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ALWAYS FORWARD

COPPER BASE ALLOYS

CASTING DEFECTS




SARBAK METAL

TİCARET VE SANAYİ ANONİM ŞİRKETİ

PİRİNÇ, BAKIR ALAŞIMLARI MAMÜLLERİ İMALATI

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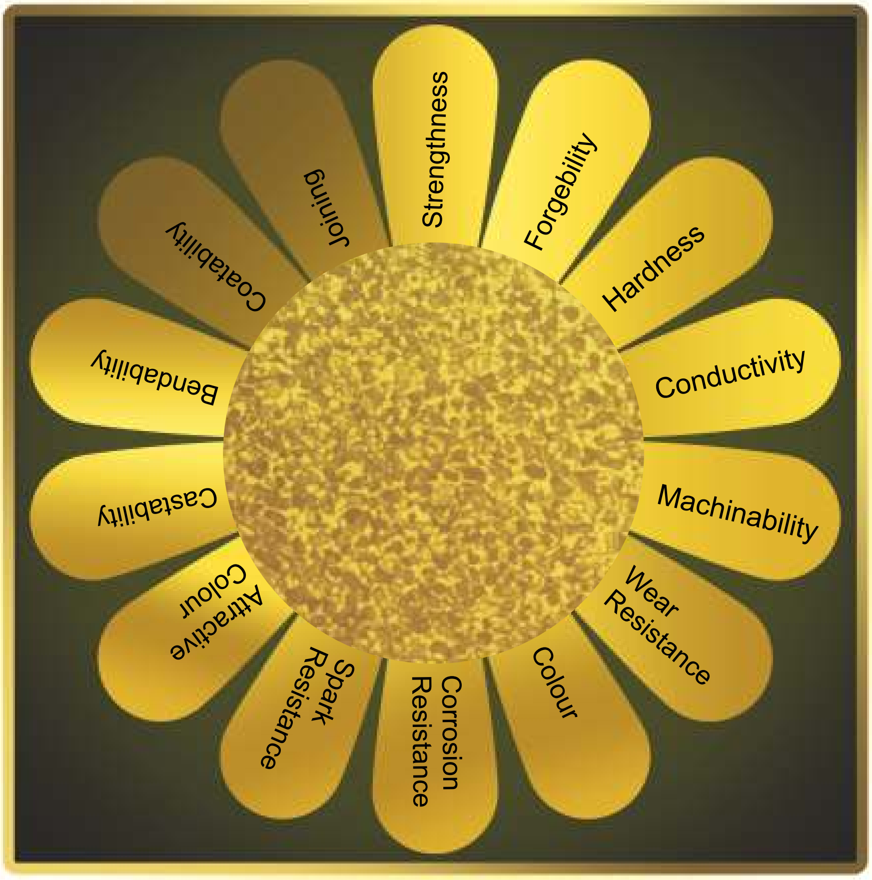
COPPER BASE ALLOYS
"CASTING DEFECTS"



SARBAK METAL
TİCARET VE SANAYİ ANONİM ŞİRKETİ
MANUFACTURE OF BRASS and COPPER ALLOYS

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COPPER BASE ALLOYS CASTING DEFECTS

COPPER BASE ALLOYS

CASTING DEFECTS

Editor: Assistant Prof. Dr. Hikmet ERBIYIK

İstanbul, 1st September 2015

SARBAK METAL A.Ş.

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Notes From The Editor

Metal casting is one of the most productive metal working production methods.
Metal casting is a basic production method that is utilized in the areas that require highest strength and safety primarily for the production of parts and components that are exposed to wearing external effects. The metal casting technique, is also a production method that is applicable in different areas for a wide range of industrial sectors.
In the course of time, ever developing casting technology procedures has rendered to achieve the best in class melting and casting process control implementations.
Thanks to the the aid of advanced computer aided mould modelling, the potential defect locations in the mould prior to casting may be defined in most cases.Due to the long standing research works on metal casting, the metellurgic data base is being expanded and inspection and testing methods are also being developed in parallel and hence better results toward eliminating casting defects are being achieved.
In practice, in the leading developed companies in the world, defected parts in the casting processes being defined as part per million. (ppm).
In general most of the casting defects arise in the form of surface defects and existing defects may be eliminated with subsequent surface improving operations.
Casting process defects may be related with the mould or core material and emerged with the casting implementations.
Metallurgic defects are defined with casting quality level that is originated from the base liquid metal and additives that are essential for the alloy (typical causes are foreign inclusions in the body, gas formation or porosity …etc).
Despite the fact that , successful leading manufacturers in the sector strive to minimize the casting defects into reasonable limits, as it is the case in most of the production methods, it is not unusual to encounter the various defects in the casting production processes time to time.
In most cases leading manufacturers in the metal casting sector take into account very little defect levels generally expressed in percentage defect level, while casting the melted metal into the mould for extremely complex parts.
The most frequently encountered spesific casting defects may be eliminated by systematic failure mode effect analysis that are made with very thorough evaluations. As a result of continuous improvement of casting processes, it may be possible to avoid or minimize the casting defects.
This valuable work published by SARBAK METAL A.Ş., namely "Copper Base Alloys Casting Defects" in your hands provides the typical defects that might be encountered in casting production process that is made with sand mould and continuous casting mould for copper based alloys.
The casting defects that are defined in this book are categorized with regard to well known defect types, defect causes and in some cases probable defect solution ways.
In some cases, despite fact that the solution of the defects that might be found intuitively may not be defined clearly, It might be considered just opposite of the defined defect.
The organization of the all required materials in the subject, are presented in such a format to be understood easily by foudry production line operators, engineers, metallurgists, and quality control personnel.
Our main aim in this issue is, while to present the most frequently encountered casting defects in easily perceived visual and comprehensive form with colour pictures to the readers, on the other hand to provide required means to the personnel that are working in the copper based alloys casting production to diagnose the most probable casting defects and to anticipate the causes and to initiate the relevant corrective actions.
With the thought that the book serves to provide convenience and assistance to the researchers and academicians that are working in this sector.

Editor: Assistant Prof. Dr. Hikmet ERBIYIK

İstanbul, 1st September 2015

Thank

The metal casting process that has a past history of thousands of years in the human life, takes part among the most frequently used production methods. The most wanted demand of all of us is to realize the production of casting parts of numerous amounts in near defectless form that needed by many sectors and require very high strength. However, at the end of the casting process there can be various defects in the poduced parts and hindering the usage of the parts. In most cases the casting defects may be ascertained in post production period or after supplying into the market. Regardless of the detection time in casting process, any defected casting part causes an undesirable situation.

Our main aim in this book of ''Copper Base Alloys Casting Defects '' that is presented to the convenience of all relevant parties in the sector, while to present the most frequently encountered casting defects in easily perceived visual and comprehensive form with colour pictures to the readers, on the other hand to provide required means in the copper based alloys casting production to diagnose the most probable casting defects and to anticipate the causes and to initiate the relevant corrective actions.Relevant useful data has been utilized as much as possible by referring the updated casting technological data base in the definition of the casting defects that are classified comprehensively in this book.We hereby wish to emphasize that we are determined to realize our quality perception in production toward focusing our target as ''to produce the best quality product with the least defect ratio''.

The issue of this book ''Copper Base Alloys Casting Defects'' is intended in the form of the continuation of the technical publication series of SARBAK METAL A.Ş. that were initiated a couple years ago, hence this outcome is obtained as the result of the sincere and devoted efforts of the team work of our colleagues. We realize and quote as the SARBAK METAL A.Ş. family that ''whatever you share is yours but not you amassed''

We hereby extend our gratitude to all those who contributed in the publication of this book, primarily "Prof. Dr. Fevzi YILMAZ" and the editor of this book "Assistant Prof. Dr. Hikmet ERBIYIK" and other colleagues;

Mr. Tuğhan Özçamsırtı (Factory Manager)
Mr. Hakan Felek (Human Resources Manager)
Mr. İbrahim Gül (Foundry Manager)
Mr. Bilal Barutçu (Technical Manager)
Mr. Serkan Hatipoğlu (Foundry Engineer)

With my sincere thanks,

Andon ARAKELYAN

SARBAK METAL A.Ş
Chairman of Board

İstanbul, 1st September 2015

Introduction

SARBAK METAL A.Ş. as embracing the quality as a life philosophy and placing it on top of the constitutional values, aim to meet the customer satisfaction at the top level by focusing zero defect in production.

Our company, SARBAK METAL A.Ş. as one the leading companies of copper alloys and brass casting sector in our country, while renovating existing know how in casting sector continuously in order to eliminate or minimize the casting defects, on the other hand has accepted the primary principle as sending the best quality products to the customer by utilizing the most updated technology in this field.

In this regard, it is intended to classify and analize the casting defects systematically and to meet the best quality at first attempt in the subsequent casting processes with the aid of this book of ''Copper Base Alloys Casting Defects'' that is published with the relentless efforts of the SARBAK METAL A.Ş. technical team.

As we have defined comprehensively in this book, we have not refrained from any sacrifice for the share of technological know how easily by the interested parties, and we hereby acknowledge sincerely that we will maintain our stand in the coming years.
With the thought that the book of ''Copper Base Alloys Casting Defects'' serves to provide convenience and efficiency for all related parties, specialists, researchers, academicians and students in the sector.
We also hope that we continue our technical publication series with another peculiar book in the near future.

With our sincere regards,

Meliha HALIGÜR

SARBAK METAL A.Ş
Deputy Chairman of Board

İstanbul, 1st September 2015

Presentation

Copper based materials are usually the kind of parts that are cast into continuous casting mould or sand mould as per the form of the material.
Many casting defects are related firstly with sand moulds and core materials and in most cases they are the results of, inconsistent and/or inadequate moulding processes or distribution or distruption of mould or core material break up during the melted metal pouring and cooling stages.
Among those casting defects vein, crust, buckle, swelling, lapping, dropping,…etc can be cited.
The other casting defects are of metallurgical types by nature and may arise in non-metal or metal moulding processes.
Those casting defects arise as originating from spesific alloy composition and solidification characteristics (such as "tin sweat'…), melted metal casting defects, foreign elements in the casting, gas formation and other micro-structure phenomenon.
The other casting defects are formed due to improper handlings;
Those are the ones that broken casting parts, cracked casting parts and hot tear defects that are formed due to improper casting geometry, non-homogeneous metal composition or inadequate casting application
SARBAK METAL A.Ş., follows up closely the most recent technological advances with its over fourty years experience in the sector, will continue to maintain its leadership position in the future by keeping the excellence and top level quality in production processes.
In this regard we embrace to the philosophy to produce the quality rather than to obtain it necessitates that our products shall be produced to meet customer demands at first instant, in time and for ever.
The previously gained experience from casting defects will provide guidance and future projection in our future production to eliminate or minimize the casting defects.
We present this book of ''Copper Base Alloys Casting Defects'' among the SARBAK METAL A.Ş technical publication series, with typical casting defects in colour pictures and comprehensive definitions to the attention of readers in a useful format and we expect that all relevant parties, specialists, academicians, researchers and students will benefit from this book to a great extent.

With our best regards,

A.Tuğhan Özçamsırtı

SARBAK METAL A.Ş.
Factory Manager

İstanbul, 1st September 2015

Foreword

Metal casting is one of the most consistent metal forming manufacturing processes. Metal casting is used as a primary manufacturing technique of critical components, that must perform safely under the most strenuous and demanding requirements. Metal castings are used for a wide variety of applications, which are used across a broad spectrum of industries.

Improved foundry procedures have led to better application of melting and pouring process controls.

Computer modeling can predict locations of potential defects before manufacturing. Research leads to better metallurgical understanding and improved inspection methods lead to reduced variability and defect rates in metal casting operations. Indeed, in many world class operations, the product return rate can reach parts per-million. Yet, common defects may occur on the surface of a casting, which are easily remedied with surface finishing practices. Process defects may pertain to mold and core materials and pouring practices. Metallurgical defects that relate to melt quality (inclusions, gas, porosity, etc.) are a constant concern given the nature of alloy charge materials and liquid metal, which is susceptible to the occurance of such defects. As with any manufacturing process, the occasional occurrence of defects in the casting process in not uncommon-although all successful procedures will minimize defects to the greatest extent possible.

In general, foundries procedure complex cast-to-shape desings very efficiently with few defects, based on percentage. Specific casting defects that are encountered repeatedly are resolved with diligent evaluation of causes and prevention, which then leads to development of prescribed standard casting process procedures to avoid and minimize casting defects.

In Casting Defects : Copper Base Alloys, many of the common types of casting defects encountered in the production of copper base alloy casting in both sand and permanent mould processes are presented.

These defects are categorized by type with possible causes and, in some cases, prevention techniques.

In many instances, the remedies are intuitively the opposite of the cause of the defect, even if not stated.

The organization of the material is presented in an easy-to-review format suitable for foundry floor operations, as well as process engineer, metallurgists and quality control personnel. It is the intention of this publication to provide a comprehensive visual atlas of the more common casting defects, which are encountered, to enable the copper base foundry personnel to quickly identify the type of defect, address possible causes, and establish corrective actions.

YENİ ÜRÜNLER

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Altıköşe,Kare / *Hexagon,Square*	5-12 mm
Dikdörtgen / *Rectangular*	Kalınlık / *Thickness*: 5-10 mm Genişlik / *Width* : 5-20 mm

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NEW PRODUCTS

Çap Ø (mm)	Ağırlık (kg/m)	Max. Kangal Ağırlığı (Kg)	Malzeme Durumu
Dia Ø (mm)	Weight (kg/m)	Max. Coil Weight (Kg)	Material Condition
EN 12166 - CW614N			
4,80	0,153	140	R430-R500
5	0,166	140	
6	0,239	140	
7	0,325	140	
8	0,425	140	
9	0,538	140	R430
10	0,664	280	
11	0,803	280	
12	0,956	280	
13	1,122	280	
14	1,301	280	

Kangal İç Çapı /*Coil inside diameter*	Ø 600 mm
Kangal Genişliği / *Coil Width*	250-400 mm
Sarım Yönü / *Coiling versus*	Anticlockwise

* Dikdörtgen, profil kangal ağırlıkları ve diğer alaşımlar için irtibata geçiniz.
* Yuvarlak ölçüler isteğe bağlı olarak kaynaklı tek parça kangal halinde 500-1000 kg arası üretilebilmektedir.
* Detaylı bilgi için bizimle irtibata geçiniz.

Ölçü (mm)	Ağırlık (kg/m)	Ağırlık (kg/m)	Max. Kangal Ağırlığı (Kg)	Malzeme Durumu
Width Across Flats (mm)	Weight (kg/m)	Weight (kg/m)	Max. Coil Weight (Kg)	Material Condition
EN 12166 - CW614N				
	Altı Köşe *Hex*	Kare *Square*		
5	0,183	0,211	140	R430 - R500
6	0,263	0,304	140	
7	0,359	0,414	140	
8	0,468	0,541	140	
9	0,593	0,684	140	R430
10	0,732	0,845	140	
11	0,885	1,022	140	
12	1,054	1,217	280	

Paket Ağırlığı ***Packing Weight***	500±100 Kg
Paket Ölçüleri ***Packing Dimensions***	genişlik x uzunluk x yükseklik: 700x700x1300 mm *width x lenght x height: 700x700x1300 mm*

* *Pls ask for rectangular, profile coils weights and other alloys.*
* *Optionally round coils can be produced with welded as a single piece of 500-1000 kg*
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EN - 1982 ✓	EN - 1982 ✓	EN - 1982 ✓	EN - 1982 ✓	EN - 1982 ✓
DIN 50930-6 ✓	DIN 50930-6 ✓	DIN 50930-6 ✓	DIN 50930-6 ✓	DIN 50930-6 ✓
UBA LIST ✓	UBA LIST ✓	UBA LIST ✓	UBA LIST ✓	UBA LIST ✓
4MS ✓	4MS ✓	4MS ✓	4MS ✓	4MS ✓
	POLISHABILITY	**POLISHABILITY**	**POLISHABILITY**	**POLISHABILITY**





MAIN SPECIFICATIONS

- ✔ Ingots freight via euro pallets which are between 1 to 2 tonnes. 64 mm x 64 mm x 380 mm, 12-13 kg / ingot.
- ✔ Suitable for loading with robot system due ingot, produced by continuous casting
- ✔ The ratio of dross on melting stage, is lower than gravity die casting due ingot, produced by continuous casting.
- ✔ Ingots suitable for gate valve, corporation stop, water meter, ball valve and faucet producing.

PLEASE CONTACT FOR OTHER ALLOYED INGOTS

TS EN-1982 : Copper and copper alloys comply with ingot and casting standards.

DIN 50930-6 : The norms of brass materials in contact with potable water.

UBA List : The list of brass materials used in drinking water, published by German Federal Environment Agency.

4MS : The committee where the members, France, Germany, the Netherlands and the United Kingdom, work together for national approval schemes for materials and products in contact with drinking water.

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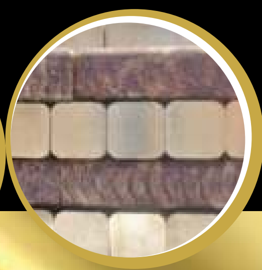

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Broken or Cracked Castings

Description

These casting defects (and rejects) result from mishandling, mechanical action, or thermal shock, which can apply to both the mold and the casting. These failures can also result from non-homogeneous alloy composition in the liquid state and from the impurities, which alter the solidification characteristics. Irregular solidification causes microstructural weakness in the casting.

