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Manufacturing Defects of Brass Products and suggested Remedies

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***Abstract*— Rejection of finished or semi-finished products in any industry is always undesirable and intolerable. The study is carried out to examine the root causes of various defects and imperfections of brass products in Brass industries that arise during different stages of manufacturing. After identification of flaws by experiments, research remedies are also determined to reduce the intensity and potential of its occurrence. In pursuance, a detailed study of manufacturing process was performed. Bottlenecks and weak points of the systems have been noted. The success of the study not only enhanced productivity of the industry but also reduced the production cost of the final product by minimizing wastage in terms of rejection thereby increased the competitiveness.**

Keywords— Cartridge Brass, NTD, hidden and visual defects, Ultrasonic Testing and thermal conductivity

I. INTRODUCTION

Brass is an alloy of 70% copper and 30% zinc. However, the proportions of copper and zinc can be varied to obtain a range of brasses with varying properties. Brass has higher malleability and low me melting point (900 to 940 °C (1652 to 1724 °F), depending on composition) and its flow characteristics make it a relatively easy material to cast. By varying the proportions of copper and zinc, the properties of the brass can be changed, allowing hard and soft brasses.

Brass has the desirable properties that make it ideal for use as a rolling element material, such as good frictional properties against hardened steel components, reasonable strength, high toughness and excellent thermal conductivity. In addition, brass has good machining and joining characteristics that help to make it very cost-effective.

The malleability of brass has made it the metal of choice. It is used for decoration for its bright gold-like appearance; for applications where low friction is required such as locks, gears, bearings, doorknobs, ammunition, and valves; for plumbing and electrical applications; and extensively in musical instruments such as horns and bells for its acoustic properties. It is also used in zippers, because it is softer than most other metals in general use, brass is often used in situations where it is important that sparks not be struck, as in fittings and tools around explosive gases.

Aluminum makes brass stronger and more corrosion resistant. Aluminum also causes a highly beneficial hard layer of aluminum oxide (Al_2O_3) to be formed on the surface that is thin, transparent and self-healing.

To enhance the machinability of brass, lead is often added in concentrations of around 2%. Since lead has a lower melting point than the other constituents of the brass, it tends to migrate towards the grain boundaries in the form of globules as it cools from casting. These effects can lead to significant lead leaching from brasses of comparatively low lead content.

Almost 90% of all brass alloys are recycled because of its non-ferrous properties and it can be separated from ferrous scrap by passing the scrap near a powerful magnet. Brass scrap is collected and transported to the foundry where it is melted and recast into billets. Billets are heated and extruded into the desired form and size.

1. Overview of the Current Manufacturing Process

Billets of 70/30 brass (cartridge brass) composed of 70% copper and 30% zinc are casted by melting together 70% process scrap and 30% pure copper and zinc (virgin metal) in a furnace. After chemical analysis the billets are then pre-heated for hot rolling process. Subsequently, slab milling followed by cold rolling process is carried out for achieving the required size. Thereafter, the strips are subjected to annealing process to relieve the residual stress developed during various machining processes. Finally, these strips are pickled and washed to get bright and oil and grease free surfaces. The manufacturing process is depicted in the figure1.

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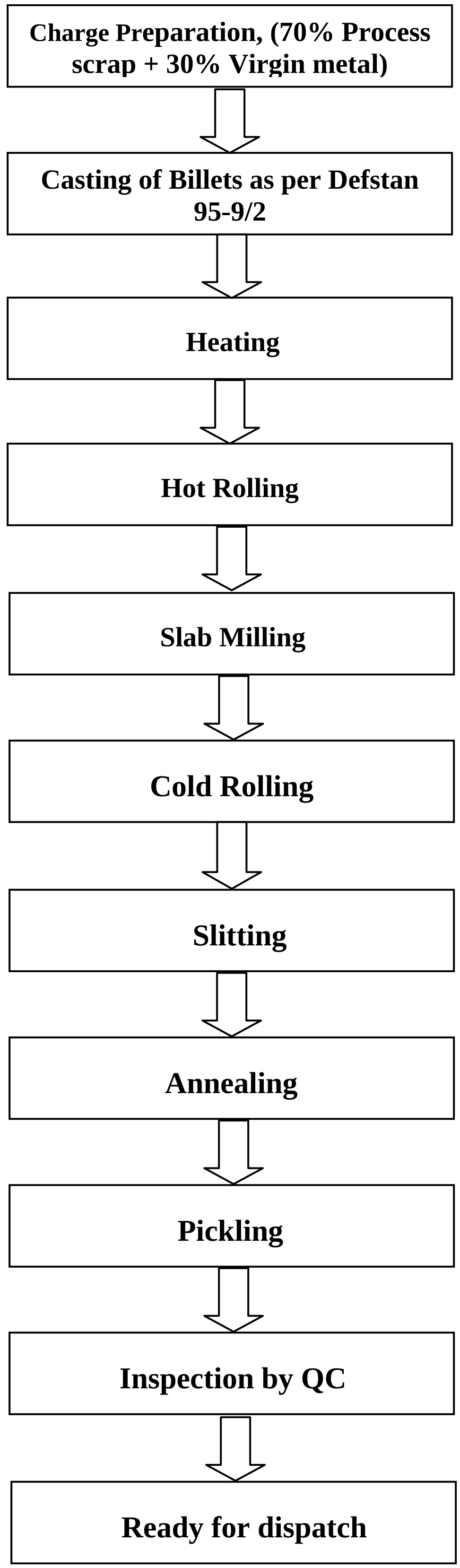

Fig. 1 Process flow chart for production brass products

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1.1 Rolling

Billets in accordance with specification are charged into pre-heating furnaces at Pre heating temperature of 840C^0-860 C^0 for 2-1/4 hours soaking time. Pre-heating temperature and soaking time are recorded by the temperature and time indicators installed on the furnaces. Billets are then subjected to hot rolling after achieving the required temperature. The hot mill reduces the thickness of the billets to form strips.

1.2 Slab milling

A machining process is carried out in which hot rolled strips are passed through a slab mill for milling its surface on both sides to finish the strips.

1.3 Cold Rolling

The strips are then subjected to cold rolling for further reduction of its thickness of the strips as per requirements in addition to improve the surface finish.

