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Analysis of parameters for casting ductile iron pipe-A Review

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Abstract— Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameter. Ductile iron pipes are casted centrifugally by using centrifugal casting machine. Various defects generated during the casting process of ductile iron pipes. Defects like thickness variations, pin holes, metal laps, thick/thin socket, over weight etc. are produced during the casting process of ductile iron pipe. These defects can be minimized by appropriate changing in parameters. Parameters that lead to the desired quality and yield, is important but difficult to achieve. In this study, the parameters like temperature and flow-rate of molten metal during the casting process are analyzed for minimization of defects and microstructure study of ductile iron pipes. In this study, at different flow-rates, variations in thickness of ductile iron pipe studied. Also the defects are observed at the same flow-rates. This paper also studied that at different temperature the microstructure of the pipe varied which greatly affect on the ductility and hence quality of the pipe. An attempt has been made to optimize the parameters for manufacturing a better quality pipe and for minimizing the casting defects.

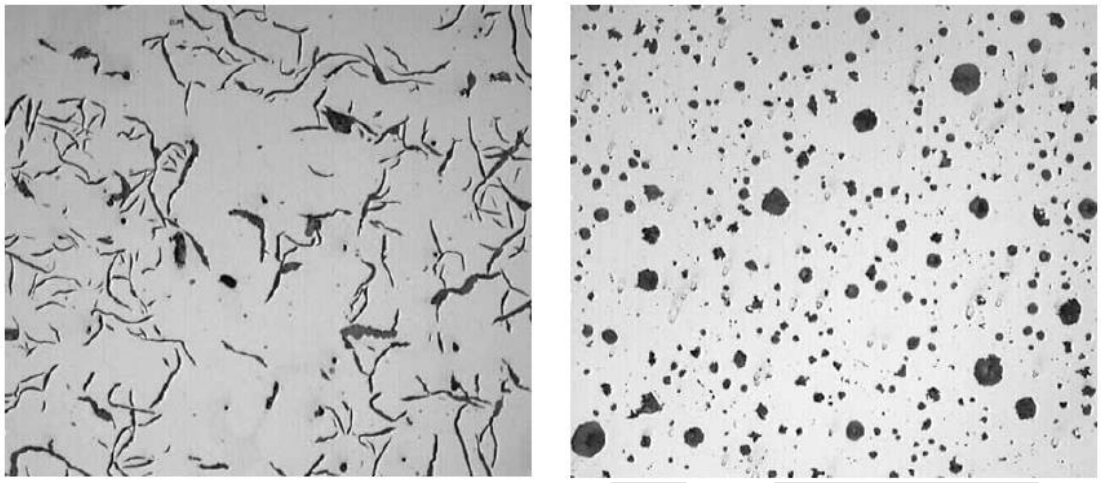
Keywords— Ductile iron pipe, Centrifugal casting, Analysis of Parameters, optimization of parameters like temperature and flow-rate of molten metal, minimization of Defects, Microstructure study, Quality of pipe

Introduction

Metal casting is a 5000 years young manufacturing process in which molten metal is poured in a mould and removed after solidification. These castings are all around us right from Simple rings to complex engine cylinders and are employed in industries varying from Aerospace, medical devices, automobiles, sanitary, electrical machineries, pipes home appliances etc. Indian casting industry with an annual production of 7.5 MT is the 2nd largest casting producers in the world after China.

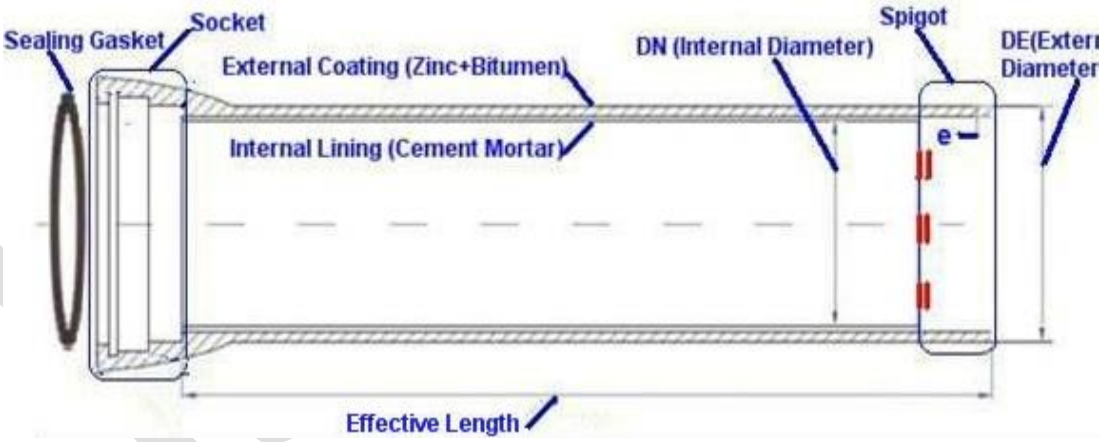
1.1 Steps in metal casting [1]

