3. Low viscosity of the slag.	1. Clean the ladle from the previous melt; use funnel or stopper ladle when pouring and coagulate the slag. 2. Check the calculation of the gating system and make sure slag collector and riser are proper ones used for such alloys. Filter net can be used in the side of the gating system. 3. Increase the viscosity of slag by spreading dried quartz sand in the ladle.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
19.	**STUD PENETRATION-** Defect inform of non-continuous joining of metal with the cooler or stud surface, as a result of dirty, incorrect mass and low pouring temperature.	1. Low pouring temperature 2.The use of oversize cooler or stud. 3. The use of poor stud or cooler.	1. Increase the pouring temperature of the molten metal to specification. 2. Use standard stud and calculate the size of cooler before use. 3. Clean the cooler and the stud from all type of dirt moisture etc. before putting it to work.
20.	**NON-METALLIC INCLUSION-** Defect inform of non-metallic body, formed as a result of chemical reaction between the molten metal and charges impurity and mould materials	1. Wrong calculation and construction of gating system. 2. Poor coupling of the mould. 3. Low strength of the moulding or core mix. 4. Weak ramming of the mould or core.	1. Check the calculation of the gating system; use slag collectors, broadening type of risers for steel, and ladles that can hold the slag with filter net in the gating system. 2. Coupling should be done with directing drift and when blowing the cavity with air, chipping of the mould should not be allowed. 3. Increase the quantity of additive in the moulding or core sand to specification. 4. Increase the degree of ramming to technological procedures; use ceramic pipe for gating system.
21,	**METALLIC INCLUSION-** Defect in form of foreign metallic inclusion at the grain boundary of cast pieces.	1. Not complying with the laid down technique of handling the raw materials and its melting procedure. 2. Low pouring temperature of the molten metal. 3. Increase in the size of internal cooler or stud used.	1.Check and correct the technological schedule laid down for materials handling and melting. 2. Increase the pouring temperature if such defect is being noticed. Adhere to specification. 3. Use standard stud and calculate the size of cooler to the technological specification before it's application.

DEFECTS, THEIR POSSIBLE CAUSES AND PREVENTION (Cont'd)

S/N	DEFECT TYPE	POSSIBLE CAUSE(S)	PREVENTION
22.	**METAL BEAD-** Defect in form of spherical shape and size of a metal trapped in the cast pieces.	1. Wrong pouring inlet of the molten metal into the mould cavity 2. Low temperature of the metallic mould (permanent mould) before pouring. 3. High moisture content of the moulding or core mix.	1. Change the construction of gating system in order to ensure uniform filling of the mould cavity with metal; the metal can be poured through siphon, then from the top through riser. 2. Heat the metallic mould up to 250 - 300 ^{o}C before pouring 3. Reduce the moisture content in the mix to minimum and to the technological specification.
23.	**CHILLING-** Defect in form of solid hard foreign body in the grey cast pieces found during machining operation to be very hard. This is as a result of the congestion of free cementic structure.	1. Not holding the chemical composition of the melt for the cast component to specification. 2. Low pouring temperature. 3. Low temperature of the metallic mould before pouring the molten metal. 4. Not applying heat treatment or violating its schedule. 5. High moisture content of the moulding sand.	1. Hold the chemical composition of silicon, phosphorous and carbon in the liquid cast iron according to specification, deoxidizer can be used. 2. Control the temperature with thermocouple or optical pyrometer to specification. 3. Heat the metallic mould up to 250 - 300 ^{o}C before use. 4. Apply heat treatment in order to remove the internal stress of the cast pieces according to specification. 5. Reduce the moisture content of the mix to minimum according to the laid down technical procedure.