Causes

1-Mechanical and Equipment

- Poor casting desing (lack of fillets)
- Irregular sections
- Improper break off notches on gates and risers
- Flask bars improperly positioned
- Shakeout too hot or rough
- Mechanical cleaning (tumbling) too rough
- Improper stacking
- Dropping the casting
- General carelessness

2-Sand, Core, and Molding Practice

- Poor sand collapsibility
- High hot compressive strength coupled with hot sand deformation
- Over-reinforced cores
- Improper use of chills
- Risers or sprues located too close to a flask bar
- Excessive ramming

3-Gating, Risering and Pouring

- Pouring temperature insufficient to allow proper mold collapsibility, thereby restraining natural thermal contraction of the casting as it solidifies (also relates to hot cracking or hot tears)
- Lack of fillets at gate and/or riser connections leading to hot spots
- Pouring too hot with excessive shrinkage

4-Metallurgical

- Non-homogenous liquid metal ready for pouring
- Impurities, which detract from hot or cold strength during solidification and subsequent metal handling

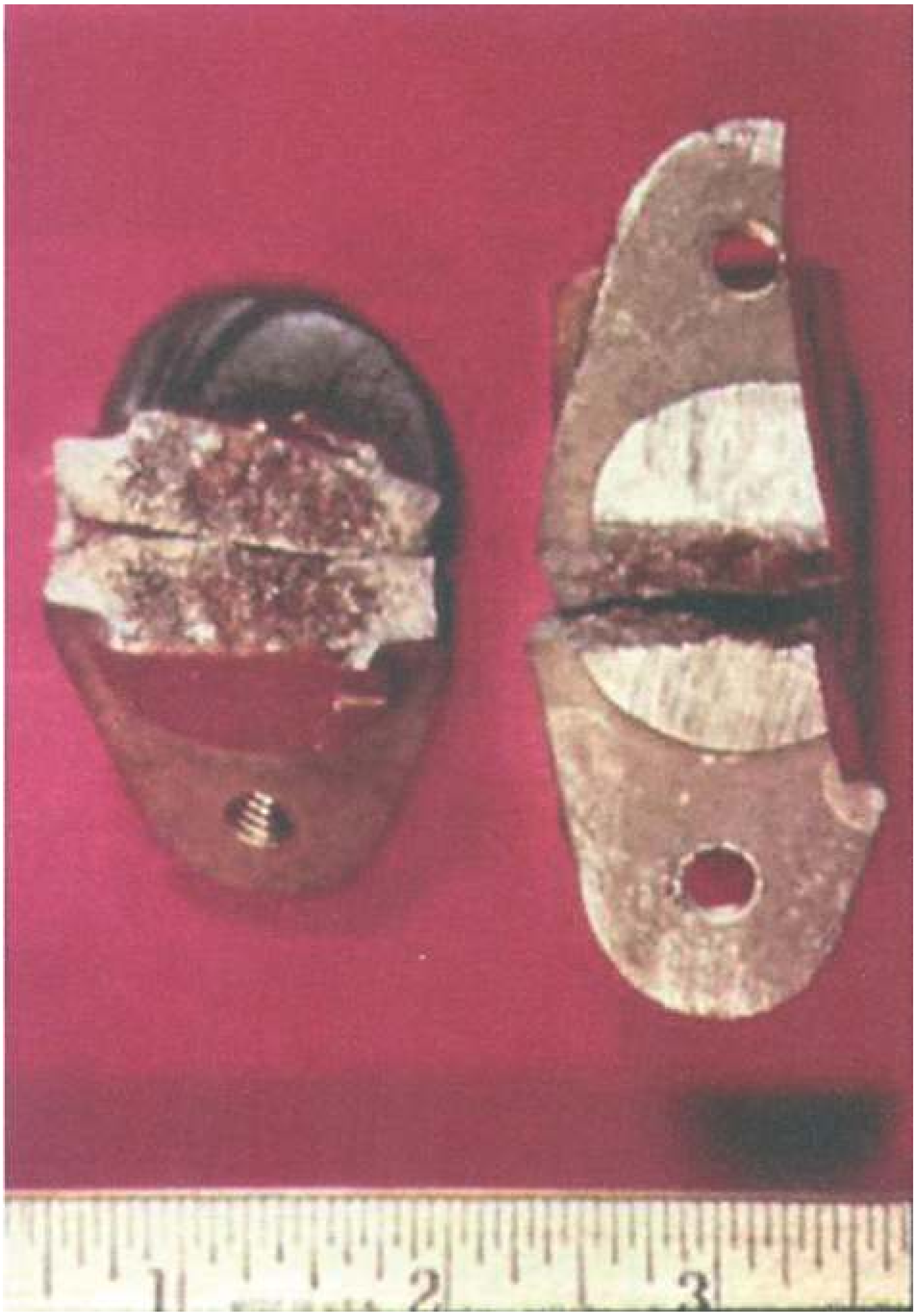


Fig. 1-1. Aluminum in red brass is an impurity that results in casting microstructural weakness prone to cracking.

Fig. 1-2. Silicon in red brass is an impurity concentration that results in casting microstructural weakness prone to cracking.

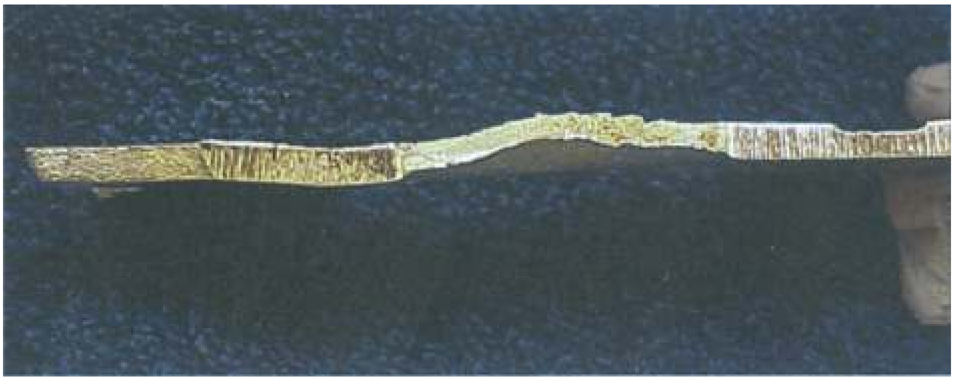


Fig. 1-3. The yellow brass handle, cast in green sand, exhibits unusually large dendritic growth. This is evidence of a melt and/or pour temperature, which is too high, and also of zinc flaring.

Fig. 1-4. The broken core shows low binder content, poor density and age.

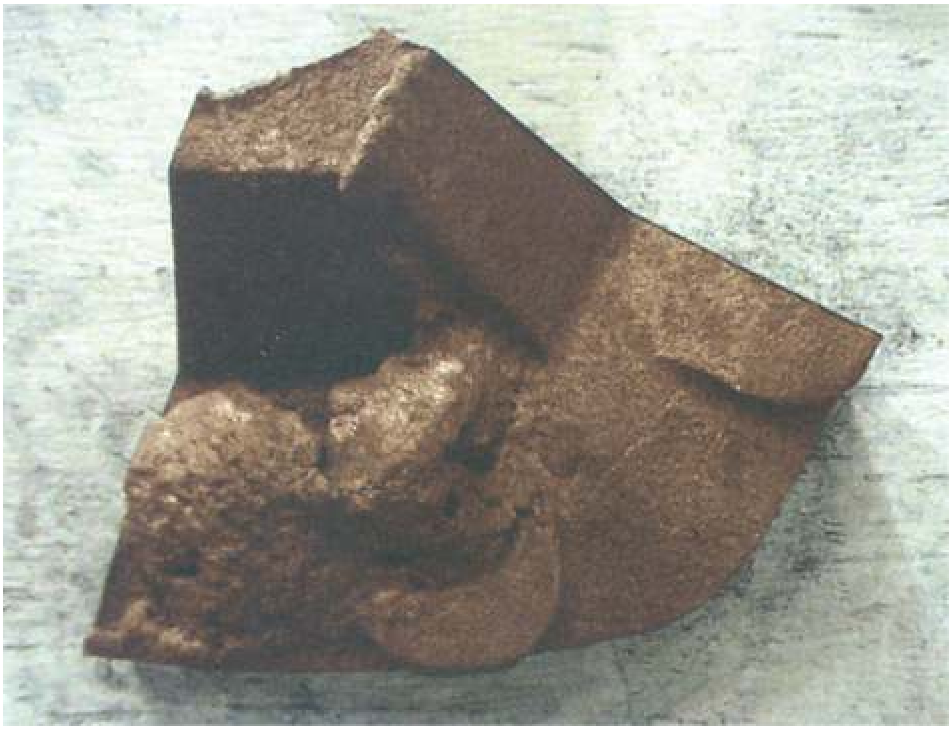


Fig. 1-5. The cracked mold is caused by push up or drop. The drag sand level is not full.

Fig. 1-6. The punch damage in red brass during de-molding is caused by sticker.
The die clearance and/or mating is incorrect.

Fig. 1-7. Broken mold.

Scars, Seams, Plates, and Flow Marks

Description

These are shallow surface defects often, but not always, seen just on larger flat surfaces of a casting. A scar is a minor, shallow mark on the casting where it does not conform to the pattern. A seam is a minor indentation, whereas a plate is a layer of metal slightly raised from the main casting surface. In general, such defects, which arise from pattern equipment and mold making, are exacerbated by inadequate pouring actions. A flow mark is a surface visual defect, encountered in metal molds where there is non-uniform liquid metal flow during filling, and is often associated with a thin oxide film.

Causes

1-Mechanical and Equipment

- Worn pattern equipment
- Abrupt changes in casting section which create turbulent metal flow
- Pattern improperly mounted
- Cope and drag shift causing thin metal sections

2-Sand, Core, and Molding Practice

- Excessive moisture
- Low permeability
- High expansion sand
- Low hot deformation

- Excessive gas forming material
- Plugged vents
- Off size or distorted cores
- Irregular core and/or core forming and ramming
- Excessive sticking, patching, mold repair

3-Gating, Risering, Pouring

- Interrupted or irregular pouring rate
- Gassy metal
- Pouring temperature too low, allows premature solidification in thin sections
- Lack of tilt in pouring thin flat horizontal sections
- Rough handling-turbulance during pouring

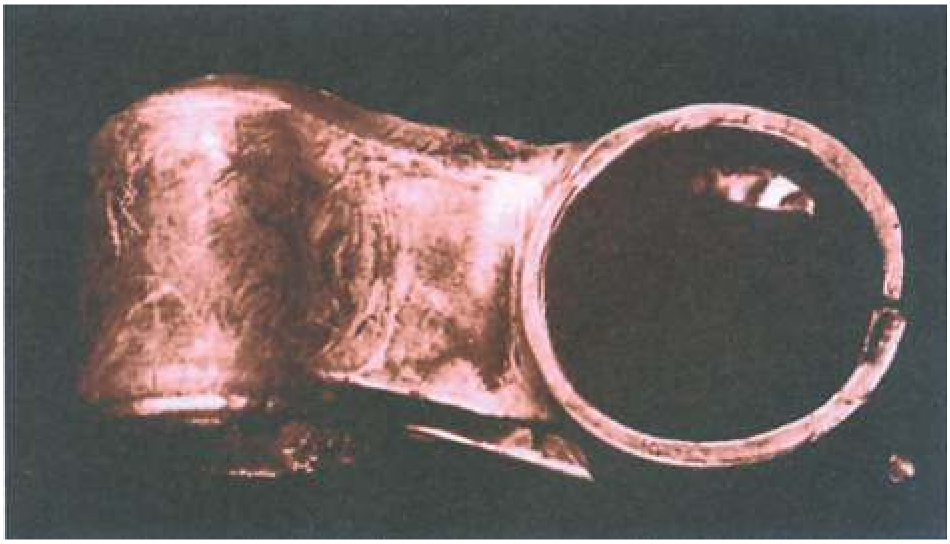


Fig. 2-1. Bicycle bracket in 90-10 cupro-aluminum, cast in permanent mold, shows seams, and oxide skins.

Fig. 2-2. Same casting as in Fig. 2-1 shows flow marks caused by high pouring temperature and turbulent filling of the mold.

Expansion Defects
(Rattails, Buckles, Scabs, Veining)

Description

These green sand defects are mainly related to problems with the molding sand and molding practice, and arise during the pouring operation. Expansion defects include rattails, buckles, scabs, and veining. Expansion (and contraction) occurs as the molding sand and cores undergo temperature cycling during the pouring operation. Silica sand undergoes the most dimensional change, although other mold material compositions are also prone. While higher temperature regime ferrous metal castings suffer more from these expansion defects, copper and copper base alloy castings can also exhibit these defects.

Causes

1-Mechanical/Equipment

- Rough mechanical handling of cores, molds and flasks leading to cracks in molds and cores
- Uneven sections in pattern equipment causing uneven heat distribution in heat processing of molds and cores
- Sharp corners that develop hot spots
- Misaligned equipment

2-Sand, Core Molding

- Poor mulling and mixing
- Improper binder level
- Poor sand distribution
- Sand grain shape too regular (too round)
- Cores and molds too weak due to insufficient molding
- Excessive moisture which cannot escape during drying
- Excess binders
- Core baking temperatures too high
- Improperly reinforced cores-rods, wires or bars
- Cores stored in high humidity conditions

3-Gating, Risering and Pouring

- Gate or riser location too close to core print, causing hot spots leading to mold or core cracking before the metal solidifies and subsequent metal penetration
- Faulty mold coating
- Excessive head pressure
- Pouring temperature too high

Rattail

A rattail is a rather shallow irregular groove-type of defect appearing usually on horizontal drag surfaces, and often extending from gate locations. Heat from the flowing metal causes steam formation of the moisture in the green sand at the surface. This causes expansion as the steam escapes and creates a protrusion, resulting in a 'negative' or rivulet as the casting surface solidifies.

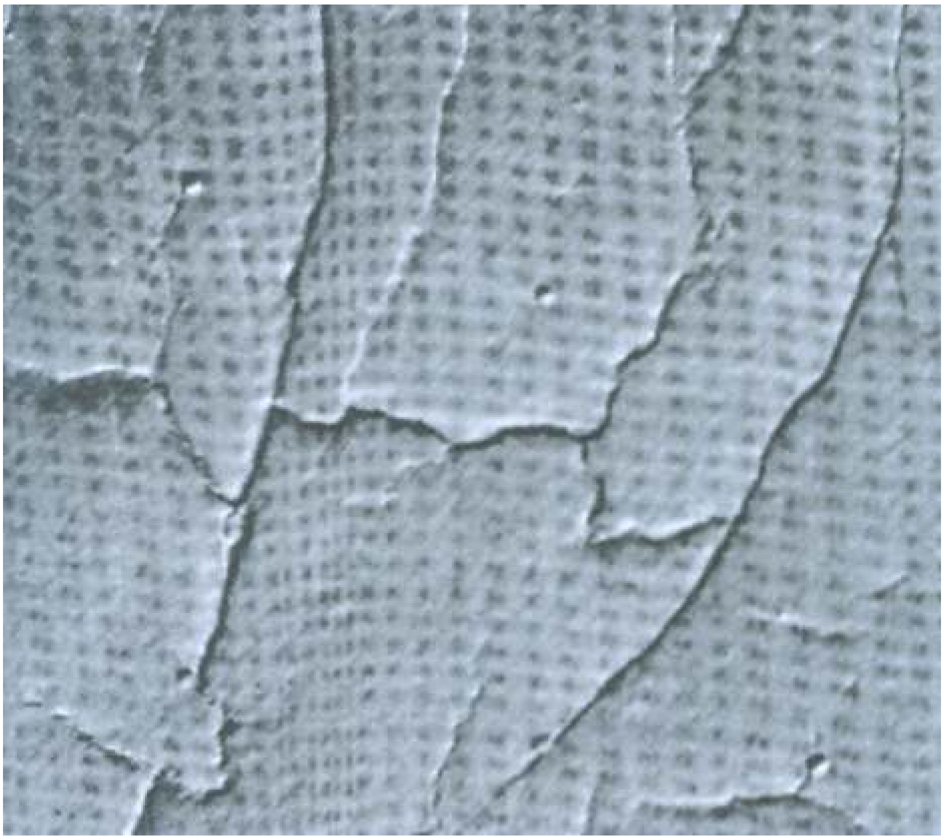


Fig. 3-1. Rattail.

Fig. 3-2. Rattail.

Fig. 3-3. Rattail.

- **Buckle**

  A buckle is a 'heaving' of the sand during pouring and is a precursor to an expansion defect. This often occurs on both horizontal cope and drag surfaces.

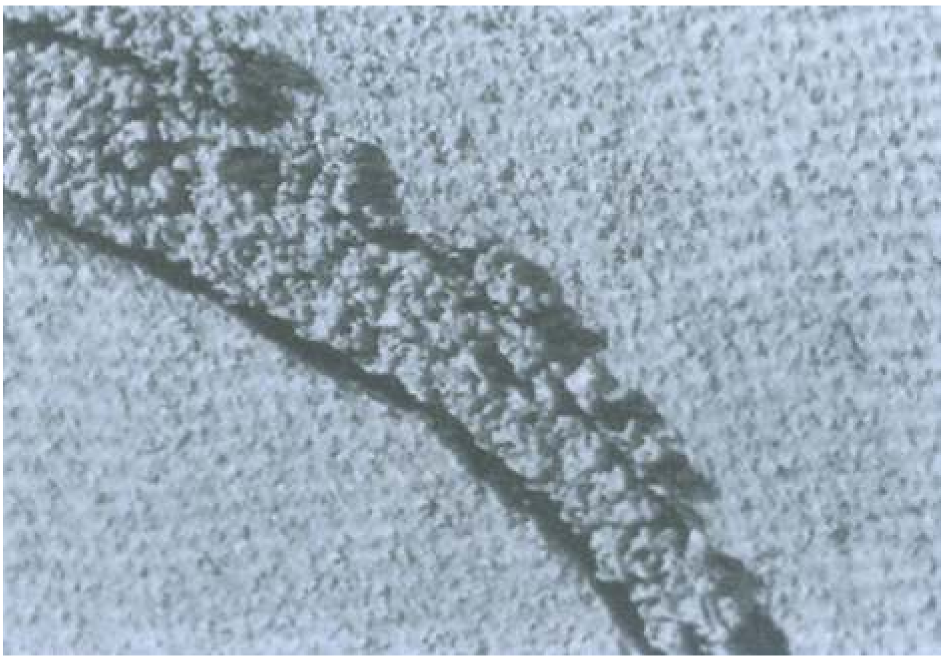


Fig. 3-4. Buckle.

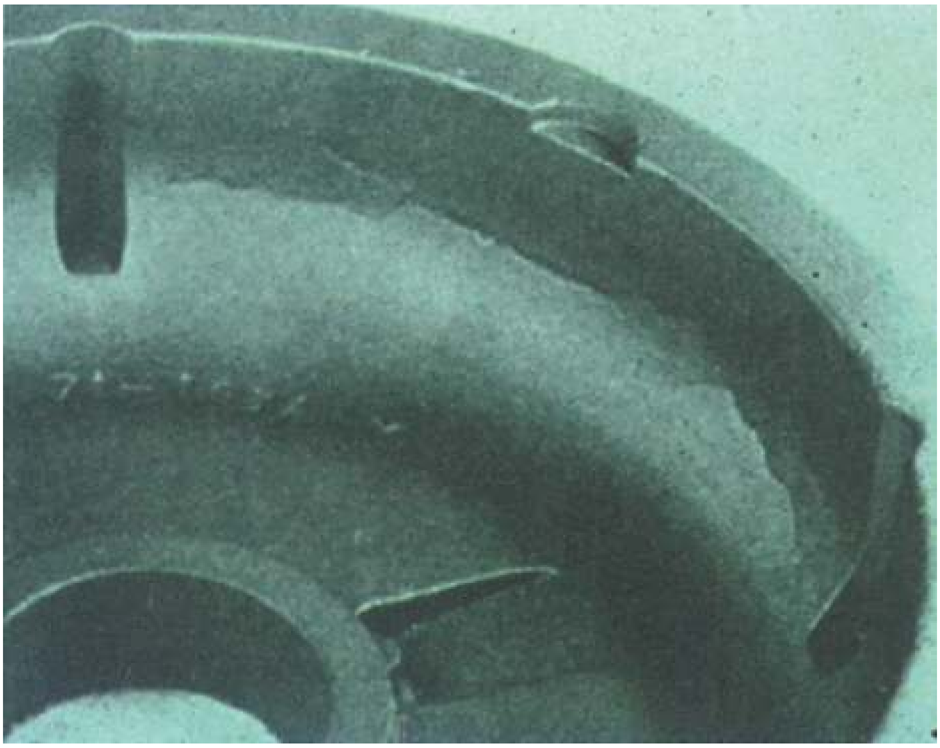


Fig. 3-5. Buckle.