1.4 Slitting

The cold rolled strips are then slitted from both sides as per width requirements.

1.5 Batch Annealing

The strips are then put in Muffle Furnaces at Temperature 580 ^{0}C for 3-1/2 hours of soaking time. This is a heat treatment process to achieve the specified characteristics such as hardness and grain size. Annealing is meant to relive the residual stresses that are developed during the various machining processes. Annealing is also used for inducing ductility, softening of material, refining the structure by making it homogeneous, and improving its cold working properties.

1.6 Pickling and washing

Heat treated strips are then pickled and washed in the following steps to clean oily and greasy surface of the strips.

i) The strips are dipped in acid tanks containing 5-10% H_2SO_4 and 90-95 % water for 5 minutes.
ii) They are then dipped in cooled water tanks for 5 minutes.
iii) After that they are dipped in Hot water tanks for 5 minutes.
iv) Finally they are put in steam dryer for 10 minutes for drying.

1.7 Inspection process

The strips are finally put up in lots to Quality Control department for 100% visual inspection for various defects such as scaly, blister, dent and red stain and then 100% checked dimensionally for High / Low in size. The good product is then dispatched whereas the defective ones are recycled.

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II. BRASS DEFECTS AND ITS IDENTIFICATION

Brass defect

A **defect** is an irregularity produced during the metal production process that is undesired and cannot be tolerated. These defects are divided into two types depending upon the process of production.

A. Hidden Defects
B. Surface Defects

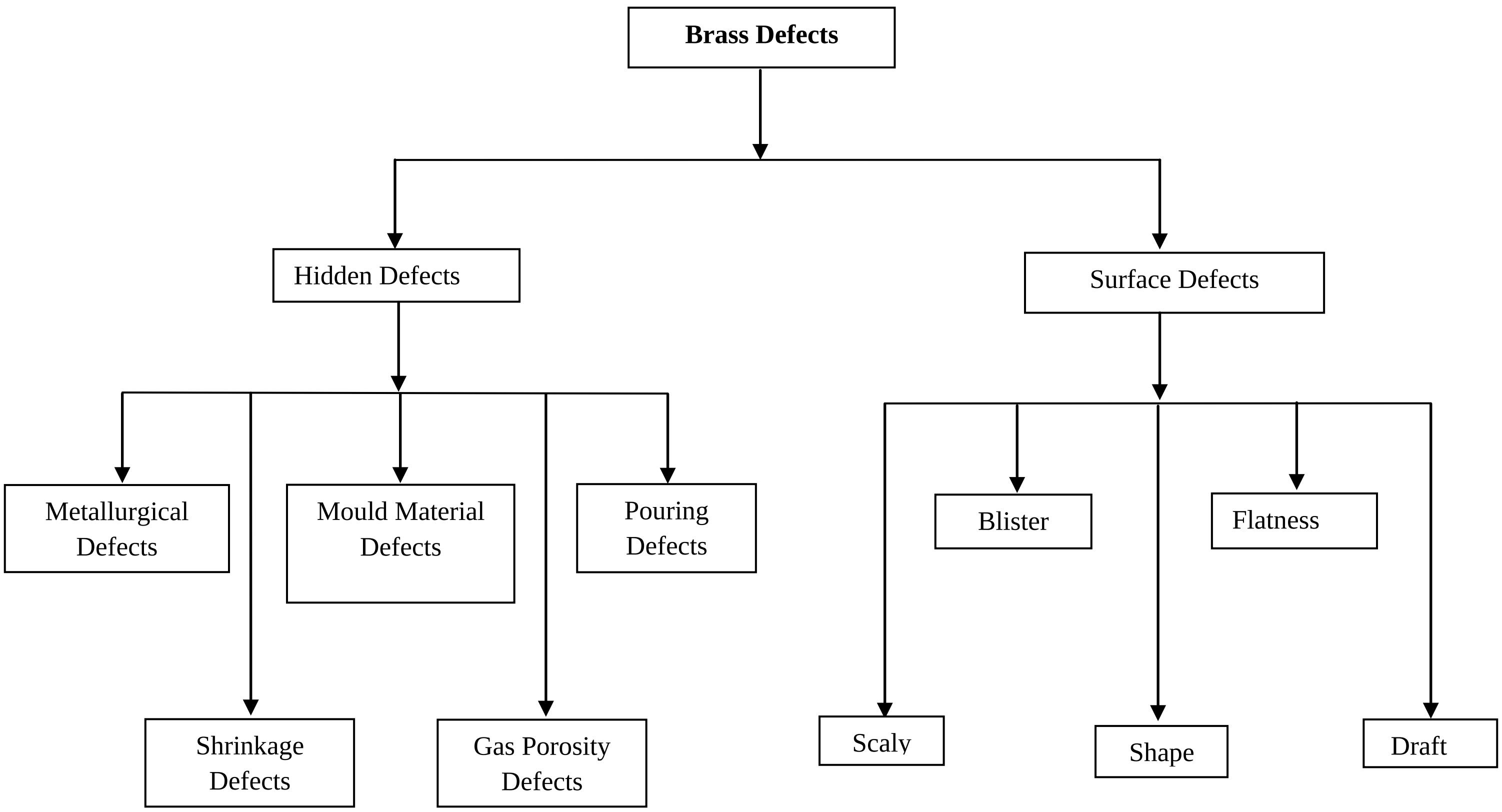

Fig. 2 Process flow chart for brass defects

A. Hidden Defects

These defects occur during casting stage of brass. These defects are hidden / undersurface and usually become evident in subsequent machining processes which lead to the rejection of finished products. There are five main categories of casting defects;

a) Shrinkage defects
b) Gas porosity
c) Mold material defects
d) Pouring metal defects
e) Metallurgical defects

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a) Shrinkage defects

Shrinkage defects are formed during solidifications which normally occur due to contraction of liquid to solid. High gas content increases its likelihood and they are formed in the following stages:

i. Melt contraction upon cooling to liquidus temperature.
ii. Alloy contraction when it gets solidifies.
iii. Solid alloy contraction when it cools from solid temperature to ambient temperature.