Casting can produce variety of products, which account for various metal processes which are Combination of complex geometry and varying weight. Almost all the metals or alloys which can be easily melted under controlled conditions are Castble. Water has always been a precious commodity, and its transmission has facilitated the advancement civilization enabled the comforts of our modern living standard. Around 150 years ago the supply of water was done by cast iron pipes. Cast iron pipes have been used for transport drinking water as well as industrial water. Since middle of the 19th century as the result of increasing industrialization and considerable growth in population with constant improvements in standard of living, the consumption of water has been steadily rising. With the necessity of conveying larger volumes of water to the consumer, operating pressure in supply line increases. Ductile Iron also referred to as **"Nodular Iron"** or Spheroid graphite iron was patented in 1948.After a decade of intensive development work in the 1950's, ductile iron had a Phenomenal increase in the use as an engineering material during the 1960's, and the rapid Increase in commercial application continues today. The word ductile comes from the Latin "ducere" which means pliable and that means malleable. In static calculations, pipes in ductile iron are therefore considered as having piable properties or being flexible pipes. An unusual combination of properties is obtained in ductile iron because the graphite occurs as spheroids rather than as graphite flakes as in grey iron.



1.2 Comparison of microstructure of gray cast iron pipes and ductile iron pipes

Ductile iron pipes are made of ductile iron commonly used for water transmission and distribution. Ductile iron pipes are the direct development of cast iron pipes which were used in earlier years for water transmission. The Ductile iron used to manufacture the ductile iron pipe is characterized by spheroidal or nodular nature of graphite within it. Chemically Ductile iron pipe is same as gray cast iron pipe but the main difference between both of them is in gray cast iron pipe the graphite is present in the form of graphite flakes while in ductile iron pipe the graphite is present in the form of nodules which give it the tensile strength 350 N/mm^2 to 1500 N/mm^2 rather than 150 N/mm^2 to 400 N/mm^2 of the gray cast iron pipe with good elongation and High Toughness. Also the cast iron or gray cast iron pipes are brittle because of the lack of Ductility. [2]



1.3 Cross section of ductile iron pipe [3]

Ductile iron pipe with its elements is shown in Figure 1.3. There are mainly three sections of ductile iron pipe:

1. Socket

Socket is the one of the end of ductile iron pipe. It is generally known as the front portion of the pipe. It is thicker portion of the pipe which is casted by providing sand-core. Core is made of silica. The core is arranged at the front portion of the centrifugal casting

machine and the socket is casted during the centrifugal casting. Sand Core is made as per the dimensions requirement of the socket. Generally the time for solidification of socket is more compare to other sections of pipe.

2. Barrel

It is the main body-section of the ductile iron pipe. It is comparatively thin section compare to socket and spigot. During casting process solidification of this section occur speedily. It the long section and covers majority of the portion of the ductile iron pipe. The thickness of the as well as the diameter of the pipe is described by this section of the pipe.

3. Spigot

Spigot is the second end of ductile iron pipe which is casted lastly during the casting process. It is the smaller section of the pipe which solidifies lastly during the centrifugal casting process. During the installation process of ductile iron pipe network for application each Spigot is jointed with socket section.

Ductile iron foundries usually melt their iron in cupola or blast furnace from recycled material pig iron. Coke, oil or natural gas is the fuel used here for melting the iron ore which is the solid raw material for casting process. Crystallisation of the carbon dissolved in liquid iron in the form of graphite nodules is achieved by the addition of magnesium into the molten metal. These days ductile iron pipes are manufactured exclusively by means of centrifugal casting process, where the centrifugal forces produce the pipe wall. The rapid cooling applied in ductile iron pipe production by the means of heat treatment of pipes is necessary in order to give them a ductile microstructure. Also the lining and protective coating is the part of production process. Throughout the entire production process there is defined control system of controls and tests to guarantee the specified properties of the product. [3]