Fig. 3-6. Buckle.

• **Scab**

A scab expansion defect occurs as the mold surface undergoes expansion and contraction during pouring and metal solidification. This defect may result from breakdown of the sand or also from erosion of mold and core washes. Scabs are 'positive' metal defects; appear crusty; may be somewhat 'loose' and can often be removed during finishing operations, if not severe.

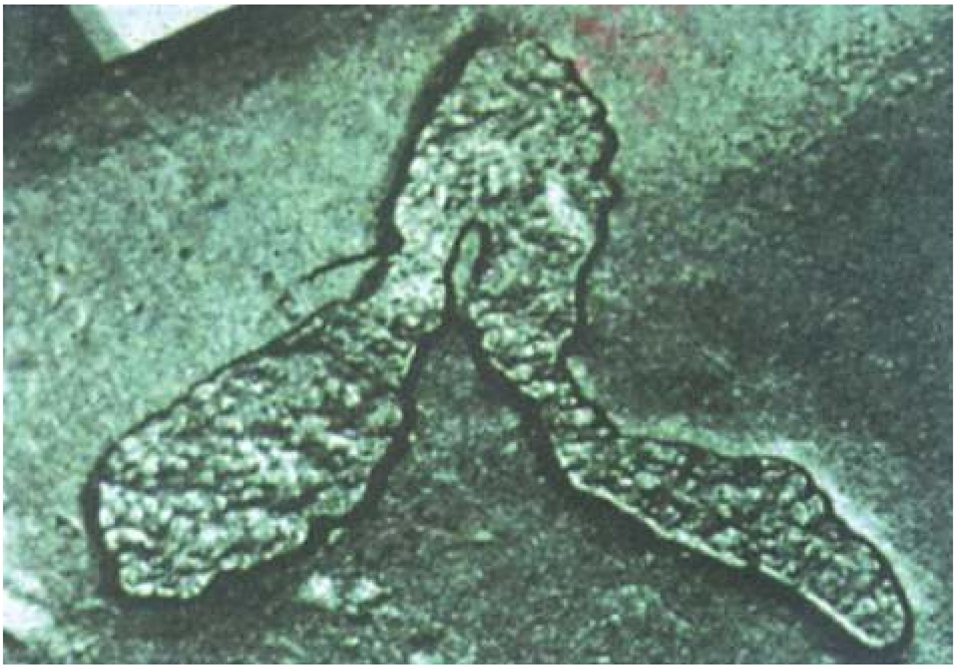


Fig. 3-7. Scab.

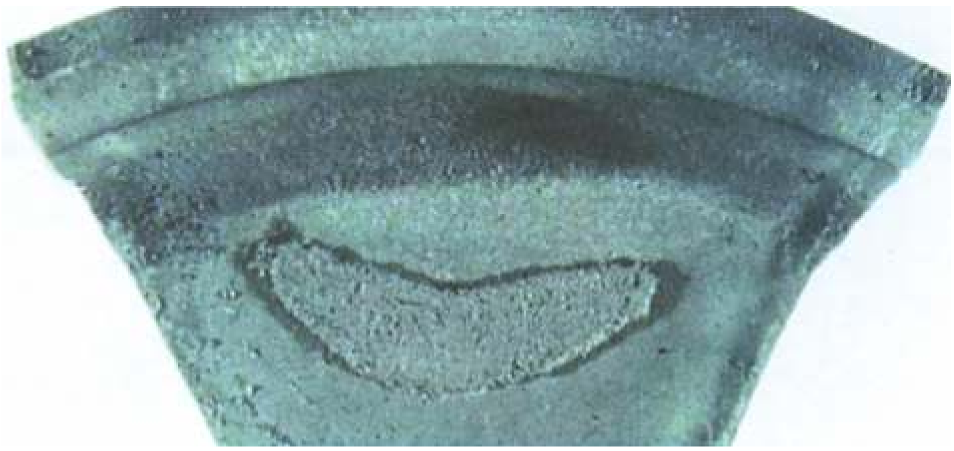


Fig. 3-8. Scab.

Fig. 3-9. Scab.

Fig. 3-10. Fillet scab.

Veining

Veining, an irregular linear defect, a ridge or projection on the casting surface, is found in the sandcasting process. Invariably there is a separation in the molding media for various reasons, and the metal fluidity is sufficient to penetrate the separation or crack in the mold and/or core material. This allows the defect to appear when the casting surface is examined.

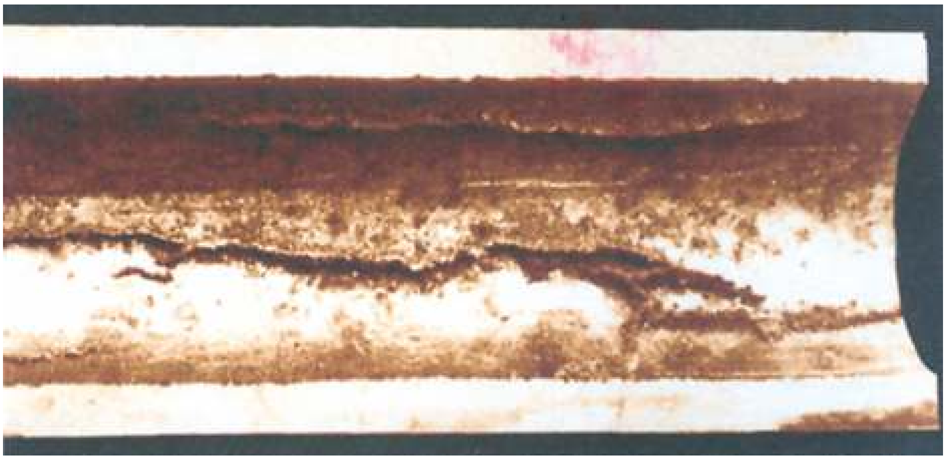


Fig. 3-11. Veining is caused by core cracks in bronze bushing and improper core baking.

Fig. 3-12. Veining.

Fig. 3-13. Severe veining in red brass C83600.

5-Flash or Finning

Flash or finning should not be confused with veining. Flash and/or finning occurs as a positive defect,which appears linearly at the mold parting line. This defect is due to inadequate mold closure or mold mismatch. In severe situations, flash or finning becomes gross run-out.

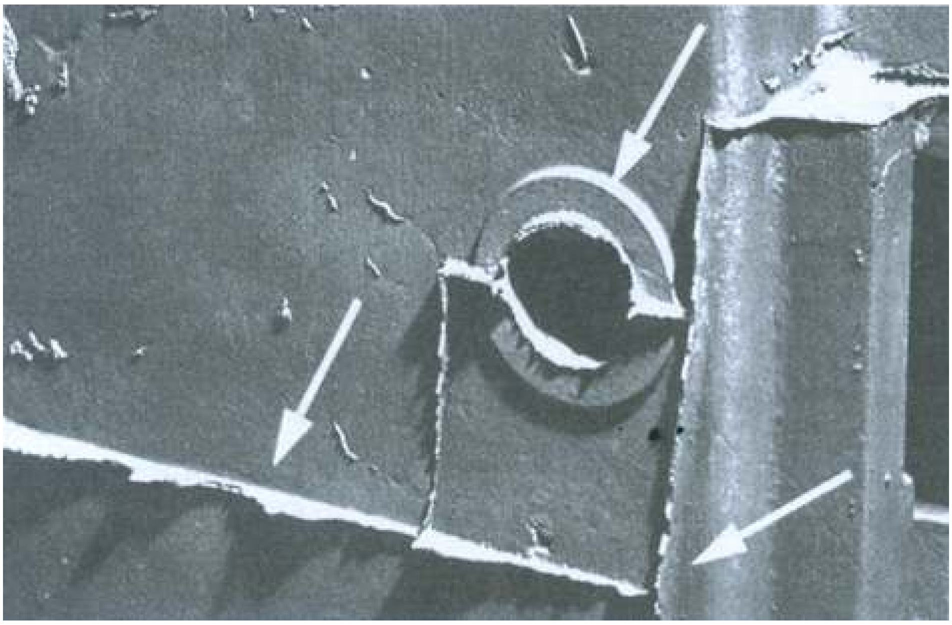


Fig. 3-14. Flash and fins.

Fig. 3-15. Run-out is due to poor mold mismatch or inadequate closure.

Sand Molding Defects
(Crushes, Swells, Sags, Drops, Erosion, Stickers, Cuts and Washes, Poor Surface)

Description

There are several defects which relate strictly to casting processes with sand molding materials. These include crushes, swell, sags, drops, erosion, stickers, cuts and washes and poor surface. Molded cores can create defects due to inadequate or incorrect core production (poor strength, insufficient curing, etc) or poor alignment and placement in registry with the main casting mold cavity.

Causes

Most Sand Molding Defects Arise from One or More of the Following Factors:

- Improper sand grain size distribution
- Inadequate mulling
- Too little or too much binder
- Too little or two much moisture
- Insufficient or excessive molding pressure
- Pattern design which does not permit sufficient material fill or pressure

• Crushes

A crush is a non-geometric projection on vertical or oblique surfaces of the casting in the direction in which the mold is closed or in which a core is placed.

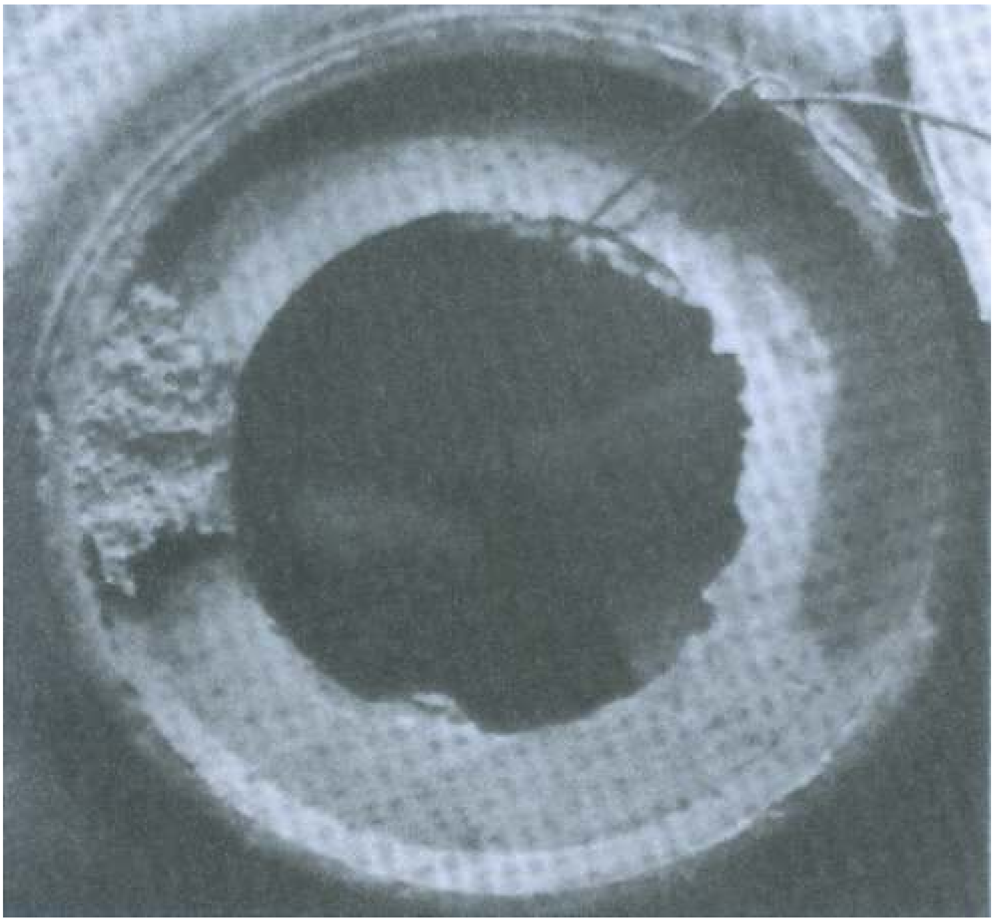


Fig. 4-1. Crush.

Fig. 4-2. Core crush from insufficient core strength.

Fig. 4-3. Crush can be caused by misaligned cope/drag, mismatched pattern haves, bad pins, and bushings.

Swells

A swell is often a massive 'wavy' irregular projection, which can be found on all surfaces of the problem casting. Swells are caused by excessive liquid metal pressure relative to the strength of the mold.

Fig. 4-4. Swell.

Fig. 4-5. Swell is caused by cracked sand mold in red brass (C83600).

Sags

A sag is an irregular, fin like projection of varying thickness and shape, having a rough and irregular surface, caused by the pressure of the metal as it contacts the mold cavity surface. The metallostatic pressure exceeds the sand strength.

Drops

A drop is a defect due to the loss of a portion of the sand from the cope or other overhanging section.

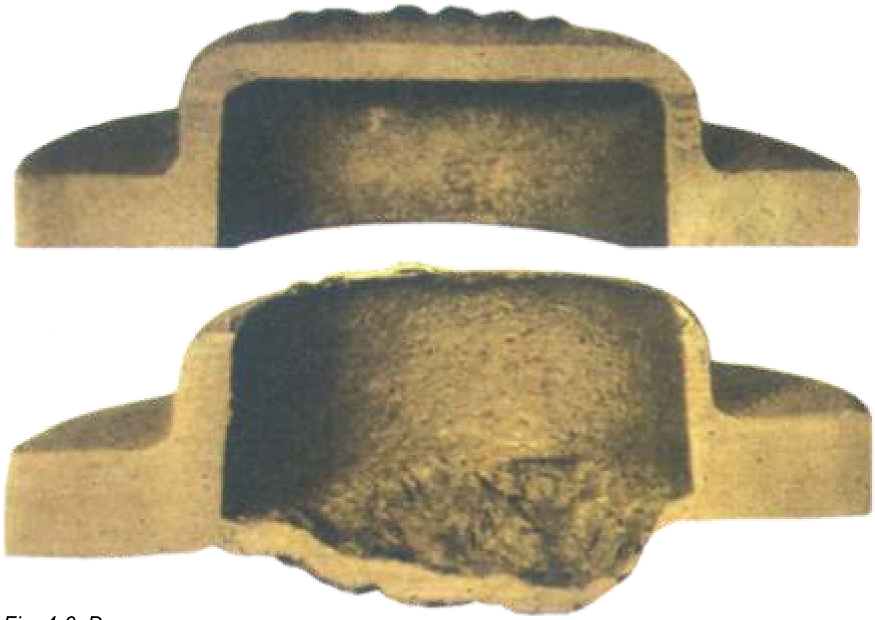


Fig. 4-6. Drop.

Erosion Scabs

While similar in appearance to an expansion scab, an erosion scab is usually found in the drag, where sand has been loosened by the metallostatic pressure of flowing metal during pouring.

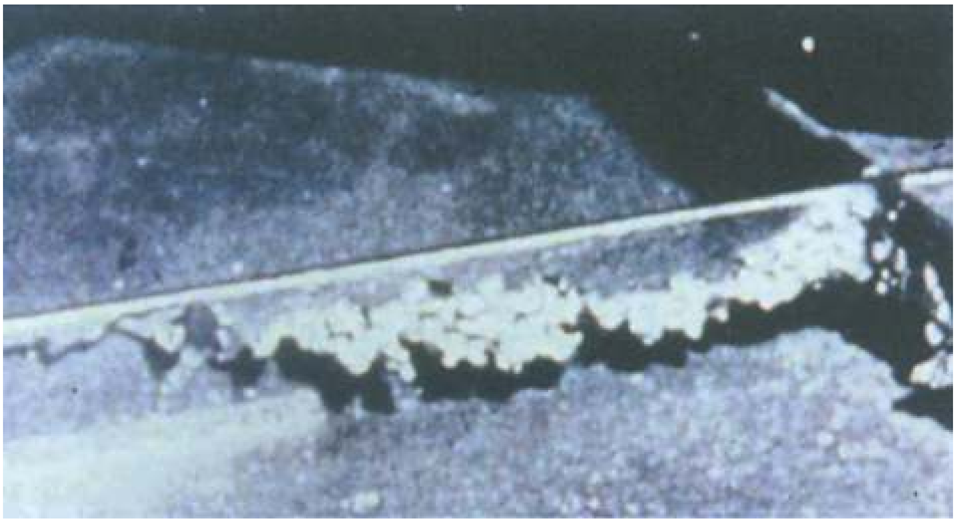


Fig. 4-7. Erosion scab.

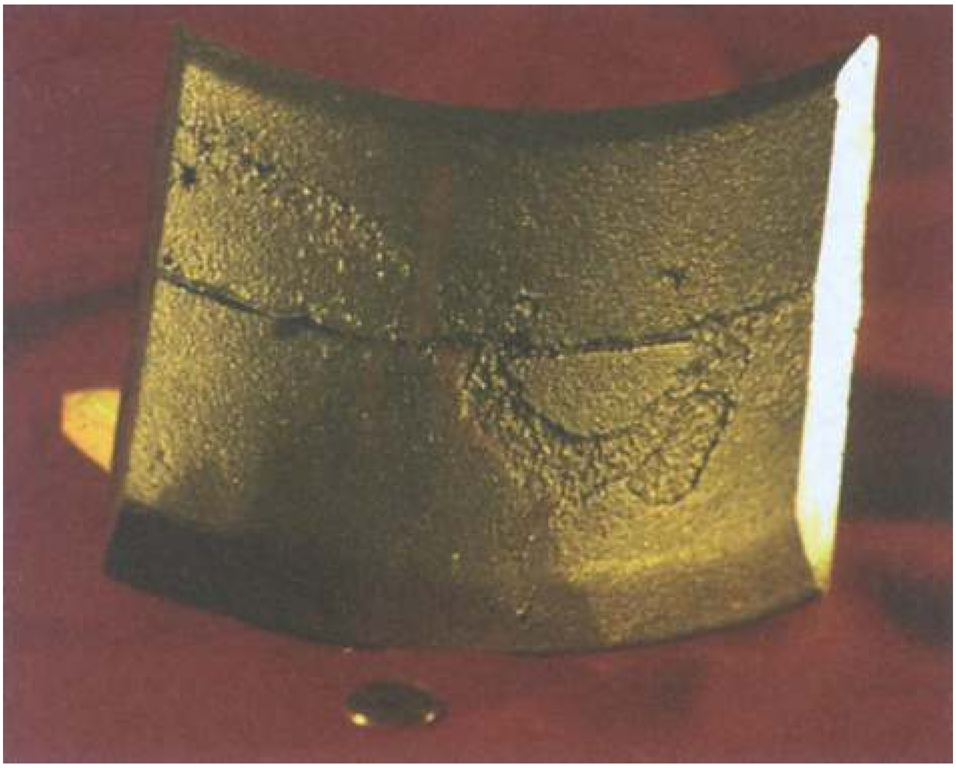


Fig. 4-8. Erosion scab.