Shrinkage defects can be divided into the following two categories:

a) **Macro Shrinkage;** A large cavity formed during solidification is called Macro Shrinkage flaw. It can be seen by the naked eye. The most common type of this flaw is piping which occurs due to lack of sufficient feed metal.
b) **Micro Shrinkage;** This is a very fine form of filamentary shrinkage which normally occurs due to gas evolution during solidification. The cavities are developed either at the grain boundaries or between the dendrite arms. These flaws cannot be seen with naked eye.

b) Gas Porosity

Gas porosity is the formation of bubbles within casting after it has cooled. Most liquid materials can hold a large amount of dissolved gas, which evolves in the form of bubbles upon solidification. These flaws appear on the surface of the casting as pores, which reduce the strength of the metal in that vicinity. Nitrogen, Oxygen and hydrogen are the most encountered gases in cases of gas porosity.
Small gas bubbles cause porosities but large gas bubbles cause blowholes or blisters as shown in figure 3. Such defects can occur by air trapped in the melt, stream or smoke from the casting or other gases from the mold.

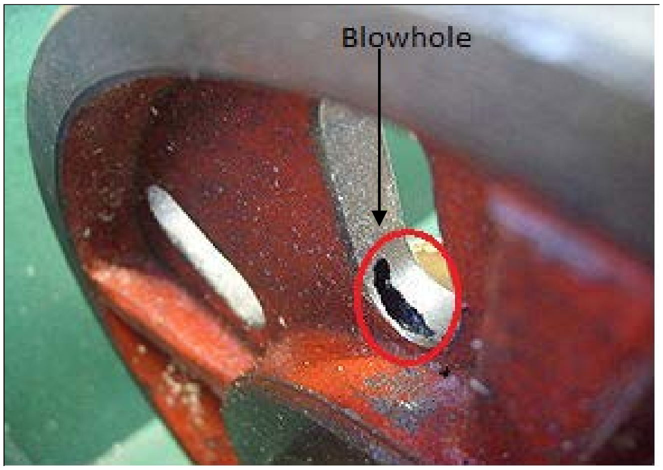

Fig. 3 Blowhole Defect in a Casting

c) Pouring Metal Defects

These are the defects which occur during the pouring or transferring of the metal into moulds. There are following three types of such defects.

i. **Misruns:** It occur when the liquid metal does not completely fill the mold cavity and leaving an unfilled portion.
ii. **Cold Shuts:** Such defects forms when two fronts of liquid metal do not fuse properly in mold cavity and leaving a weak spot. Both of these defects are caused by either lack of fluidity in the molten metal or cross sections that are too narrow. Another probable cause is back pressure from improperly vented mold cavities.

iii. **Inclusion:** These are usually metal oxides, nitrides, carbides, calcites or sulphides. These defects are formed from a material that is eroded from furnace or lining or inclusion may be either dross if solid, or slag if liquid.

d) Cracks or Stress Cracks

Such defects are produced in from of straight cracks when the metal is completely solid. They are appeared as well defined, smooth and dark lines.

e) Metallurgical Defects

These defects are also called Hot Cracking, which includes failures of casting that occur during cooling of casting. This happens because the metal is weak when it is hot and the residual stresses, in the material can cause the casting to fail when it gets cools.

B. Machining Defects

In hot rolling, if the temperature of the work piece is not uniform, then the flow of material will occur more in the warmer parts and less in the cooler. Similarly, more temperature has difference can results in cracking and tearing. Following are the common defects which occur during different stages of manufacturing process:

a. Profile

It is the measurement of crown and wedge. Crown is the thickness in the centre as compare to the average thickness at the edges of the work piece.

b. Flatness

Maintaining a Uniform gap between the rolls is difficult because the rolls deflect under the load required to deform the work piece. The deflection causes non uniform deformations of the work piece i.e. thickness variation of the work piece in the centre and at the edges [13]. Flatness defects can be classified into following main categories:

i. **Symmetrical Edge Wave**; The edges on both sides of the work piece are 'wavy' due to the material at the edges being longer than in the centre.
ii. **Asymmetrical Edge Wave;** One edge is 'wavy' due to the material at one side being longer than the other side.
iii. **Centre Buckle:** The centre of the strip is 'wavy' due to the strip in the centre being longer than the strip at the edges.
iv. **Quarter Buckle;** In such defect in the quarter regions, the fiber is elongated. This is a rare defect and normally caused due to excessive Rolling.

c. Draft

Draft basically defines the difference between initial and rolled work piece. Equation 2.2 represents the draft ***d***

$$\boldsymbol{d} = \boldsymbol{t_o} - \boldsymbol{t_f} \qquad \textbf{(1)}$$

where $\boldsymbol{t_o}$ is initial thickness and $\boldsymbol{t_f}$ is final thickness

Similarly, equation 2.2 represents maximum draft which can be achieved with rollers of radius ***R*** and coefficient of static friction ***f*** between the roller and the metal surface

$$\boldsymbol{d_{max}} = f^2 R \qquad \textbf{(2)}$$

The above equation is true when the frictional force on the metal from inlet contact equals the negative force from the exit contact.

C. Surface Defects

Following are the common types of surface defects:

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i. **Blister;** This form when air traps in the material and develops envelops which appears on one or both sides of the strip consisting of swellings. Smooth film of oxides is trapped in the interior surface of the blister. The blister is originated in the billet cavity and become more prominent during hot rolling as walls covering the oxides film become too thin to withstand internal pressure

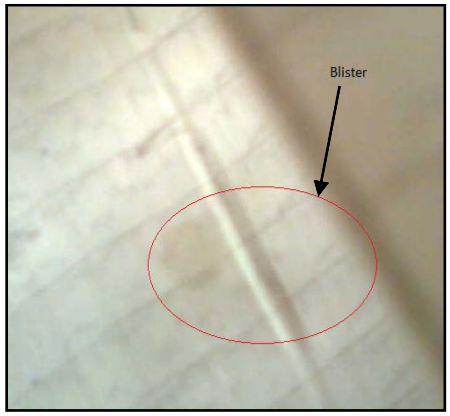

Fig. 4 Blister defect in brass strip

ii. **Scaly;** This defect develops as a result of peeling / bursting of blister during Hot or Cold rolling. It is has been observed that the number of defects in brass products increases with reduction in its thickness.