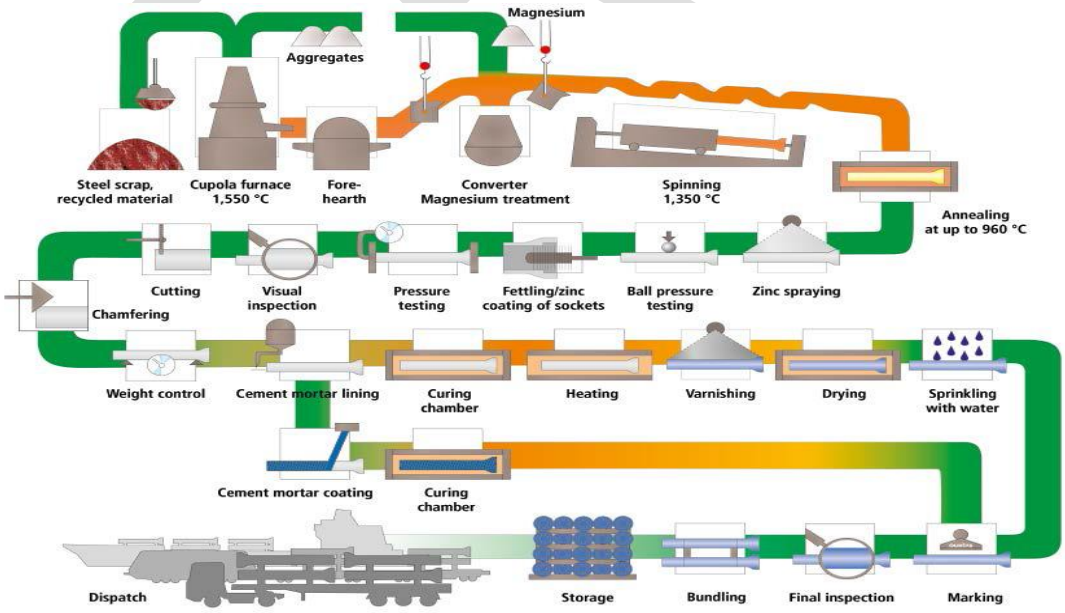


Figure 1.4: Process of manufacturing the ductile iron pipes [3]

TABLE 1.1: THICKNESS AND WEIGHT CHART OF DUCTILE IRON PIPE:[4]

DN(mm)	Thickness(mm)	DE(mm)	Weights of pipes in kg.		
			4.0	**5.0**	**6.0**
80	5.0	98	44.612	54.915	65.218
100	5.0	118	54.375	66.894	79.413
125	5.0	14	67.297	82.696	98.095
150	5.0	170	80.219	98.498	116.778
200	5.0	222	106.462	130.503	154.543
250	5.3	274	140.417	171.971	203.525
300	5.6	326	177.621	217.376	257.131
350	6.0	378	221.519	270.974	320.428
400	6.3	429	265.319	324.323	383.328
450	6.6	480	312.915	382.143	451.372
500	7.0	532	368.510	449.938	531.365
600	7.7	635	487.395	594.418	701.442
700	9.0	738	660.592	805.965	951.338
750	9.7	789	760.762	928.252	1095.743
800	10.4	842	869.117	1060.764	1252.375
900	11.2	945	1056.827	1288.559	1520.291
1000	12.0	1048	1263.130	1538.588	1814.046

Advantages of ductile iron pipes

1. High tensile strength, good elastic module and excellent ductility, making it suitable for high stress applications and where pressure surge may be experienced.
2. High corrosion resistance.
3. Excellent hydraulic flow.
4. High working pressure compared to other types of pipes.
5. Ease to installation.
6. Long lifetime.
7. Accommodate ground movement

Applications

1. Drinking and irrigation water networks.

2. Sewerage networks.

3. Fire fighting systems.

Defects analysis in ductile iron pipes

Foundry industries in developing countries suffer from poor quality and productivity due to involvement of number of process parameters in casting process. Even in a completely controlled process, defects in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects. Various defects which can generate during the process of centrifugal casting of ductile iron pipes are:

1. Thickness variation

This defect occurs due to the change in flow-rate; mould RPM of centrifugal casing machine and machine down time. Flow-rate is one of the major reasons of thickness variation as mould RPM and machine down time are set constant. Thickness of the wall in ductile iron pipe, especially in bigger diameter sizes, is very important property during the installation process. Also the uneven cement lining distribution could be occurring due to this defect. This defect reduces the proposed life of ductile iron pipe.

2. **Blowhole/pinhole**

It is a kind of cavities defect, which is also divided into pinhole and surface blowhole. Pinhole is very tiny hole which can generate during the solidification of metal inside the mould. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as cavity.

3. **Metal laps**

It is the defect in which metal laps are seen on the outer surface of the ductile iron pipe. Laps are the major reason of failure of ductile iron pipes as that portion of the pipe is observed as weak portion. Metal laps are caused during the solidification of molten metal, mostly due to the lower temperature of the liquid metal before the casting process.

4. Crack marks

It is the defect which is also seen on the surface of the ductile iron pipe after the casting process. Crack marks are shown on the outer surface of the pipe. The cause of this defect is also the lower temperature of molten metal before the casting or the improper metal composition.