• **Stickers**

A sticker defect is an irregular massive projection usually found on the cope surface and suggests a detachment of the mold wall. Stickers can be mechanically related-pattern equipment, molding apparatus or inadequate sand molding procedures.

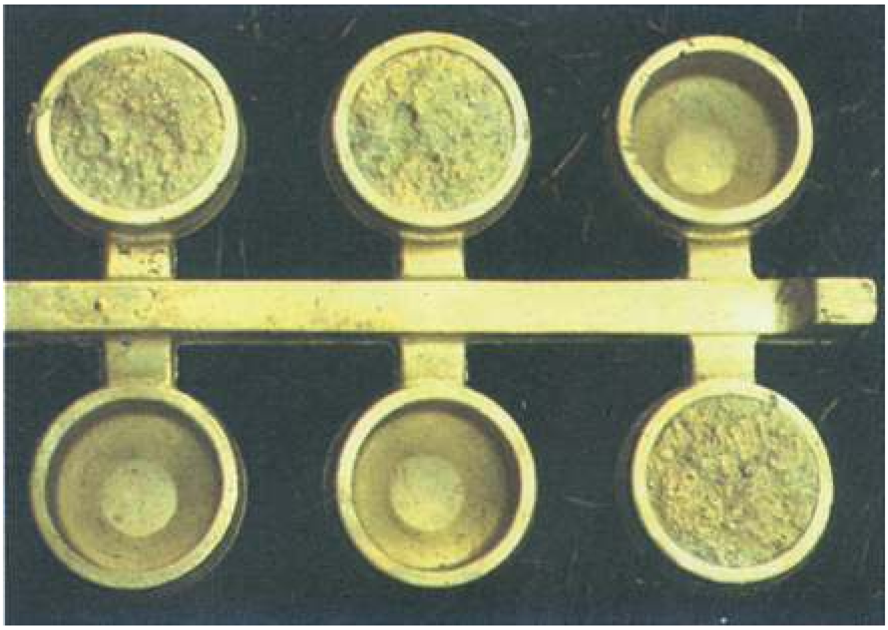


Fig. 4-9. Sticker.

Fig. 4-10. Sticker is caused by poor sand molding and pattern problems.

- **Cuts and Washes**

Cuts and washes are irregular, rough projections on the surfaces of a casting. They are usually in the vicinity of gates or on the drag surface following a line along the course of metal flow into the mold cavity.

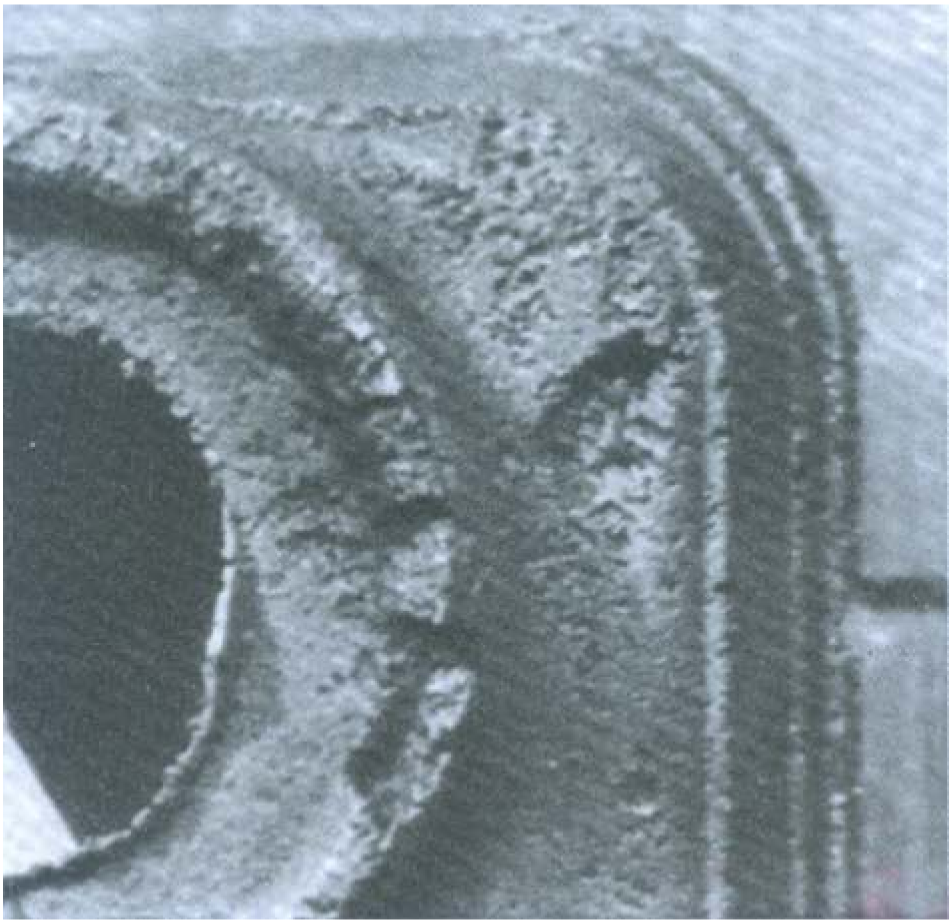


Fig. 4-11. Wash.

Fig. 4-12. Wash.

- **Poor Surface**

Poor surface is generally the result of grain fineness distribution being too coarse, insufficient green sand strength or erosion of the mold surface during pouring (too turbulent).

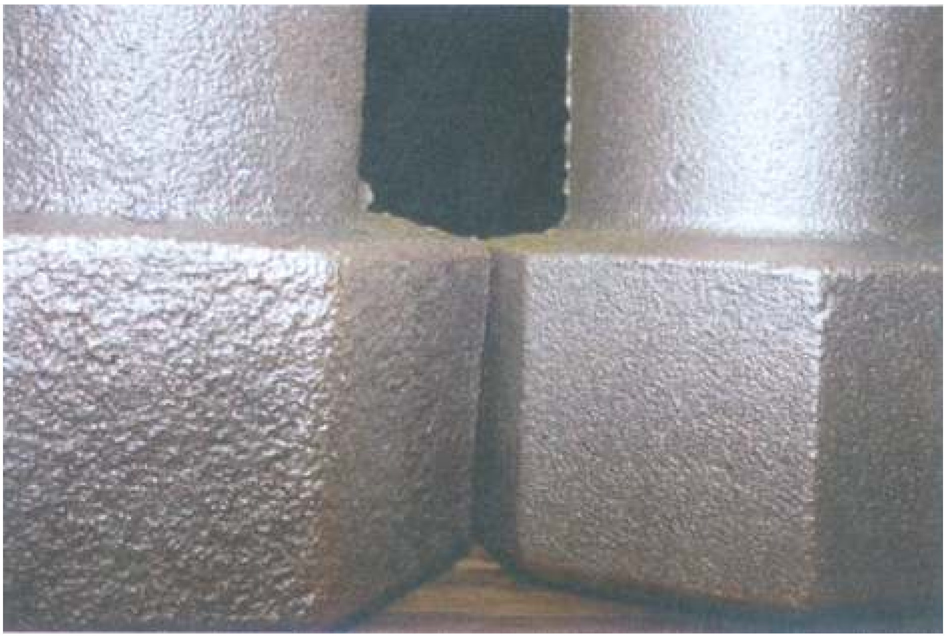


Fig. 4-13. Rough surface on red brass is due to wet sand (moisture too high).

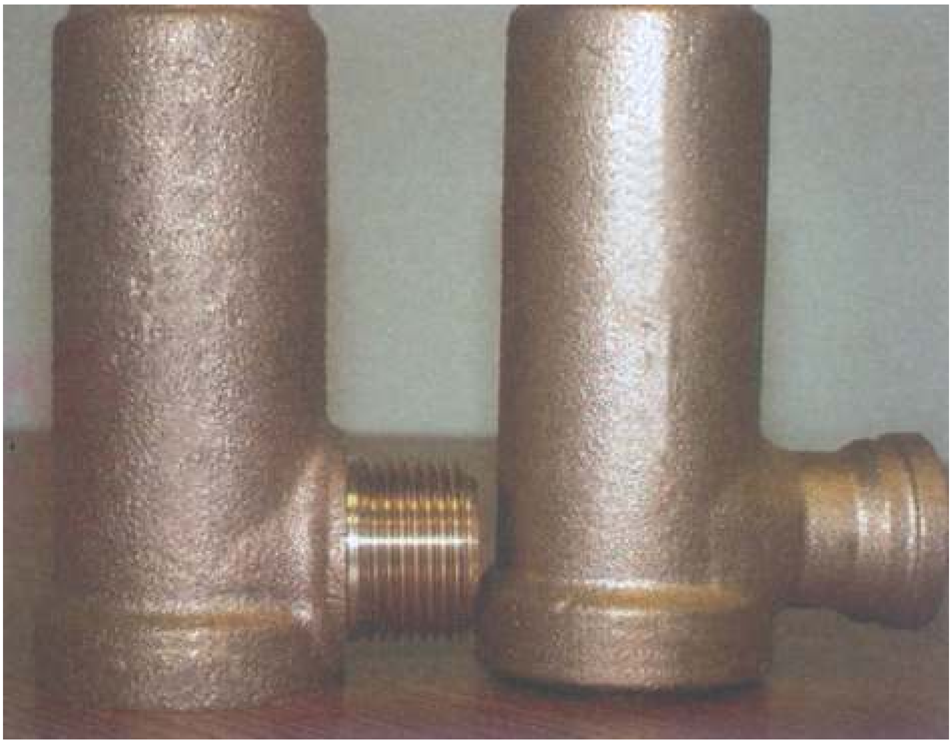


Fig. 4-14. Rough surface on red brass is due to too coarse grain fineness distribution.

• Core Problems

Core problems result from improper to incorrect core production (sizing) or inadequate core setting within the mold prior to closing.

Fig. 4-15. Dimensionally incorrect core in red brass results in crush.

Fig. 4-16. Improper core alignment in red brass.

Fig. 4-17. Improper core placement in red brass.

Fig. 4-18. Core lift results from inadequate placement; worn core prints allow 'float' in the mold.

Misruns and Coldshuts

Description

A misrun casting is one in which the casting detail is incomplete due to a failure to fill the mold cavity.
A portion of the casting may be missing, and/or necessary sharp corners may be rounded. Since these defects are related to casting design and also pouring practice, all casting methods (green sand, chemically bonded sand, permanent and semi-permanent mold) can be susceptible.
A cold shut involves a visual and structural discontinuity due to separate metal flows or where two or more metal streams have come together and fused. This can occur especially in large thin flat sections of the casting.
Both defects result from inadequate pouring practice, although casting geometry, molding equipment, and mold condition play important roles.

Causes

1-Casting Geometry

- Irregular casting sections resulting in interrupted metal flow
- Casting sections too thin relative to metal fluidity
- Isolated thin sections

2-Mechanical and Equipment

- Worn pattern equipment
- Misalignment of pattern equipment
- Core shift
- Weak or improperly reinforced flasks
- Cope or drag shift

3-Sand, Core, Molding Practice

- Excessive moisture
- Sand organic components too high
- Sand too weak causing mold distortion
- Permeability too low creating back pressure
- Inadequate venting
- Improper core size resulting in decreased metal sections
- Excessive mold wash
- Mold and core material with excessive chill reducing metal fluidity

4-Gating, Risering, Pouring Practice

- Inadequate gate and/or runner sizing
- Sprue too small
- Multiple sprues
- Interrupted pouring
- Pour temperature too low
- Inadequate pour height and/or metal pressure
- Pouring too slowly
- Debris in mold hindering metal flow
- Solid debris in metal pour stream
- Poured short (pour volume inadequate)
- Inadequate venting
- Dirty or gassy metal which reduces fluidity

Fig. 5-1. A bronze screw nut cast in green sand shows effect of interrupted pouring.

Fig. 5-2. A cupro-aluminum permanent mold casting exhibits a misrun due to lack of venting.

Fig. 5-3. A brass valve body cast in permanent mold shows a misrun caused by entrapped air.

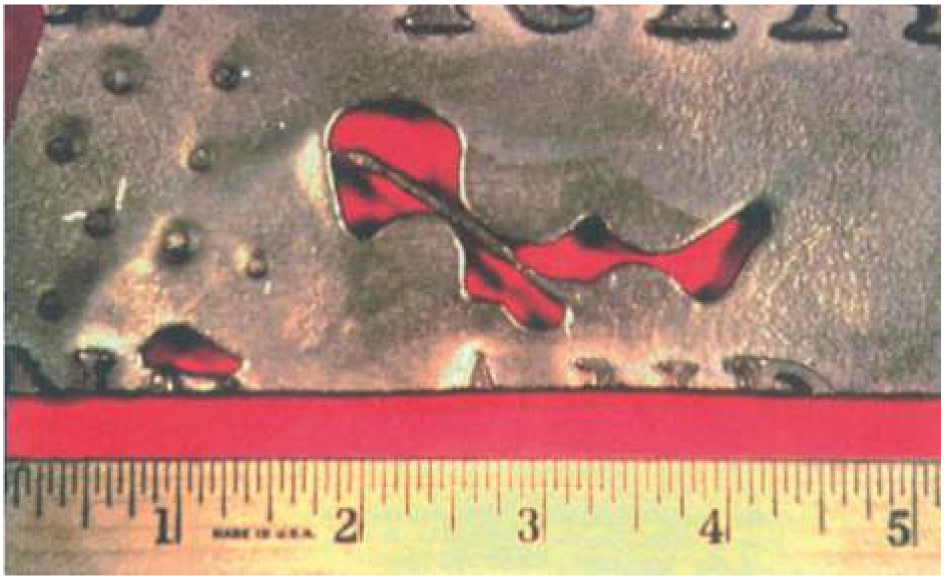


Fig. 5-4. Misrun due to improper gating. When non-pressurized gating was subsequently used, the defect no longer occured.

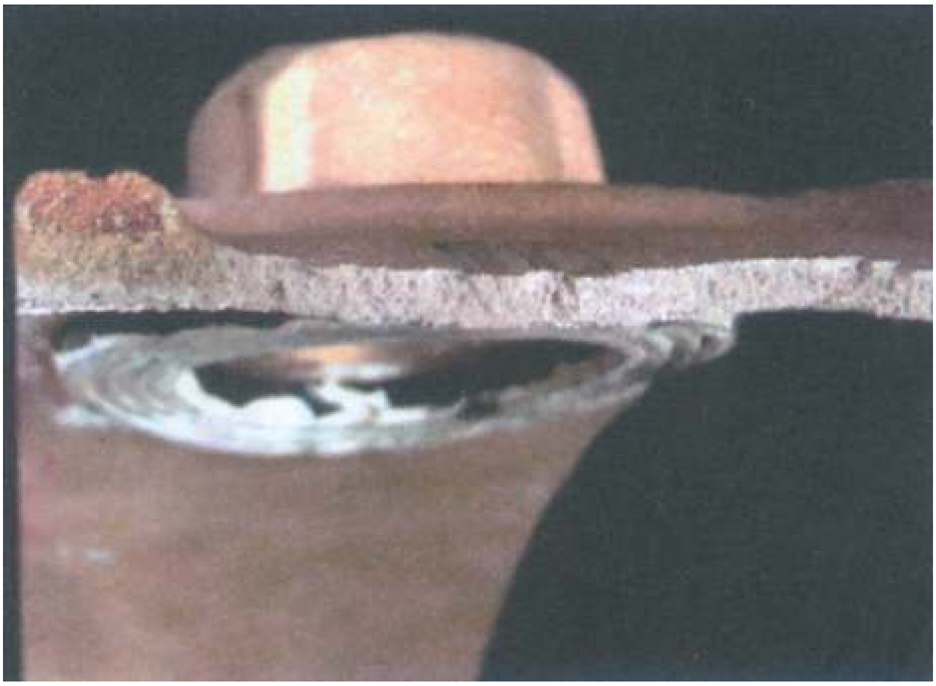
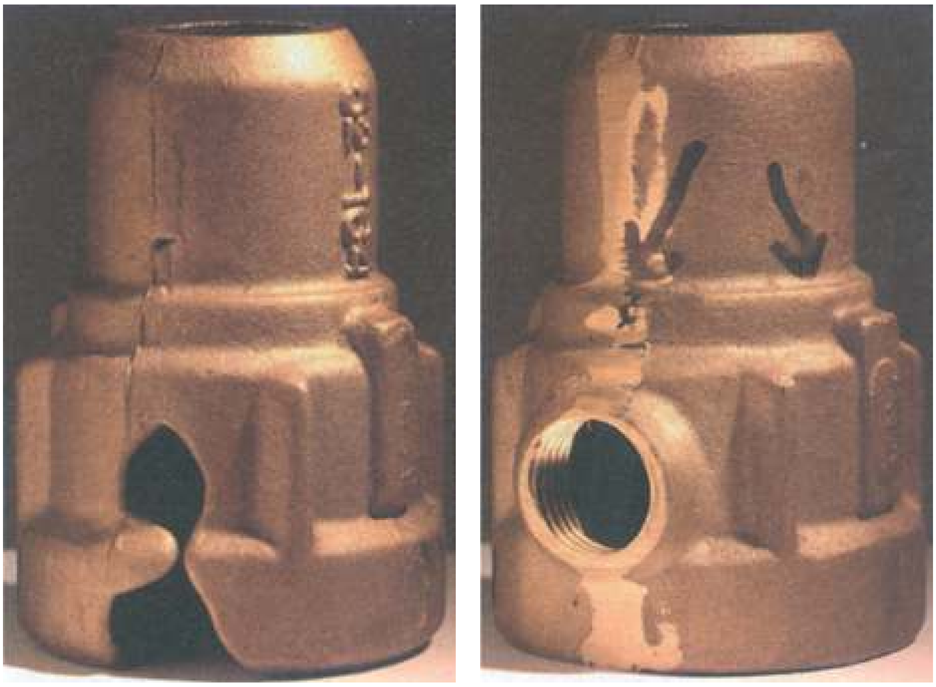


Fig. 5-5. Unsatisfactory ingate solidification in leaded red brass.



(a) (b)

Fig. 5-6. Cold shut and incomplete filling is visible in this red brass casting: (a) left view and (b) right view. Possible causes (any and all) include core gas evolution, inadequate venting, and low pouring temperature.