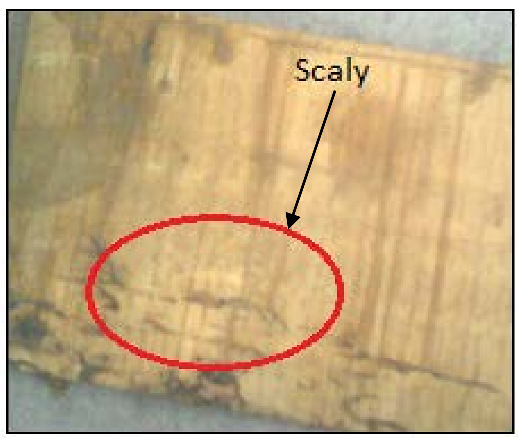

Fig. 5 Scaly defect in

a brass strip

iii. **Red strains;** This defect occurs when Un-dissolved copper appears on the upper surface of the strip after pickling in H_2SO_4 solution.

iv. **Cracks;** Such type of defects is due to breakage of grains & improper mixing of material during lead rolling mixing.

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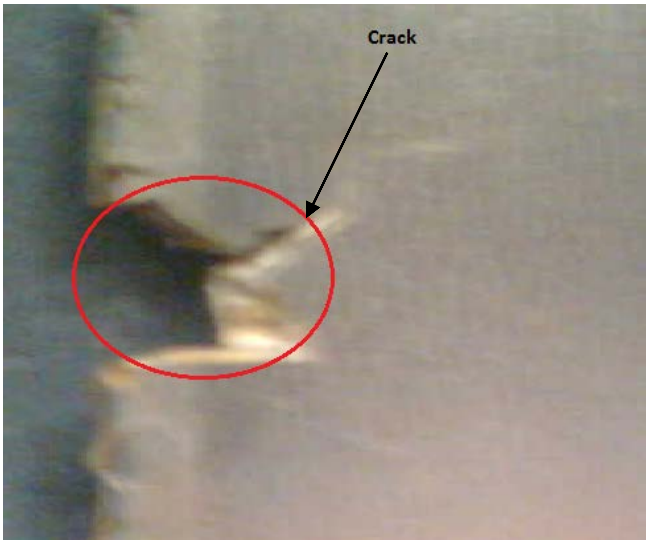

Fig. 6 Crack Defect in a brass strip

III. STEPS FOR CASTING PROCESS OF BRASS

According to international specification Defense Standard 95-9/3 the chemical composition for 70/30 Brass is given in table 1.

Table 1 Chemical composition of 70 / 30 brass

Description	Cu%	Zn%	Pb%	Sn%	Fe%	Ni%	As%
70/30 brass	68.5-72	28-31.5	0.02	0.03	0.03	0.1	0.01

To achieve the above mentioned composition 70% process scrap and 30% virgin is melted for producing brass billets. Heat number is allotted to each Billet and stamped at the bottom of the Billet. During melting, samples are sent to Laboratory for chemical Analysis according to specification already mentioned. Upon receipt of chemical Analysis report marking of billets is carried out according to color code that is red cross is for out of specification billets whereas white tick is marked on the billet found in accordance with required specification. White tick marked billets are then subjected to other process such as rolling while the Red Cross billets are recycled. Following steps are followed during casting of Brass.

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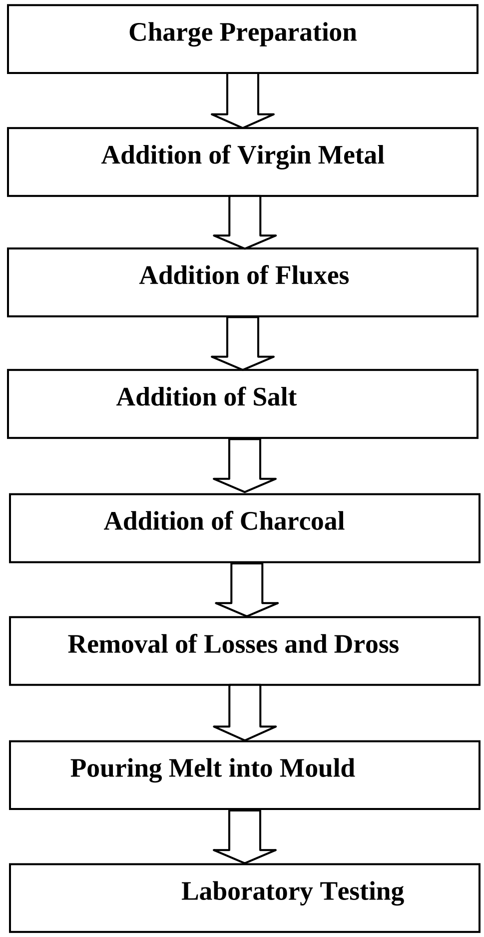

Fig. 7 Process flow chart for production of casting

IV. TECHNIQUES FOR IDENTIFICATION OF DEFECTS

Detection of defects / flaws is common to metal industries. It is imperative to locate shrinkage cavities, blow holes, crakes, cold shuts in cast product. Likewise it is also important to detect other characteristic defects such as piping, blister and scales in rolled products. In the case of foundries where non-finished products are supplied to the customer for subsequent machining. These castings contain numerous physical flaws which do not become visible until the outer castings surface is removed by machining. Therefore, it is of prime importance, to provide means of detecting such flaws at initial stages prior to shipment of the product, thereby saving the costs of shipping defective castings to the customer as well as eliminating the expenses of handling, machining and returning the rejected castings to the foundry for re-melting. Identification of such hidden flaws also facilitates to take remedial measures to eliminate the causes of the defects in subsequent pouring during the same run, and hence, helps to reduce the heavy expenses of pouring, handling and shipping large quantities of defective semi-finished products.