5. Metal Fin

Metal fin is shown after the casting process at the socket or spigot sections of the pipe.fin is the thin metal portion which is shown at the upper side of the socket or spigot after the casting process of the pipe.

6. Sponge socket

During the casting process sometimes for easy and smooth flow of liquid metal from the runner to the mould, graphite coating is applied on the runner surface. This graphite coating is done completely manually. So the quantity of graphite should not be remains same at all time due to human errors. Sometimes due to more amount of graphite coating more quantity of graphite flows with liquid metal and sticks inside the socket portion of the pipe which cannot be removed easily. It is called the sponge socket defect.

7. Thick socket

Sometimes due to the change of speed of travelling of the centrifugal casting machine in longitudinal direction or due to change of flow rate of metal due to excess tilting of hopper, excess liquid metal at the socket side gathers than required which causes thick socket. This is also the defect which occurs during the casting process as explained.

8. Thin socket

As discussed earlier in the thick socket, in thin socket less metal gathers at socket side due to low tilting of hopper, change of speed of machine or down the machine manually before required socket filling of metal.

9. Thin barrel

In thin barrel, the main body of the pipe casted with less thickness than minimum required. It is due to the low metal quantity of metal inside the hopper or by changing the automatic down time of the casting machine.

These are the main defects which can be seen in ductile iron pipe. Among these most of the defects generated during the casting process. All these defects can be encountered by optimizing various parameters. But still it is difficult to overcome all the defects at the same time and make the defects-free pipe with better quality. In this study, two parameters, temperature and flow-rate of molten metal are considered as these are the parameters which greatly affect on most of these defects during the casting process.

LITERATURE REVIEW

Ductile iron pipes have been produced since 1951 and from that year many successive studies have been done by different researchers.

Effect of Heat treatment procedures on microstructure and Mechanical Properties of Nodular iron was studied. In this paper heat treatment affection on nodular iron was studied which shows the pearl tic, ferrite, and cemented percent of nodular iron after the heat treatment procedure. [5] Study about the defects, their causes and remedies in casting process showed the root causes of casting defects which helped to quality department of different industries for finding roots and remedies of different defects. Different research papers were studied and casting defects, causes and their remedies were listed. [6] Variation in tensile properties and fracture properties for ductile cast iron by experiments and numerical analysis was studied. By fractrographic analysis it was possible to establish a relation between elongation at fracture and size of slag defects. Relative contribution to the loss of ductility, size of slag defects, perlitic contents, nodularity and changing graphite were demonstrated by deterministic models. [7] Solidification rate greatly affect on the microstructure, quality and mechanical property. The rotational speed effect the solidification of liquid metal during the centrifugal casting process. It was found that setting 800 RPM. Of die in centrifugal casting machine the metal poured was directly lifted and rapid solidification took place and finer grain size can be achieved compare to 400 and 600 RPM of the die which improved the microstructure of casting. This helped to achieve the best quality pipe. [8] The design of easy locking and un-locking arrangement by using electromagnet lock plate to avoid the excess metal fly-out was found. The productivity also increased by using the electromagnetic plate which minimizes dwell time. [9] Investigation about the effect of electromagnetic force on the centrifugal force in centrifugal casting was done. It was found that under 0.15T electromagnetic field intensity both absolute pressure of metal flow to

mould wall and metal flow velocity on same location had some differences between electromagnetic centrifugal casting and centrifugal casting. [10]

Enhancement of wear resistance on the surface of ductile cast iron by using satellite 6 Alloy was investigated. The result showed that microstructure of surface alloyed layer consisted of carbide dispersed in co-based solid solution matrix with dendrites structure. This microstructure was responsible for improvement of hardness and wear resistance coating. [11] Also the discussion about the effect of mould wall thickness on the rate of solidification of centrifugal casting was investigated. Result of this paper was as mould thickness increases, due to chilling effect solidification time decreased. Rapid solidification showed well distributed fine grains and slow solidification showed coarse grains. [12] Development in production and technology of ductile cast iron was studied in china. Also the processes parameters and properties were evaluated for better quality. Due to great development and technology, better quality pipes were produced. [13] Discussion about modes and causes of gray cast iron pipes failures was investigated. Various failure causes were found. Also the causes of remedies were predicted as per the failure modes. Also it was observed that failure was always unexpected and produces emergencies which were mostly shown in medium and large diameter pipes. [14]

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CONCLUSION

1. It is concluded from above study that by optimizing the parameters like flow-rate and temperature of molten metal during the centrifugal casting process of ductile iron pipe, various defects can be minimized.

2. The effect of temperature on the microstructure of the pipe during the casting process is also studied to increase the ductility of the pipe and for producing a better quality pipe.

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