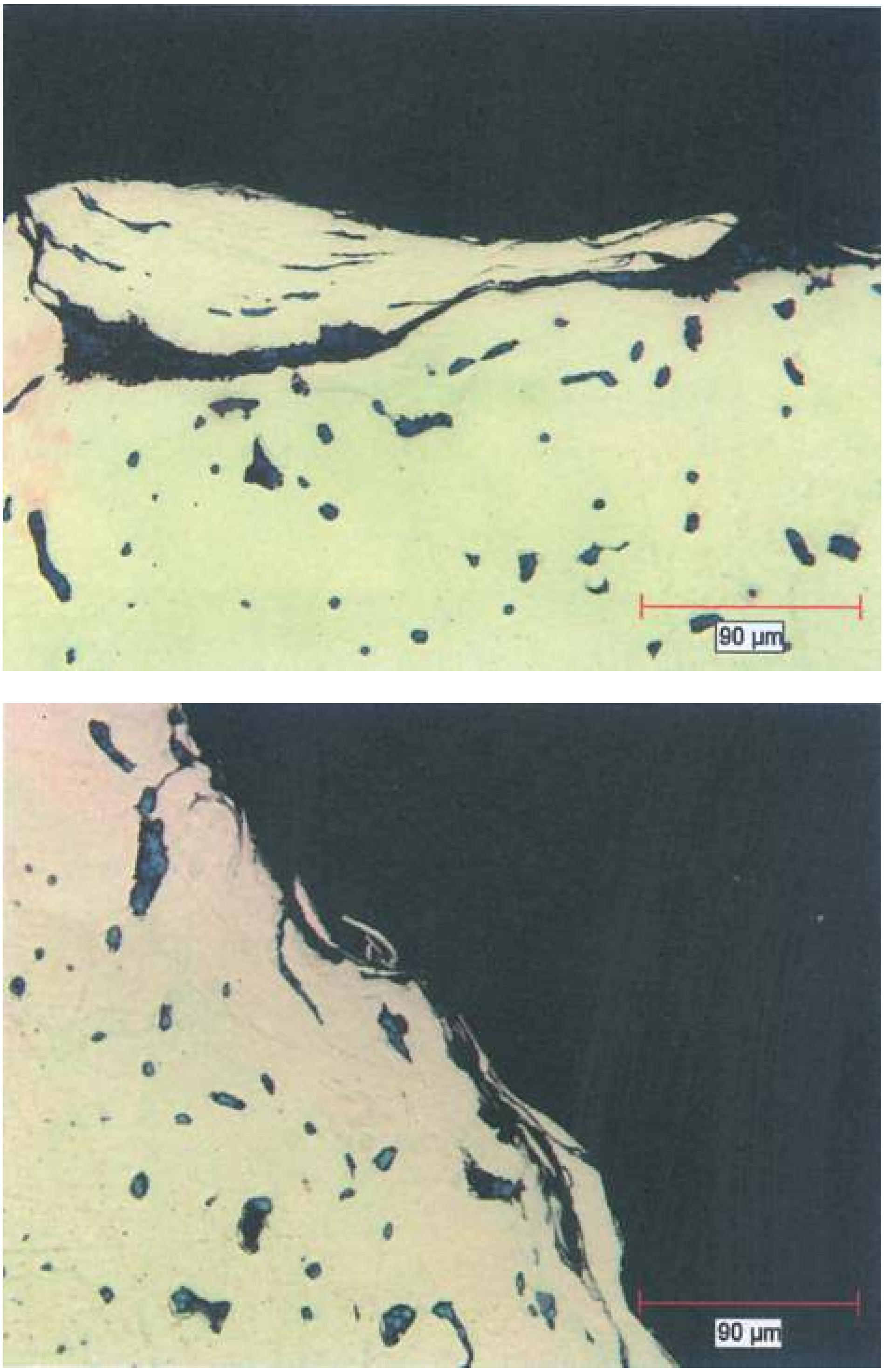


Fig. 5-7. Folds, misrun in yellow brass are due to improper pouring procedure and possible low temperature.

Fig. 5-8. A misrun in red brass is caused by low temperature, inadequate gating and low phosphorus deoxidation.

Fig. 5-9. A red brass casting shows a short pour and inadequate volume.

Fig. 5-10. A dimensionally incorrect red brass casting due to core shift.

Hot Tearing

Description

Hot tearing occurs in nonferrous casting during the pouring and solidification process before the casting becomes compeletely solid. Phsycal constraints restrict the casting from normal contraction. Causes of hot tearing are many-casting design, molding practices, pouring and basic metallurgy of the alloy. The crack or tear in the casting is usually interdendritic with an oxidized surface because of the high temperature.

Causes

1-Mechanical and Equipment Related

- Lack of adequate fillets
- Abrupt changes in section thickness
- Flask equipment preventing adequate casting contraction
- Rough handling too soon after pouring

2-Sand, Core, and Molding Practice

- Poor sand collabsibility (strength too high)
- Grain size too large
- Sand too low in combustibles
- Low hot deformation capability
- Vitrification of the sand
- Excessively rigid molds and cores
- Failure to use chills or chills improperly placed
- Delayed shakeout

3-Metal Molds

- Mold open too soon; casting damaged during extraction
- Rough mold surface
- Cores improperly aligned
- Excessive pouring temperature
- Excessive mold temperature
- Poor ejector locations causing bending stresses
- Excessive cooling time prior to knockout

4-Pouring

- Pouring temperature too low to promote collapsibility
- Excessive pouring temperature creating hot spots in thin sections
- Inadequate flow (filling) of liquid metal in the mold cavity
- Cooling too fast
- Shakeout too soon

5-Metallurgical

- Alloy segregation with low melting point metal (tin, lead, zinc) concentration in last metal to solidify
- Contaminants, tramp elements
- Large grain size

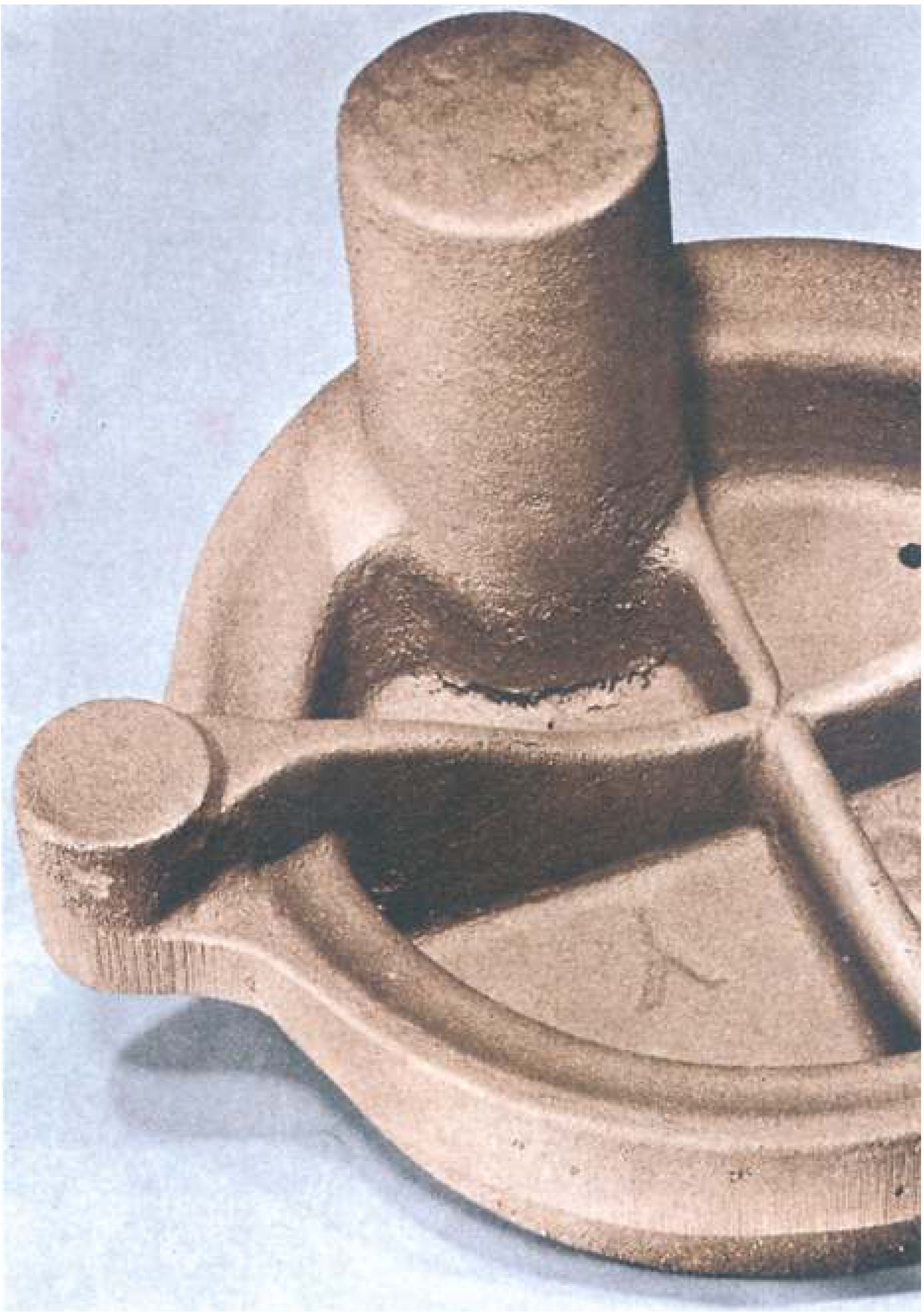


Fig. 6-1. Bronze alloy in dry sand that shows shrinkage extending to surface as a hot tear.

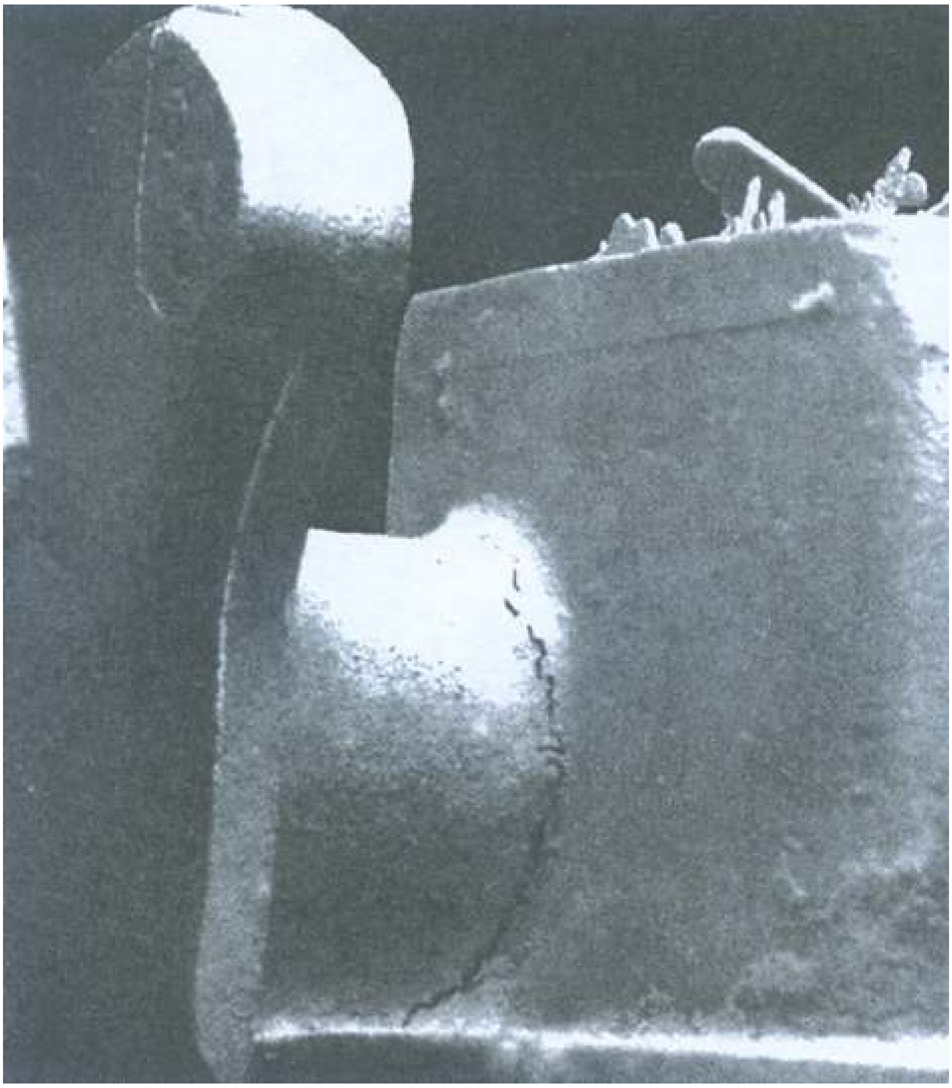


Fig. 6-2. Green sand oil reservoir thin casting of 10% Sn, 1% Zn bronze shows a hot tear, caused by restrained contraction.

Fig. 6-3. The hot tear in the brass valve body in green sand is due to restrained contraction and excessive pouring temperature.

Fig. 6-4. A fracture in red brass cast in green sand exhibits excessive dendrite growth due to excessive melt and/or pouring temperature; venting helps.

Fig. 6-5. Hot tear in red brass caused by shakeout, which is too soon and/or too hot.

Fig. 6-6. The hot crack in the brass sand casting is due to mold constraint and high pouring temperature.

Fig. 6-7. The hot tear in red brass resulted from the binder content being too high and from mold restraint.

Fig. 6-8. Hot tear in a leaded semi-red brass.

Gas Defects

Description

Gas defects arise from the presence of gas in the liquid metal which forms porosity in the casting as the metal solidifies. The porosity may take the form of a cavity or visual blowhole, pinholes, or blisters. Sources of the gas, which may include hydrogen, air or volatile organics, include gas soluble in the liquid metal, gas arising from moisture in the sand, core out gasing, entrapped air and mold and core wash out-gassing. Gas defects are detrimental to machining, surface finishing, and mechanical properties of the casting.

Causes

1-Mechanical and Equipment

- Insufficient mold and/or core permeability
- Lack of adequate venting of mold cavity

2-Sand, Core, Molding Practice

- Moisture content too high
- Poorly mixed sand
- Clay content too high
- Wet coatings
- Inadequate permeability for volatile organic burn-off
- Under-cured cores
- Excessive binder
- Inadequate venting
- Wet core paste
- Absorbed moisture during storage
- Chill or sealing materials not dried
- Excessive gas-producing material in core sand or wash
- Insufficient dried molds

- Excessive patching
- Hard spots caused by improper ramming for conditions involved

3-Gating, Risering, Pouring

- Wet pouring basins and/or sprues
- Sprue and/or gating system inadequately sized
- Entrainment of air due to turbulance in the sprue and runner system
- Turbulent or interrupted pouring
- Short pours unable to fill mold cavity
- Cold, damp ladles
- Pouring rate too fast or too slow
- High humidity condensation on cold mold sprue and gating system

4-Metallurgical

- Melt too gassy or inadequately degassed and/or de-oxidized
- Excessive melt and/or pouring temperatures
- Metallic impurities in the melt with affinity for hydrogen

Fig. 7-1. A rise is associated with gas porosity in the casting.

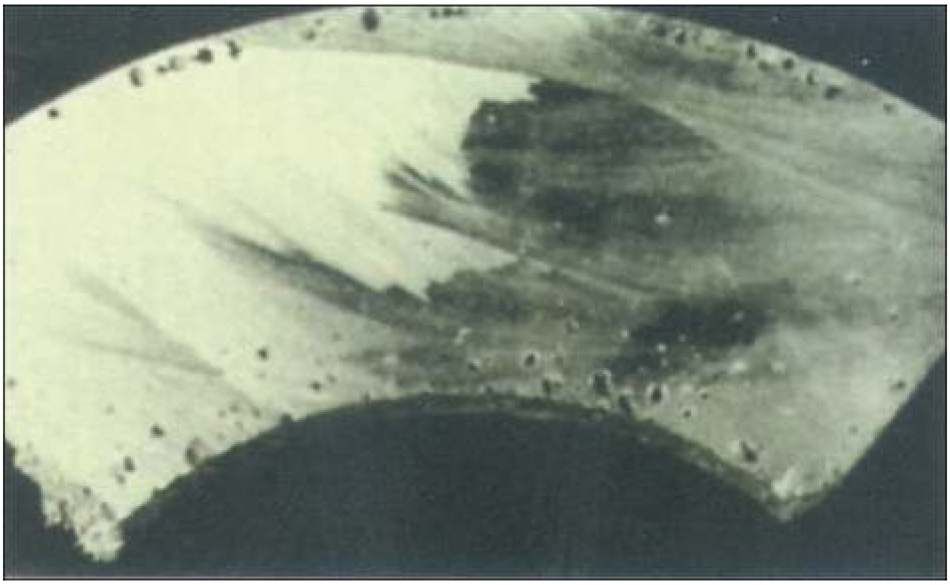


Fig. 7-2. Gassing due to metal mold reaction.

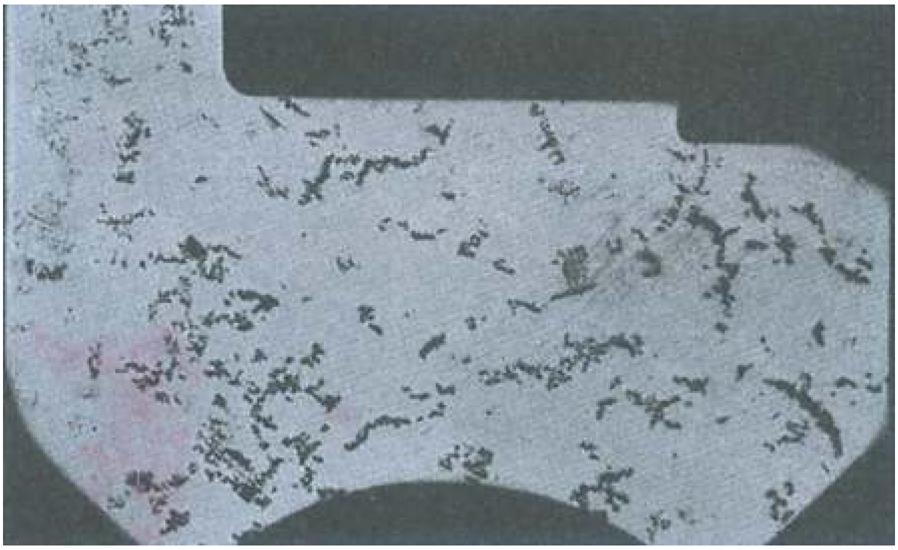


Fig. 7-3. A bronze casting displays macro-porosity.

Fig. 7-4. Tin bronze alloy cast in dry sand has blowholes due to gassy melt.