Several techniques are adopted which relates to rapid and non-destructive tests for location for cracks, blow-holes, leaks, piping, seems, shrinkage cavities and other defects in metallic products. These techniques include:

a) Ultrasonic Testing (UT)
b) Liquid Penetrant Inspection (LPI)
c) Radiography Testing (RT)

However, in this paper only **Ultrasonic Testing** is applied.

a) Ultrasonic Testing (UT)

Ultrasonic is the most commonly used NDT Technique in industries for detection of imperfections in the utilizations of frequency of sound waves beyond Human hearing. The sound waves are used as beam of illumination and measure the reflected beams from defects, in-homogeneities of the back wall of the martial to be tested. Ultrasonic testing is, used to find out the thickness of materials and to determine the location of discontinuity within a part or struck are by accurately measuring the time taken by ultrasonic pulse to travel through the material and reflect back from the discontinuity. This technique can be used to check porosity, gas holes, shrinkage cavities, air locks and inclusions in cast materials. Depending upon the grain size, proper selection of frequency is required, because coarse grains give rise to scattering of signals which in turn highly attenuates the signal. Hence, conventional testing is not suitable for very coarse castings.

Working Principle:

Ultrasonic waves are emitted from a transducer which is made of crystalline material having piezoelectric properties such as quartz. Piezoelectric materials keep vibrating upon application of electricity. Ultrasonic waves move in every direction when emitted by transducer. These waves are directed over the object to be tested. The presence of any flaw come in the way of ultrasonic waves is displayed and analyzed from the amplitude of the returning sound wave bounced back from a particular flaw. Mechanical energy is converted into electrical energy when comes back to transducer in the same way as piezoelectric materials converts electrical energy into sound energy. It is pertinent to mention here that absorptive material is added behind the transducer to prevent the interference of ultrasonic waves and the returning waves from flaw or defect.

The working principle of Ultrasonic testing technique is explained in figure 8.

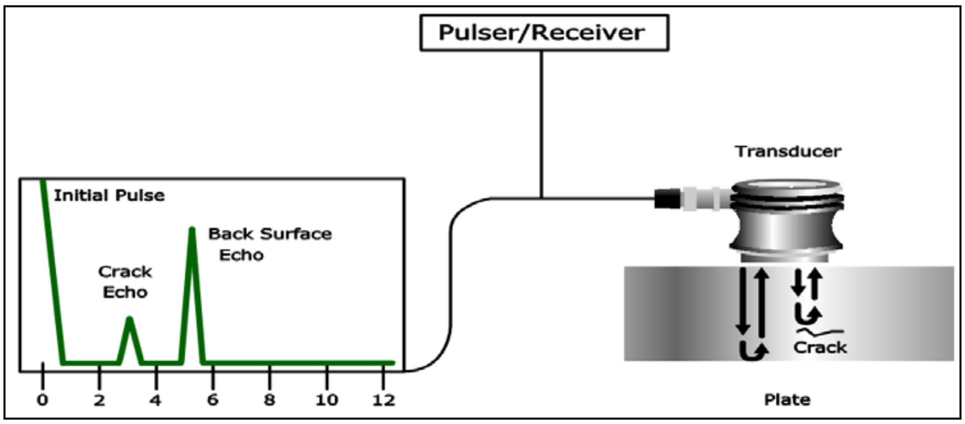

Fig. 8 Principle of ultrasonic testing in Pulse-Echo mode

Here, single transducer is used as transmitter as well as receiver, which is placed on the test material. This is called pulse-echo (P.E) mode of ultrasonic testing. A good couplent (oil, water, Vaseline etc) is required for proper coupling between the transducer and test material. A pulser is used to send electrical pulse to the transducer.

V. DEFECTS IN BRASS PRODUCTION PROCESSES

Defects may be either undersurface / hidden or above surface / visual. As mentioned earlier various NDT techniques are applied for detection of undersurface / hidden defects or irregularities. In this particular study Ultrasonic Flaw Detector is used to measures defects produced during casting of Brass.

Detection of Undersurface / Hidden Defects

Randomly billets were taken from the casting produced in the foundry. The same were shifted to laboratory where these were subjected to experiment / test.

The Krautkramer VSIP-11 Ultrasonic Flaw Detector is first calibrated. For this purpose a calibration block or standard reference calibration block made of low alloy grained steel with 25 mm thickness is used. The linear display shows from 0 to 10 graduations points. The zero point on the scale presents the surface of the test object. Depending upon the thickness of the test object a scale factor is first defined as per 10 scale graduation on horizontal

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display scale. For example on gradation point is equal to 10mm for block having 100mm thickness and so on and so forth.

By coupling the probe onto Standard Block (lying flat wise), the Back Wall Echo from the 25 mm steel path is shown in Fig.9.

Probe = B2S-N

Frequency = 2MHz

Gain Control =24dB

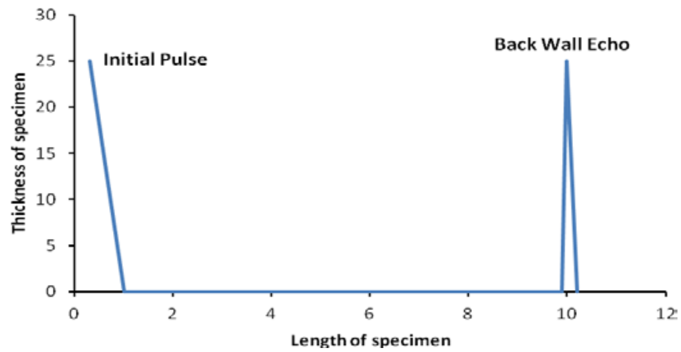

Fig. 9 Back Wall Echo from Standard Steel Block

Work piece of the same material as the test object whose dimensions are known is required to be used. To test Brass material a standard Block of Brass of known dimensions that is 25 mm thick, 100 mm wide and 250 mm is used for Calibration purpose with under mentioned input parameters.