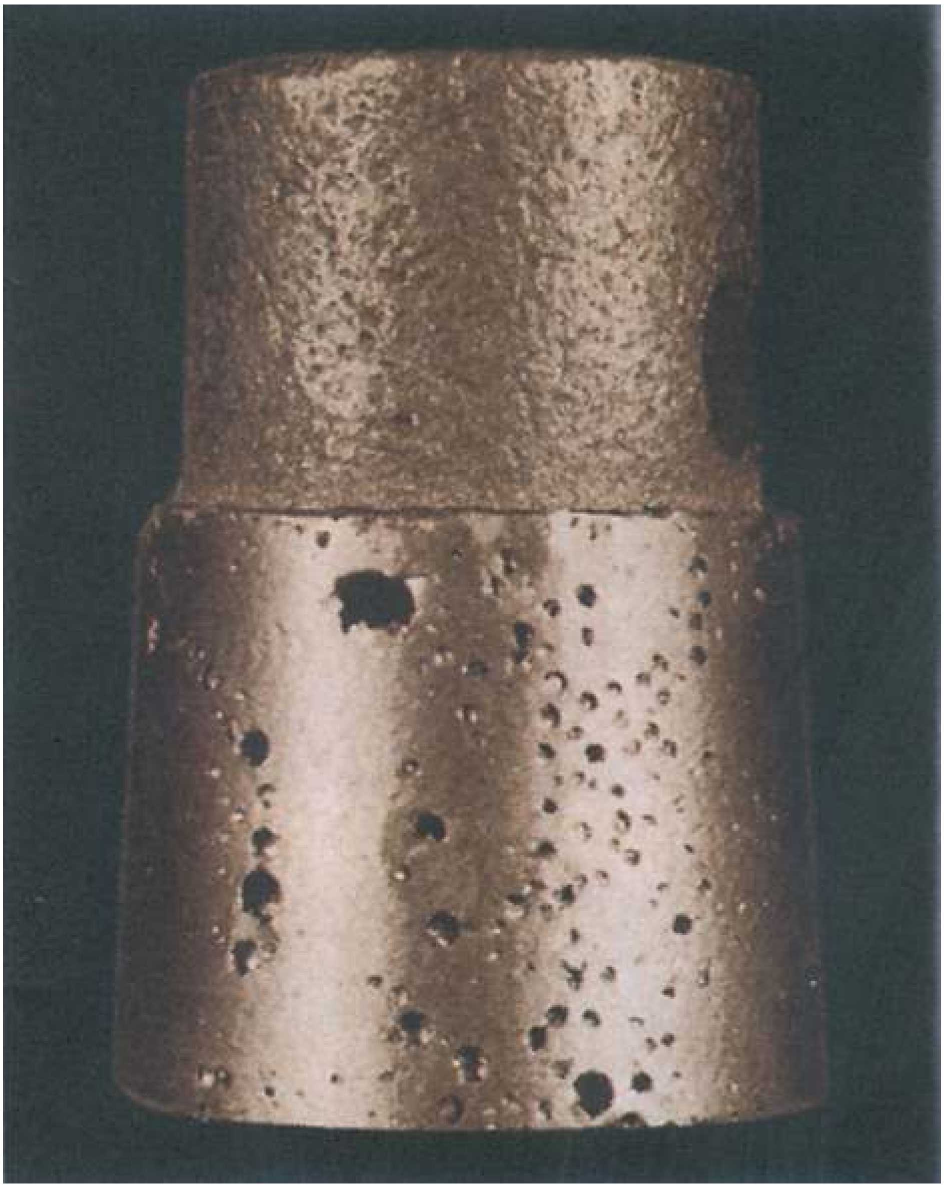


Fig. 7-5. Bronze stopper cast in green sand has blowholes due to gassy melt and/or mold/metal reaction with excessive moisture in the sand.

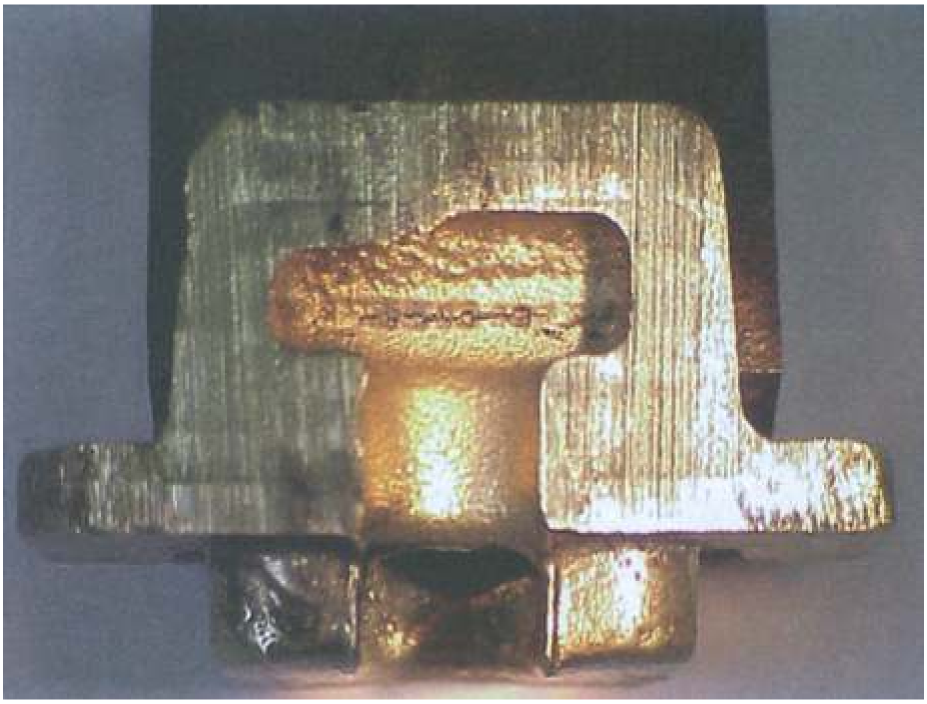


Fig. 7-6. A heavy section of a red brass faucet reveals centerline shrinkage and/or gas porosity.

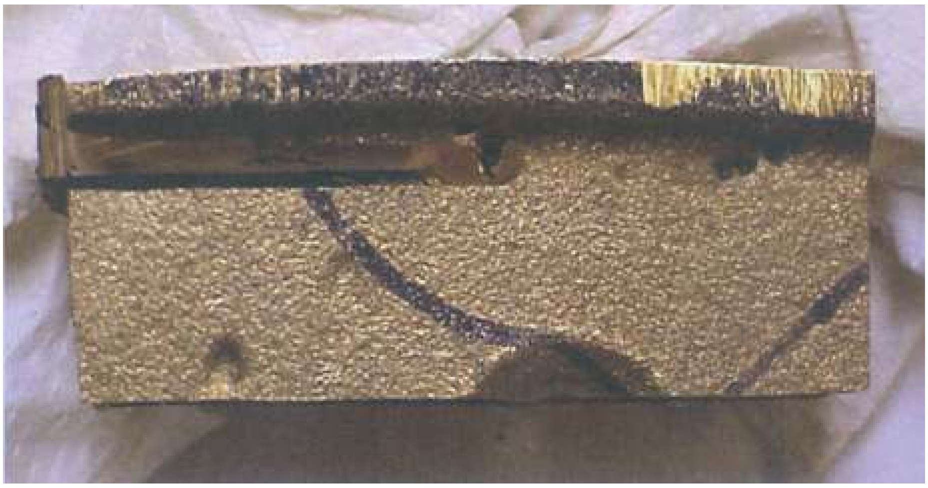


Fig. 7-7. A red brass casting exhibits a gas blow.

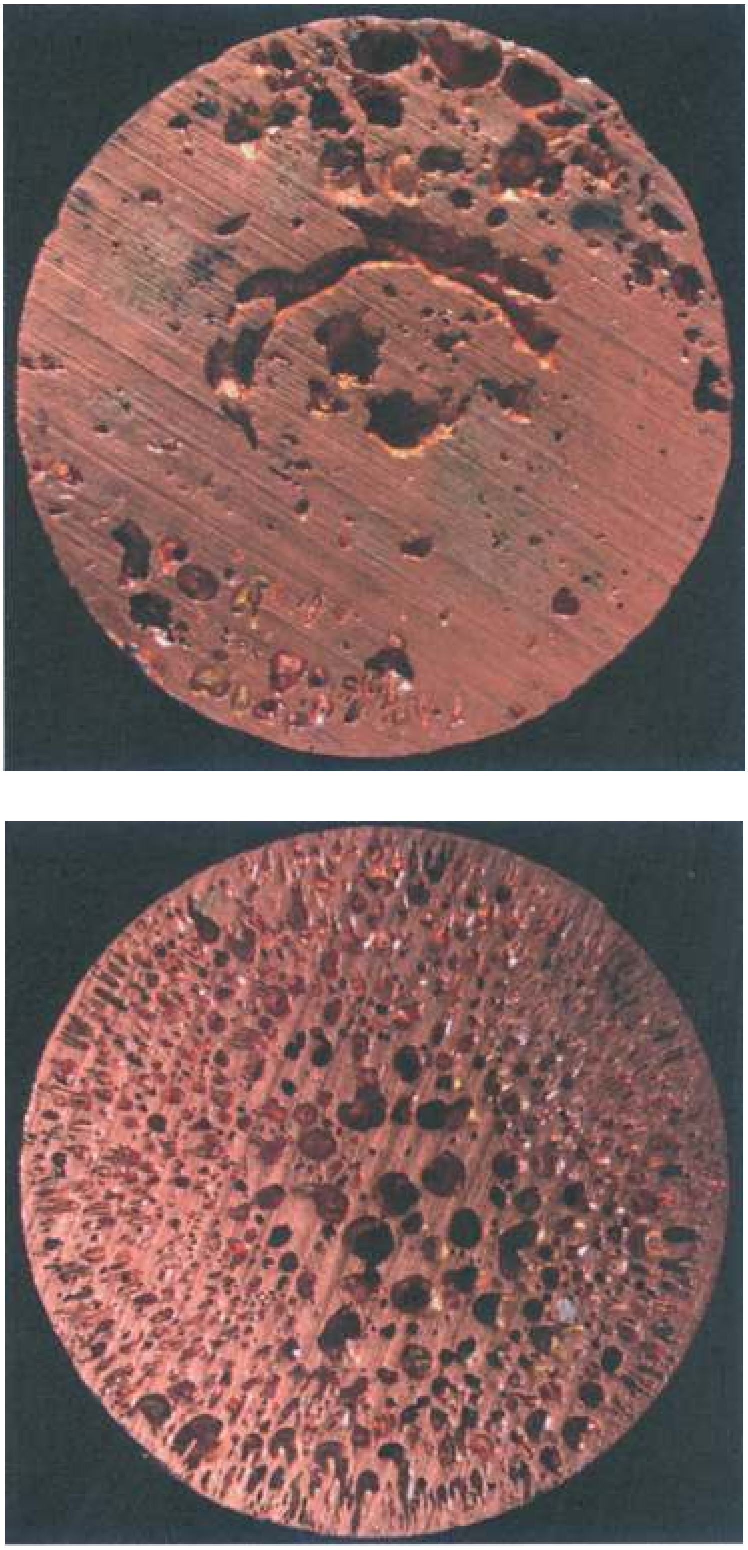


Fig. 7-8. Two views of a high copper casting, exhibiting massive porosity due to poor or no deoxidation and/or degassing.

Fig. 7-9. A discoloration and porosity in red brass is due to gas evolution and high pouring temperature.

Fig. 7-10. X-ray of cast test bar exhibits gross porosity in brass.

Fig. 7-11. Severe gas porosity is seen in red brass.

Fig. 7-12. A copper base casting shows a 'mushroom' gas evolution.

Fig. 7-13. A core gas blow in leaded red brass is the result of poor venting and pouring temperature being too high. Also, inadequate gating causes localized heating at a thick section and a concentrated gas blow within the casting.

Fig. 7-14. A gross blow and dispersed porosity in red brass is the result of a wet core adhesive and improper venting.

Fig. 7-15. Pinholes in aluminum bronze result from inadequate degassing.

Fig. 7-16. The 'mushrooming' copper casting is due to high gas content in the melt.

Fig. 7-17. Heavy section brass casting exhibits gas blow during final solidification. Potential solutions are de-gas; provide better feeding; use of chills and lower pouring temperature.

Shrinkage Defects

Description

As a casting solidifies, there is a contraction from liquid to solid state. The casting design geometry should allow for generalized controlled overall shrinkage. Often, however, there is undesirable localized shrinkage. A shrinkage depression or cavity in a casting may form, and may or may not be related to the presence of gas. Shrinkage as a depression on the surface is considered to be macro-shrinkage, while in the interior of a casting there may be dispersed or microshrinkage. Macro-shrinkage is usually associated with or surrounded by a cast interdendritic structure, often spongy, and is related to inadequate mold filling. Micro-shrinkage takes the form of pinholes or small cavities within the interdendritic network.

Micro-shrinkage often occurs in the last section of the casting to solidify and also may be related to gas content evolving during solidification as well as inadequate feedin.

Causes

1-Mechanical and Equipment

- Abrupt changes in casting section thickness
- Inadequate fillets
- Insufficient feeding
- Insufficient cope height

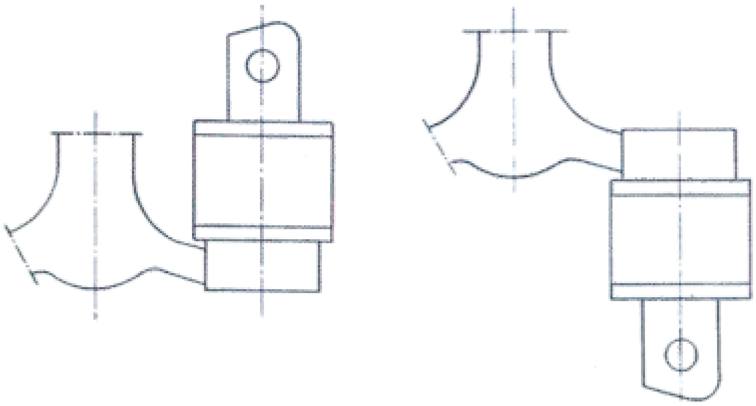
2-Sand, Core, Molding Practice

- Wet sand
- Low compressive strength
- High hot deformation
- Core shift
- Weak cores
- Lack of fillets
- Soft ramming
- Mold wall movement under pouring pressure

3-Gating, Risering, Pouring

- Inadequate riser volume
- Insufficient riser placement
- Lack of necessary chills
- Need for exothermic riser compounds or sleeves
- Pouring too hot or too cold
- Failure to top off risers with hot metal
- Incorrect gating for part design

Fig. 8-1. Brass sand casting shows centerline shrinkage crack. Lowering iron and tin content, increasing riser size and reducing pouring temperature would eliminate the shrink.



(a) Existing Gating (b) Bettern Solution

Fig. 8-2. Permanent mold cupro-aluminum casting exhibits shrinkage cavity due to inadequate feeding through bottom gating into the heavier section.

Fig. 8-3. Centerline shrinkage in red brass is caused by insufficient feeding.

Fig. 8-4. Severe macro shrinkage in leaded red brass is caused by too low of a pouring temperature and/or insufficient feeding.

Fig. 8-5. Shrinkage porosity in red brass is caused by poor solidification (low pouring temperature, inadequate feeding).

(a)

(b)

Fig. 8-6. Sink and shrinkage crack in permanent mold cast gunmetal resulted from the temperature being too low and form mold coating erosion: (a) crack in casting; (b) defect magnified.

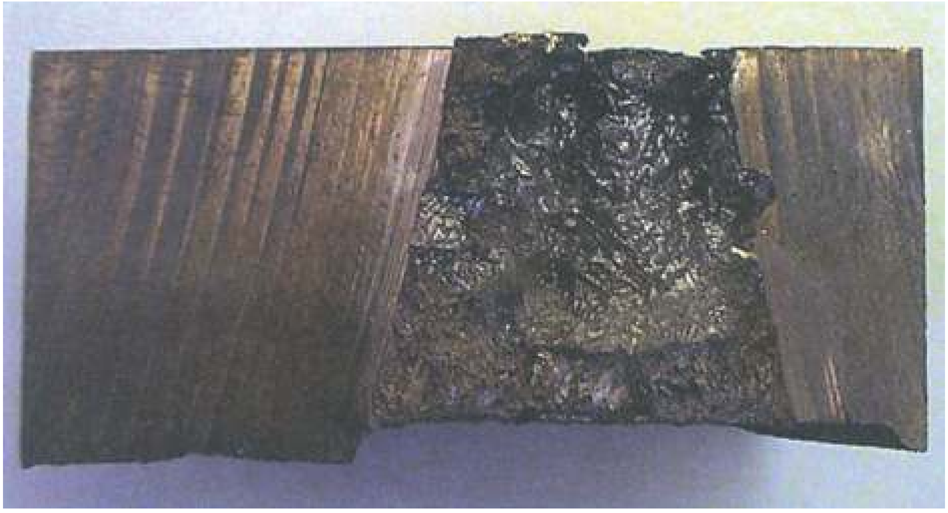


Fig. 8-7. Shrink in semi-leaded red brass resulted from incorrect pouring temperature and inadequate risering.

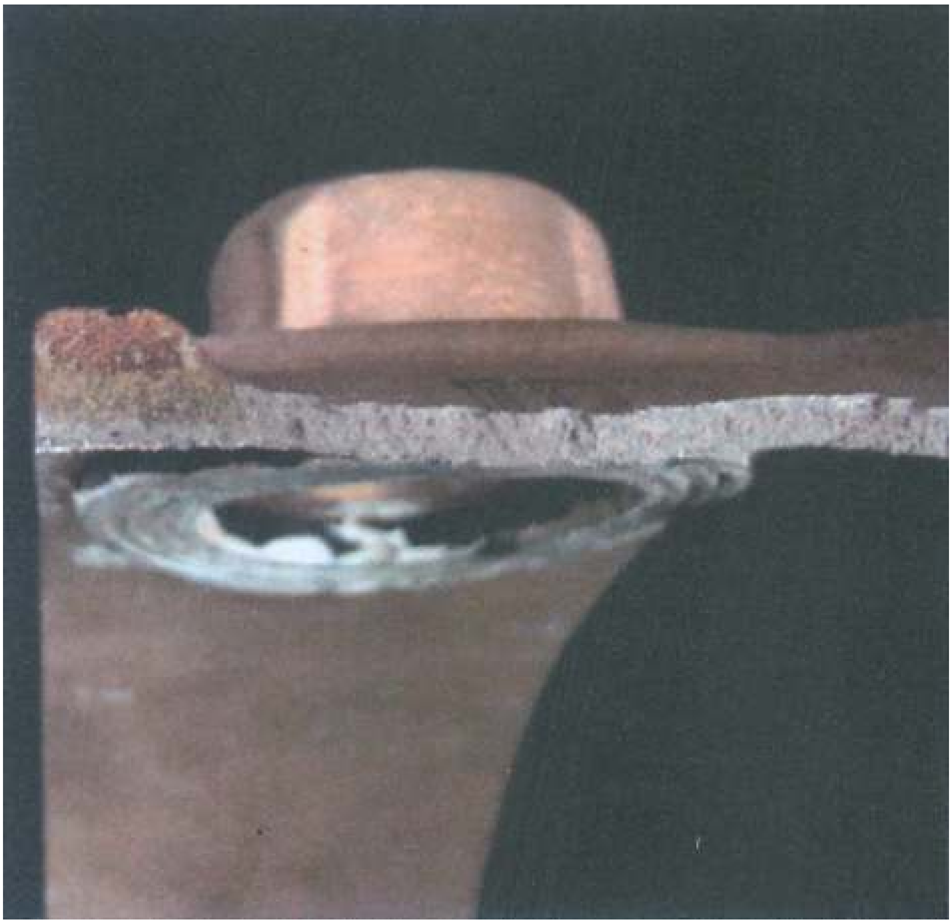


Fig. 8-8. Casting shows shrinkage from inadequate ingate solidification.

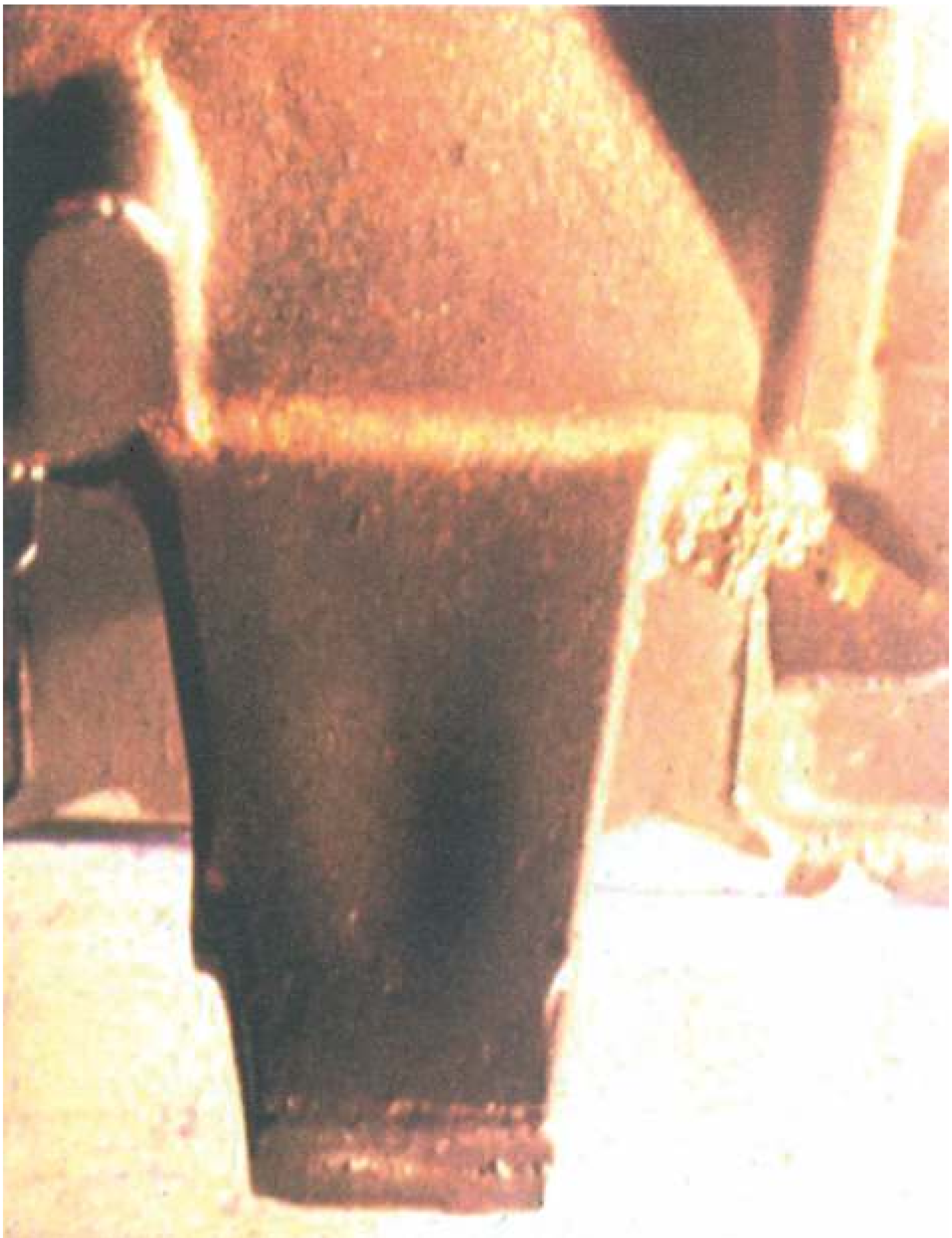


Fig. 8-9. Surface sink is due to lack of feeding; uniform shrinkage occurs without rupturing the surface.

Metal Penetration

Description

Metal penetration defects occur in the sand casting process due to high fluidity of the liquid metal and weakness in the mold surface. A somewhat less insidious interaction between the liquid metal and the mold is burn-on, which is a strongly adherent crust of sand. A visual discoloration of the mold surface results, as well as localized increased grain size in the microstructure, which may or may not to be detrimental depending upon the casting's utilization. Burn-on sand must usually be removed by grinding rather than blast cleaning.

Causes

1-Mechanical and Equipment

- Sharp corners

2-Sand, Core, and Molding Practice

- Poorly sand mixing
- Irregular grain size distribution leading to poor ramming
- Low mold density
- Excessive mold permeability
- Soft cores
- Incorrect core material
- Rough core surface
- Insufficient core binder or curing
- Poorly patched areas
- Excessive usage of parting compounds
- Uneven mold coating application

3-Gating, Risering, Pouring

- Too close positioning of gates and risers promoting overheating of the sand
- Pouring too hot
- Excessive pouring height
- Turbulent metal flow during pouring

Fig. 9-1. A bronze alloy in green sand exhibits burn-on.

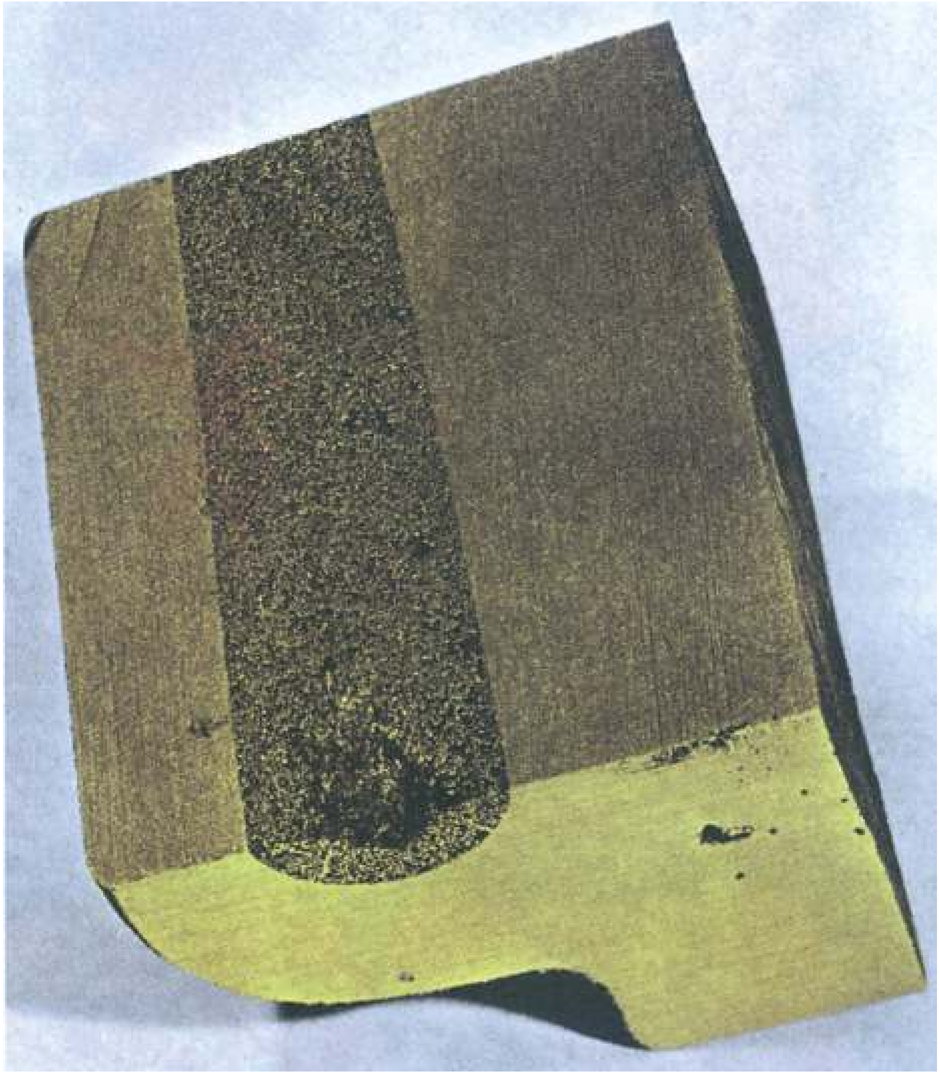


Fig. 9-2. A bronze alloy in dry sand exhibits metal penetration at the core despite use of a core wash. The remedy is to switch to shell core.

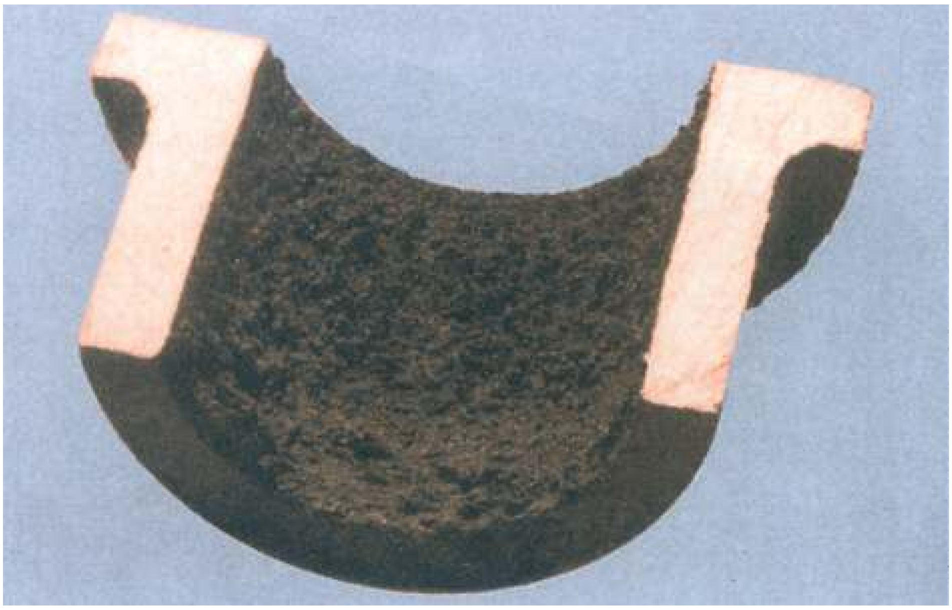


Fig. 9-3. Phosphor bronze green sand casting shows uniform penetration due to low surface tension liquid metal and lack of proper core wash coat (graphite). The solution is to employ higher density sand with higher thermal conductivity to enhance faster solidification.

Fig. 9-4. The casting shows a burn in or metal penetration caused by improper sand mixture, excessive metal fluidity, and pouring temperature.

Inclusion Defects

Description

Inclusion defects occur as the existence of insoluble particulate material trapped within the casting during solidification. Inclusions arise from the melting process; from contaminants; from fluxes and other melt treatment product debris; from breakdown of furnace and ladle refractories; from breakdown of mold and core materials and coatings during pouring and from turbulent pouring. Inclusions may be oxides or intermetallic compounds, dross or slag. Grain refining practices can create hard intermetallic constituents. Machining, surface finishing operations and mechanical properties are usually compromised by the presence of inclusions.

Causes

1-Mechanical and Equipment

- Casting design factors that contribute to metal flow problems in sand molds will increase tendency for inclusions to form
- Casting pattern design that prevents inadequate molding will increase tendency for loose sand to become entrapped within the casting
- Rough handling of molds and flasks
- Gouging of the mold during closing or core setting
- Inadequate venting

2-Sand, Core, and Molding Practice

- Inadequately mulled sand
- Sand grain size too irregular
- Inadequate molding resulting in low strength
- Metal-mold reaction
- Weak cores
- Excessive and/or improperly cured mold and core wash coatings

3-Gating, Risering, Pouring

- Gating systems which create turbulent flow
- Turbulent pouring
- Dirty ladles
- Inadequate dross separation from the melt prior to pouring
- Weak ladle refractories which spall during pouring
- Intermittent pouring
- Excessive pouring temperature

4-Melt and Metallurgical

- Tramp element impurities in excess of solubility limit, forming inter-metallic inclusions
- Charge mix with excessive fines and/or oxides
- Flux inclusions
- Melting furnace refractory erosion
- Excessive melt temperature
- Inadequate de-oxidation of the melt

Fig. 10-1. Brass casting contains dross inclusions.

Fig. 10-2. Bronze valve body cast in green sand shows sand inclusions caused by core erosion.

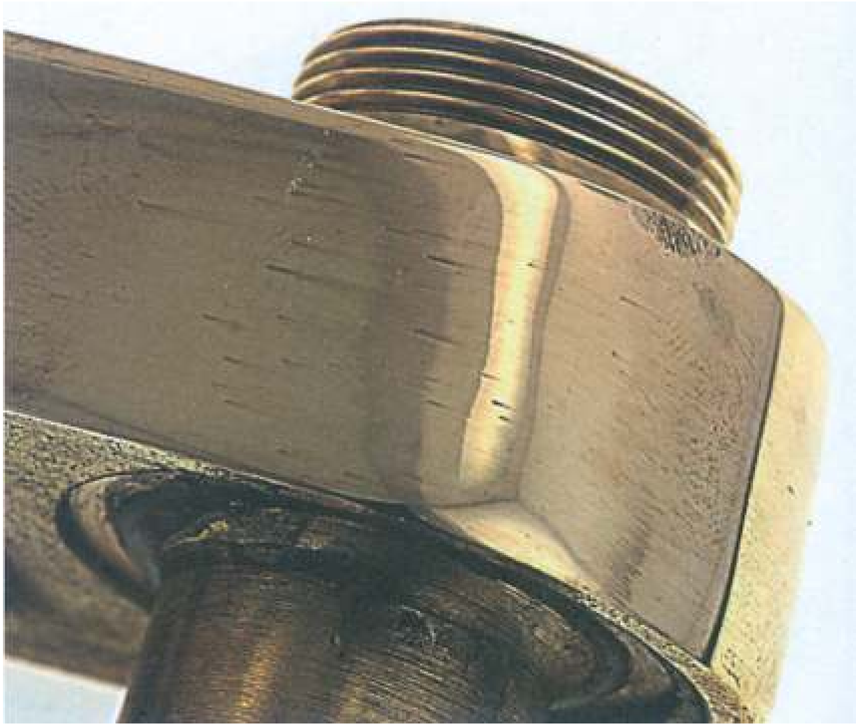


Fig. 10-3. The yellow brass has a comet tail blemish on the polished surface after machining. Possibly an iron-boron inclusion resulted from grain refining with boron.

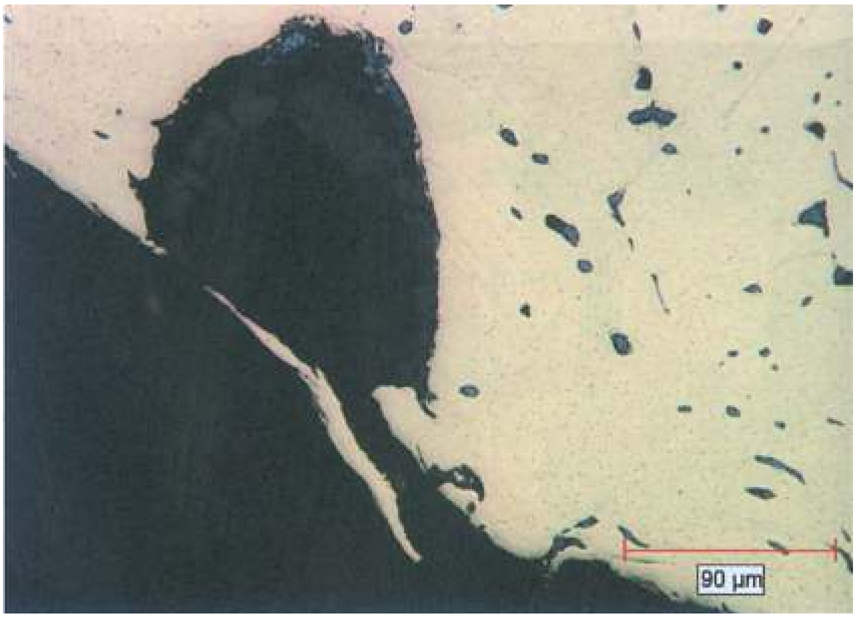


Fig. 10-4. A trapped sand grain is seen yellow brass. Mold erosion due to turbulent pouring and/or weak sand.

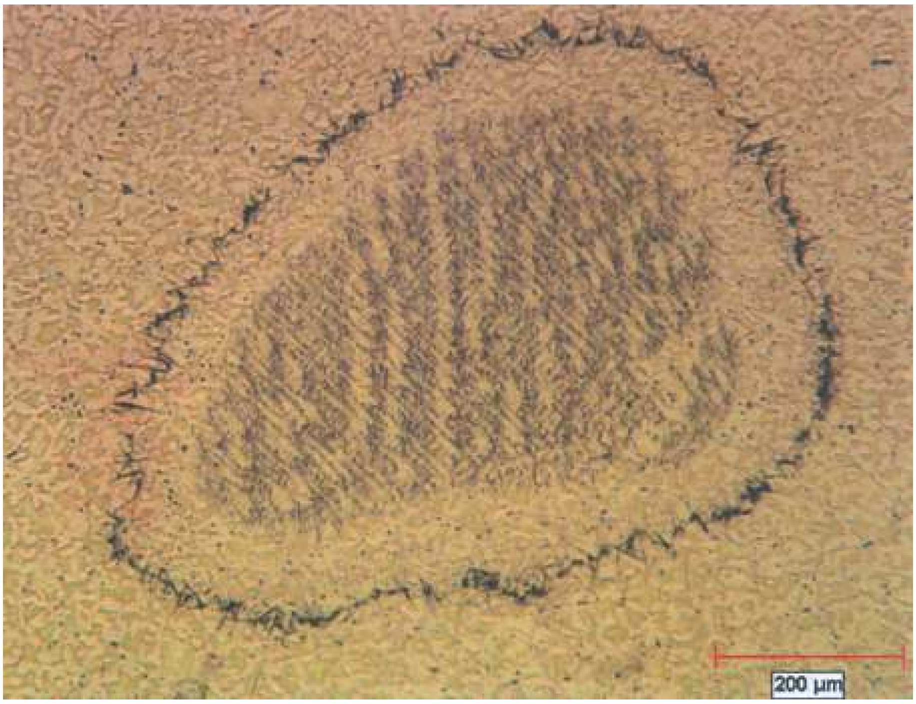


Fig. 10-5. Hard iron-containing particles in yellow brass are commonly found when grain refining with boron; controlling iron below 0,05% is a remedy.