Probe = B2S-N
Frequency = 2MHz
Gain Control =42db

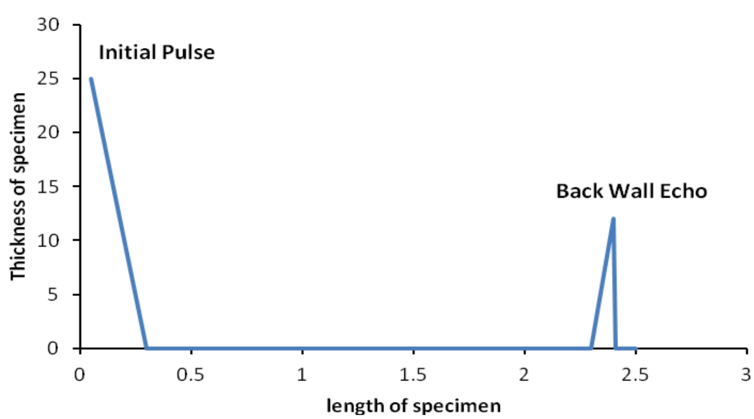

Fig. 8 Back Wall Echo from Standard Brass Block

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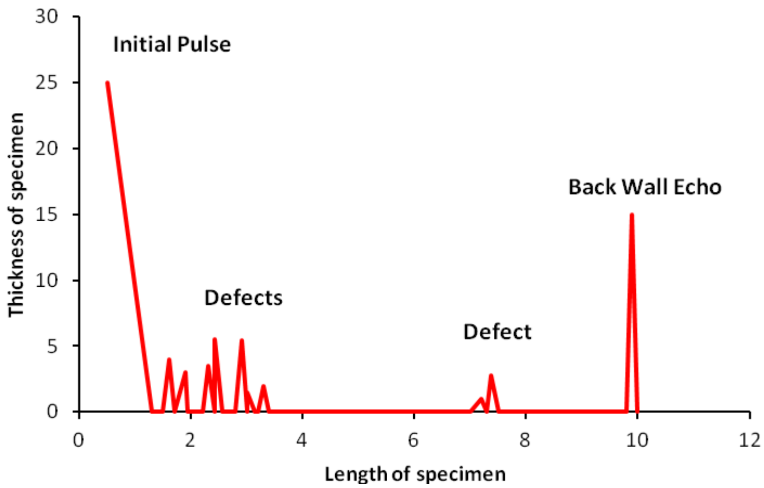

Fig. 9 Defects analysis of 100 mm Brass Billet

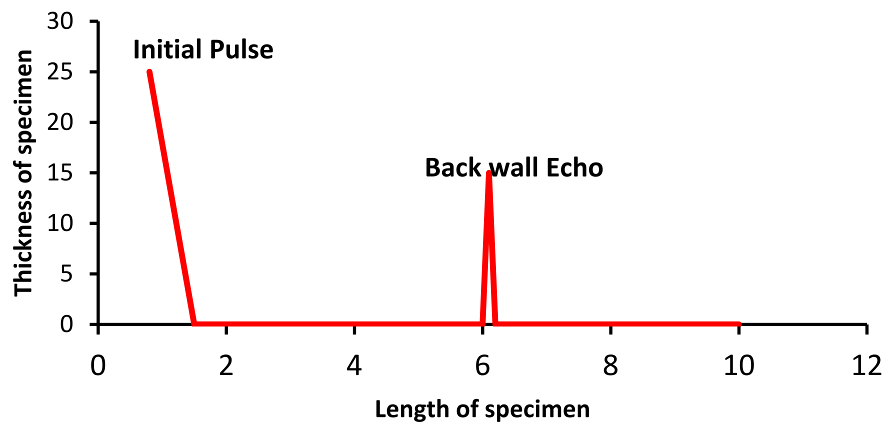

Fig. 10 Defects analysis of 60 mm Brass Billet

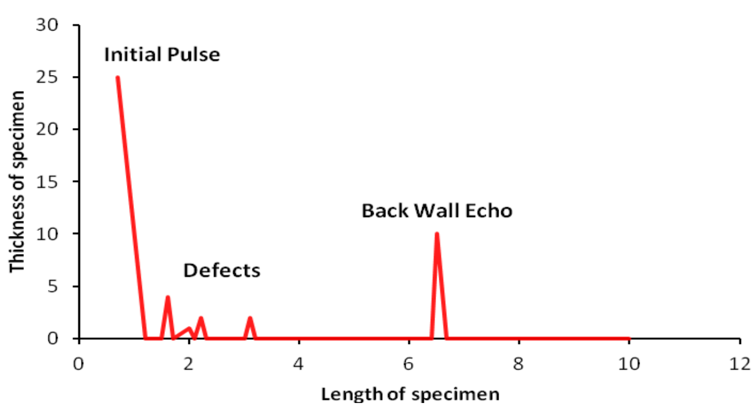

Fig. 11 Defects analysis of 65 mm Brass Billet

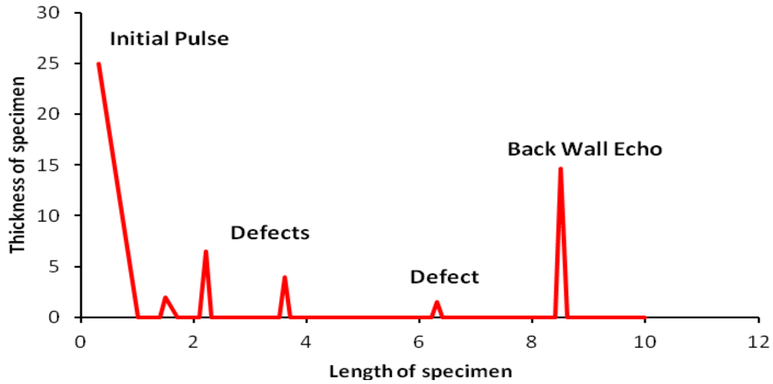

Fig. 12 Defect analysis of 90 mm Brass Billet

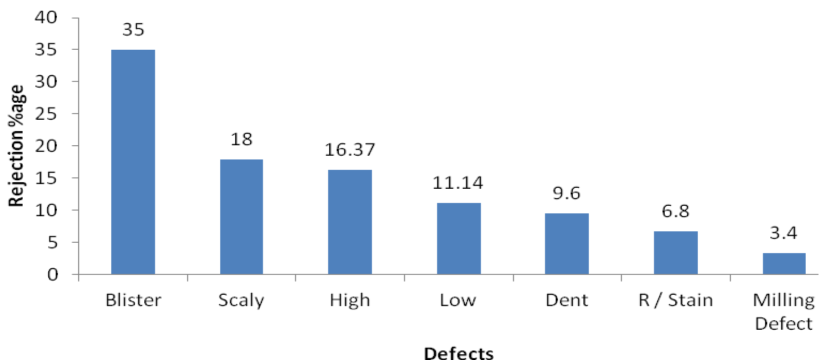

Fig. 13 Defect Analysis of Brass Strips for December 20

VI. REMEDIES FOR BRASS DEFECTS

The prime objective of the study is to exercise remedial measures to eliminate the above mentioned defects to reduce wastage in the manufacturing of Brass products. Literature review and thorough examination of the whole manufacturing process of Brass material following remedies have been identified and presented.

Table 2 Problems and its remedies in brass manufacturing process

S.No.	Operation	Problem	Remedies
1	Charge Preparation	i) Contaminated, oily, greasy and mixed scrap used. ii) Large pieces of Scrap used. iii) Inadequate quantity of virgin metal used.	i) Oil, grease and other impurities free scrap ensured before subjecting to furnace for melting. Segregation of scrap carried out by manual, mechanical and magnetic means to prevent melting of unwanted elements with brass scrap. ii) Cut large pieces into small size to avoid bridging and gap between scrap pieces. iii) Ensured approved quantity of virgin metal.
2	Addition of melt	No proper application of fluxes which	Used appropriate fluxes (metallic and

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	cover	in turn caused many defects.	non metallic) to avoid oxidation and reduction.
3	Composition of melt	No segregation of iron, steel and other unwanted constituent from scrap which consequently increased the permissible range of elements present in the required specification.	Used neat and clean scrap duly segregated. Also ensued use of approved quantity of virgin metal to keep the specified percentage of each constituent.
4	Pouring of melt	Found slow pouring of melt into mould which results entrance of atmospheric gases into the mould by oxidation.	Pouring carried out as quickly as possible to prevent oxidation.
5	Temperature control	i) No temperature measuring device found for measurement of molten metal temperature. ii) Poor supply of electricity to induction furnaces.	i) Pyrometers were inserted for measuring molten metal temperature. ii) Increased supply to the furnaces.
6	Pre heating temperature and soaking time	No system available to note the soaking time and pre heating temperature before subjecting the billets to hot rolling process.	Gauge was installed to exactly measure the pre heating temperature. Also extreme care carried out to give recommended soaking time to billets.
7	Cleaning of baths and moulds	No proper cleaning found moulds and baths found to remove the scale and sludge produced during casting as a byproduct.	A schedule was chalked out to carry out cleaning of baths and moulds at regular intervals.
8	Handling and shifting	Dents and scratches produced on finished products due to rough handling and shifting.	Strengthen the supervision of staff for safe handling of material.
9	Machines and tools	No schedule maintenance plants and machines observed. Also No timely replacement of worn out tools found.	Plan for Schedule maintenance of plants and machines chalked out. Replaced worn out tools with new one.
10	Patrolling of inspection authorities.	No stage inspection of quality control representative observed.	Patrol check of QC authorities reduced the likelihood of huge rejection at final stage of inspection.

VII. EXPERIMENTAL RESULTS

After thorough study of complete casting and manufacturing process of Brass industry and suggestion of remedial measures, next step is implementation of such remedies to assess its effectiveness towards reduction of waste of Brass products at various stages.

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Subsequently, all the remedies were implemented in true letter and spirit and the result is represented by repetition of the exercise mentioned above. Ultrasonic tests are performed for detection of hidden and undersurface defects / flaws after implementation of remedies.

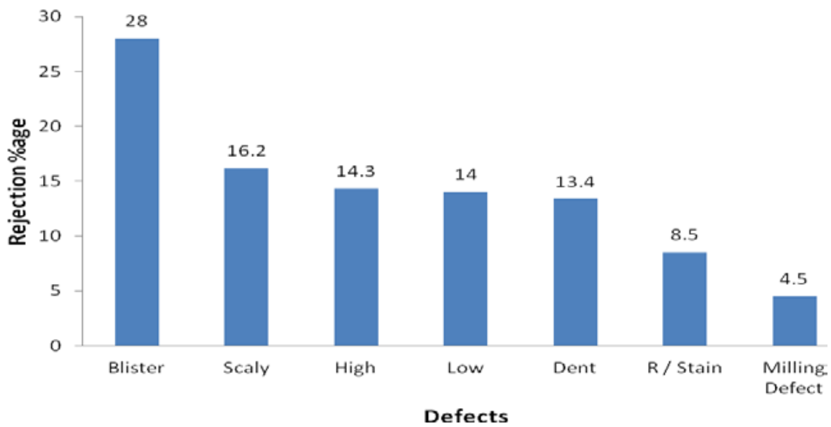

Fig. 16 Defect Analysis of Brass Strips for June 2013

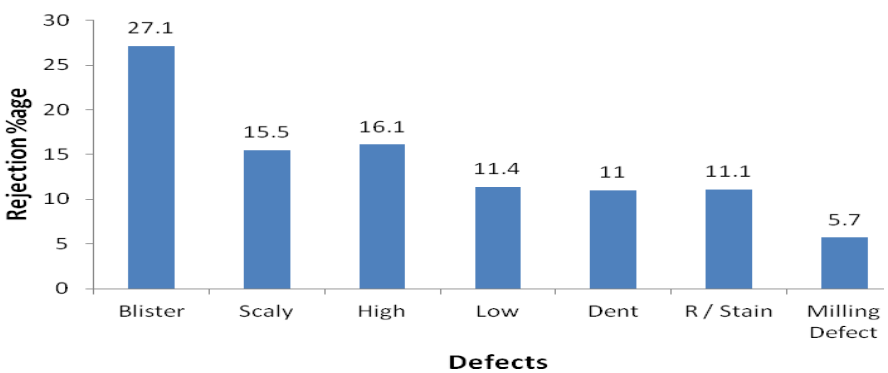

Fig. 14 Defect Analysis of Brass Strips for July 2013

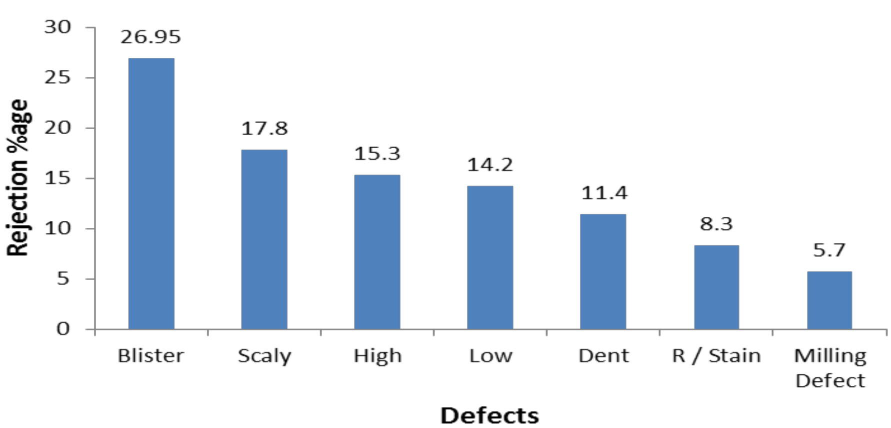

Fig. 18 Defect Analysis of Brass Strips for February 2015

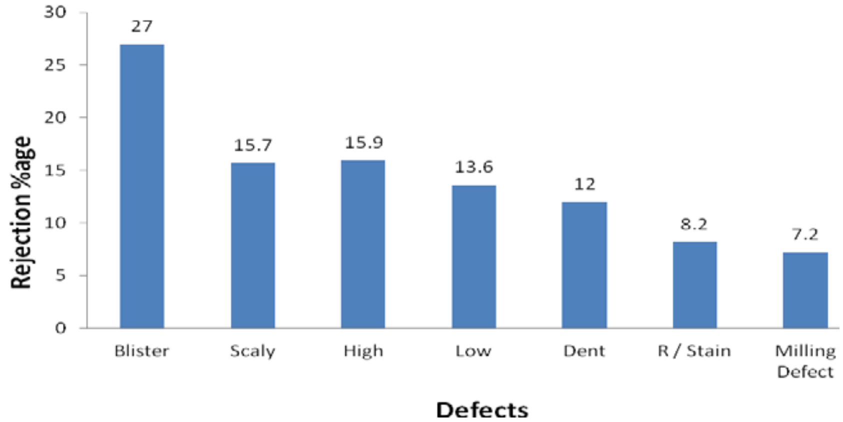

Fig. 19 Defect Analysis of Brass Strips for August 2013

VIII. RESULTS

Fig. 20 present result of the study. Comparison of %age rejection with respect to Quantity Rejected has been carried out. The first 03 bars shows average % age rejection before application of remedies presented in the research, whereas, the other bars shows % age rejection in the months of June, July and August 2013 after implementation the suggested remedies which clearly reveals approximately 50% reduction in the Rejection of Brass Materials.

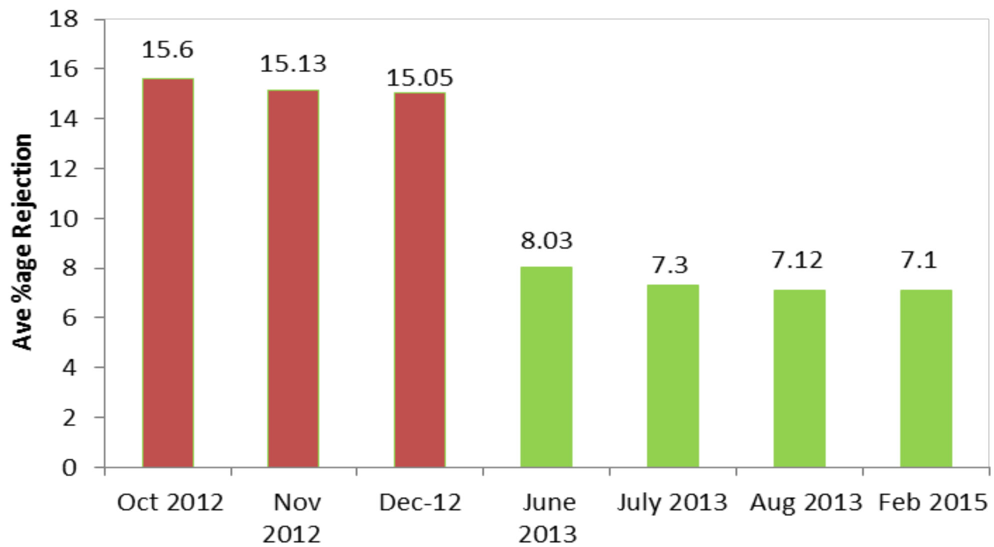

Fig. 20 Comparison of Ave %age Rejection before and after the research

It is clear from the above comparison bar chart that the objective of the research / study to eliminate / reduce the rejection percentage has been met by application of remedies. Consequently, quality of the product is improved; cost of the Brass products is decreased which enhanced productivity of the industry. It is therefore, concluded that key goal of the study regarding reduction in percentage of Brass products has been achieved. Hence the study is successful.

IX. CONCLUSIONS

The brass production industry was facing very serious challenges due to excessive rejection, 17-20%. A systematic study was carried with the key objective to reduce the rejection to bare minimum level. During the course of study, different remedies / tools were used which produced very fruitful results i.e rejection was brought down to 8-10% so that the prime purpose of the study has been achieved to a large extent. Following are some key results of the research.

i. Furnace charge should comprise of 30% virgin metal and 70% clean process scrap. This scrap should be free from adherent dirt, oxide and oil.
ii. Mould dressing, flux and charcoal must be dried before use. In the case of mould dressing, it should be boiled to expel all moisture.
iii. Adequate amount of flux should be added to the charge. Half of it to be added with the charge and remaining quantity to be added on melting.
iv. Melting temperature should be ensured before pouring molten metal into mould. The molten metal should not be poured unless melting temperature is attained as per material requirement.
v. Slow pouring into the mould should be avoided since it leads to rapid oxidation and may produce inclusions in the Billet. Speedy pouring should be carried out to maintain an adequate level of molten metal in the Tendish in order to prevent inclusion of gases in the metal resulting from interrupted pouring.
vi. Excessive application of mould dressing to the mould faces should be avoided. A thin coat of dressing on the mould surface and Tendish is adequate.
vii. For smooth solidification of molten metal poured into the moulds, un-interrupted supply of water to the moulds should be ensured.
viii. Mould faces should be smooth and free from cracks, pits or dents etc.
ix. Slag / Dross should be thoroughly skimmed off before pouring. For this purpose, non-perforated spoon shall be used.
x. Quality can be enhanced by patrolling of inspections authorities and deployment of trained operators and competent supervisory staff.
xi. Rough handling / shifting of finished products should be avoided’

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