Fig. 10-6. A macro-inclusion in brass casting is a possible refractory vessel erosion.

Fig. 10-7. Poor surface on aluminum bronze casting is due to excessive dross formation and lack of removal prior to pouring.

Others

Description

Another defect which can occur in copper alloy casting relates to low temperature metal alloy constituents (lead, tin), that segregate during latter stages of solification and exude from the surface of the casting.Exudation of the residual liquid occurs due to forces of contraction and the pressure of released gas. This surface defect is often accompained by microporosity. An example is tin sweat.

Flaring, or zinc flaring, is manifested as a surface visual defect that may also be accompained by an excessive reduction in zinc content in the casting. This occurs predominantly in yellow brass alloys.

It is due to excessive melt and pouring temperatures.

Cracked castings prior to service may arise from severe stress on the part due to machining. Any alloy segregation or inclusions may exacerbate this problem.

Fig. 11-1. Leaded tin bronze cast in green sand. Sprue exhibits tin sweat.

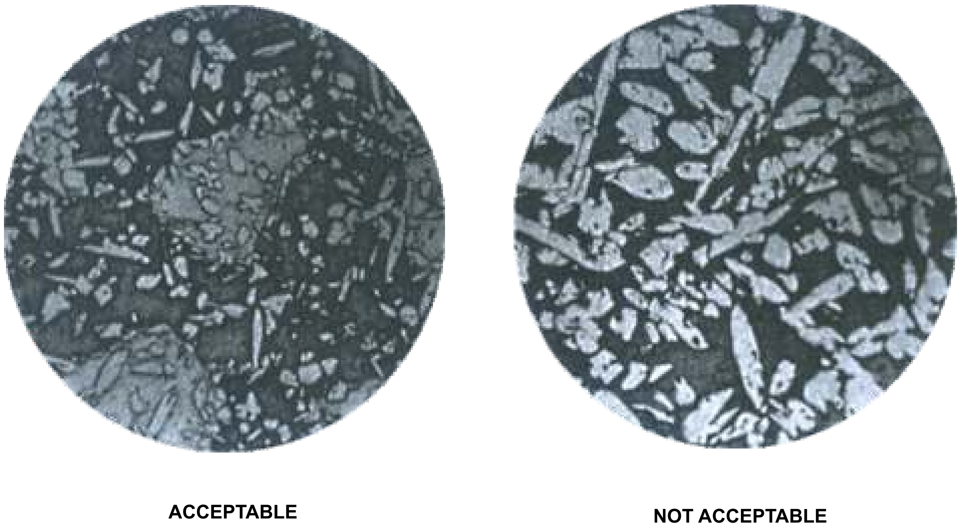


Fig. 11-2. Unacceptable manganese bronze microstructure had less zinc, even after a make-up addition, and exhibited lower mechanical properties.

Fig. 11-3. Red brass exhibits tin sweat, caused by long solidification and gas evolution. Proper degassing and directional solidification are remedies.

Fig. 11-4. Yellow brass casting crack, observed after machining, is possibly due to severe residual stress and/or temperature state during machining.

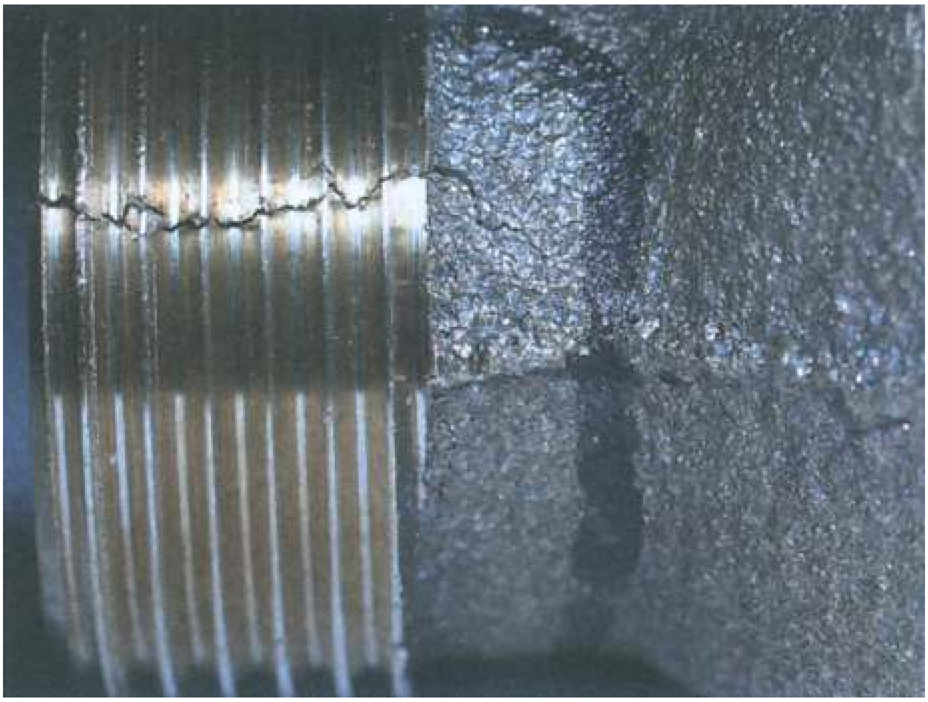


Fig. 11-5. Lead-free brass casting, cracked during machining, is caused by severe stress and heat.


Fig. 11-6. Over blast damage on brass casting is due to excessive shot or grit casting cleaning.

Investigations of Defects in Ecocast Castings

Three ECOCAST- castings with several defects have been investigated.

Objects of investigation

A pipe-shape part (Fig. 12-1) with cracks at the surface (Fig. 12-2) and at one location an irregular bulge of the surface (Fig. 12-3).

The body of a drain valve with a bore (Fig. 12-4). At the ground of the bore (Fig. 12-5), at one location a blue coloured surface contamination is visible (Fig. 12-6). At a different location, fine surface cracks are visible (Fig. 12-7).

A cone-shaped part with a blind hole in the center (Fig. 12-8). The inner surface of the hole exhibits defective areas (Fig. 12-9).

Fig. 12-1. Object 1, exhibiting surface cracks and a surface bulge at the location indicated by the circle at the right border of the image.

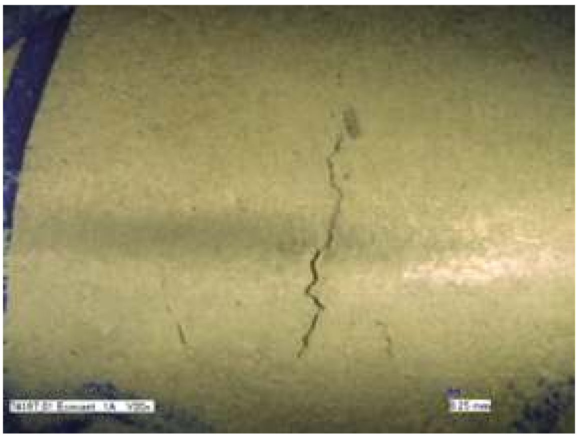


Fig.12-2. Enlarged view (digital microscope) of the surface cracks at object 1.

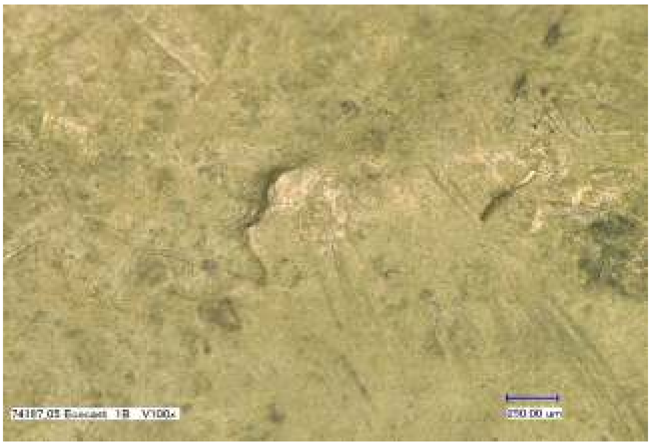


Fig.12-3. Enlarged view (digital microscope) of the surface bulge at object 1.

Fig. 12-4. Object 2 (body of a drain valve). At the bottom of the large bore in the center of the cast body, two defect areas were detected.

Fig.12-5. Defect areas at the bottom of the large bore.

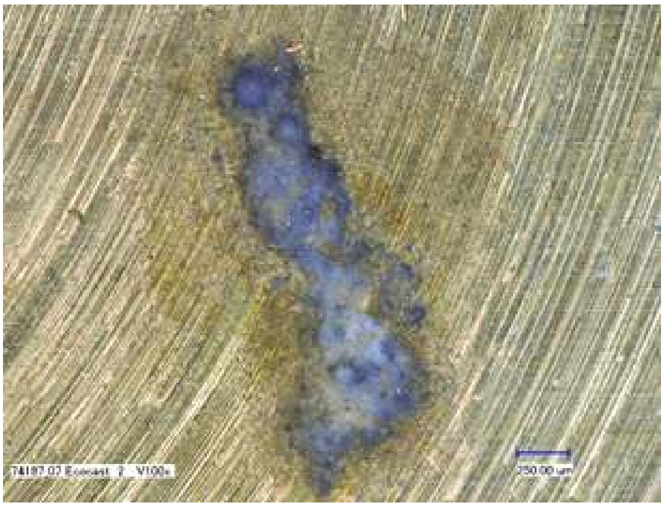


Fig.12-6. Defect at the bottom of the large bore: blue surface contamination.

Fig.12-7. Defect at the bottom of the large bore: Networks of fine surface cracks.

Fig.12-8. Object 3, a cone-shape casting with a blind hole at the center.

Fig.12-9. Defect area inside the blind hole.

Methods of investigation

- Enlarged macroscopic imaging using a Keyence digital microscope.
- Metallographic cross sections through defects investigated by light optical microscopy Scanning Electron Microscopy (SEM) combined with Energy Dispersive X-ray Spectroscopy (EDX).

Results

Object 1

Surface Cracks

In an enlarged view (Fig. 12-10), it can be seen that the surface cracks at object 1 are relatively wide open. The crack border is comparatively smooth and even the crack tips have a round shape.

A metallographic target section through one of the cracks has been produced (Fig. 12-11). In the section, it can be seen that the crack is perpendicular to the surface and penetrates into the material with a length of several hundred µm.

The shape of the cracks suggests that the origin of the cracks is the phenomenon of hot cracking or hot tearing, which occurs especially for relatively thin-walled objects which are cast parts using a core.

This assumption is confirmed by the fracture surface of one of the cracks, which is tarnished from high-temperature oxidation and shows an as-solidified column-like surface morphology (Fig. 12-12).

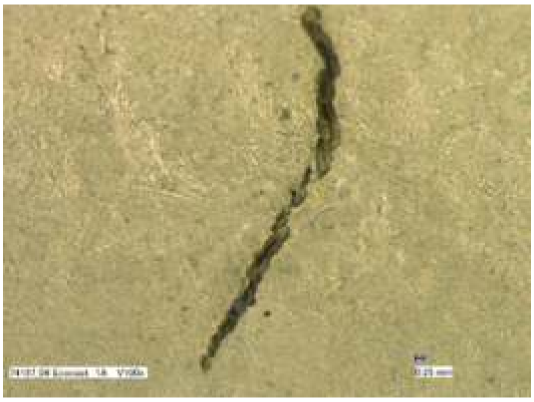


Fig.12-10. Enlarged view using microscope of one of the surface cracks at Object 1.

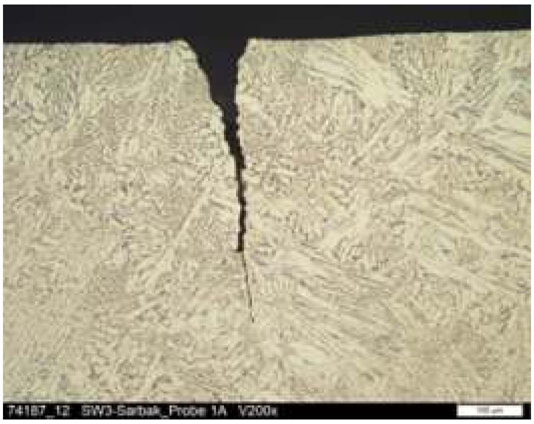


Fig.12-11. Target cross-section through one of the surface cracks at Object 1.

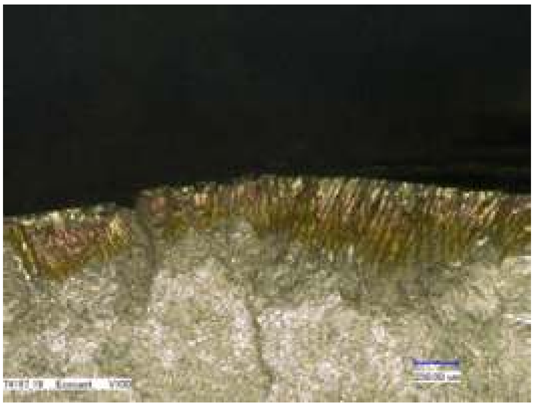


Fig.12-12. Fracture surface of one of the surface cracks at Object 1.
Only the tarnished, rippled surface at the top is the original surface of the crack. The lower part was caused by opening the crack.

Surface Bulge

A metallographic target section through the surface bulge (Fig. 12-13) does not show any irregularities concerning the microstructure, so that the surface bulge might be related to a defect of the casting mould. This can, however, not be verified by the present investigation.

Fig.12-13. Target cross section through the surface bulge at Object 1.

Object 2

Surface Contamination

As can be seen from (Fig. 12-6), the surface contamination is located on top of the machined bottom surface of the bore. The contamination itself is not affected by machining. Thus, it has been generated after the machining of the bore, maybe immediately after machining still inside the machining center.
Scanning electron microscopy (SEM) combined with local chemical analysis employing energy dispersive X-ray spectroscopy (EDX) has been used to determine the chemical composition of the blue coloured defect site at the bottom of the bore in object 2 (Figs 12-14 and 12-15, Table 12-1). Beside the alloy elements copper (Cu), zinc (Zn) and silicon (Si), significant amounts of fluorine (F), sodium (Na), potassium (K) and also oxygen (O) and aluminum (Al) have been detected.

With this information, the origin of the contamination has to be found by analyzing the production process.

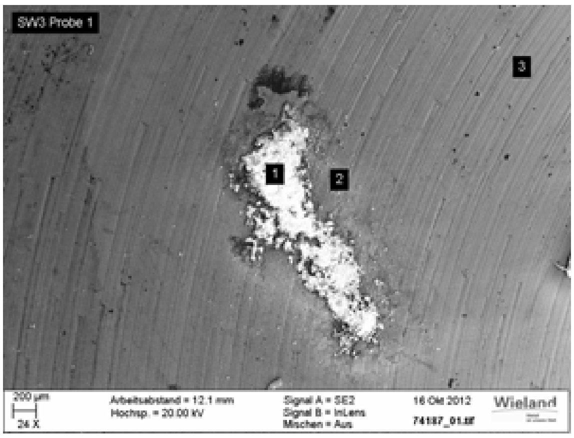


Fig.12-14. SEM image of the surface contamination.

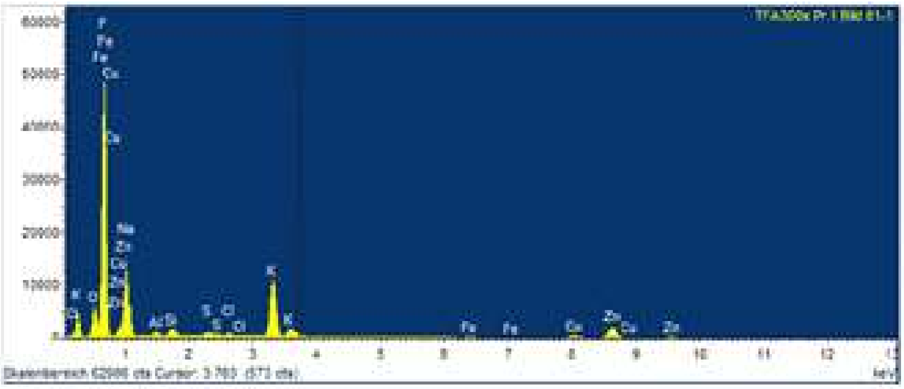


Fig.12-15. EDX spectrum at location 1 in Fig. 12-13 (surface contamination).

Element	Massen%	Atom%
O K	7.30	9.91
F K	62.67	71.67
Na K	9.97	9.42
Al K	0.42	0.34
Si K	0.77	0.59
S K	0.29	0.19
Cl K	0.22	0.13
K K	7.19	3.99
Fe K	0.21	0.08
Cu K	2.10	0.72
Zn K	8.87	2.95

Table 12-1. Chemical analysis by EDX at location 1 in Fig. 12-13.

Surface Cracks

A metallographic target section through the fine surface cracks at the bottom of the same bore reveals that these surface cracks are connected with shrinkage cavities (Figs 12-16 and 12-17) underneath the surface.

Fig.12-16. Metallographic cross-section through the area of fine surface cracks at Object 2. Large shrinkage cavities can be seen in this area.

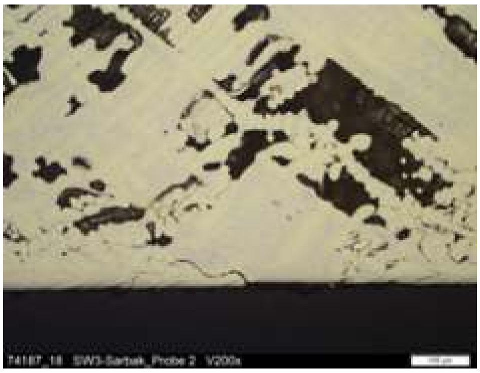


Fig.12-17. Enlarged view of the metallographic cross-section through the area of fine surface cracks at Object 2. It can be seen that the shrinkage cavities are responsible for the fine cracks at the surface.

Object 3

For Object 3, already a macroscopic detail investigation shows that the surface of the defect area exhibits a dendrite-like solidification surface (Fig. 12-18). The defect is thus also a shrinkage cavity.
Because of the clearness of this macroscopic image, a metallographic cross-section was not necessary.

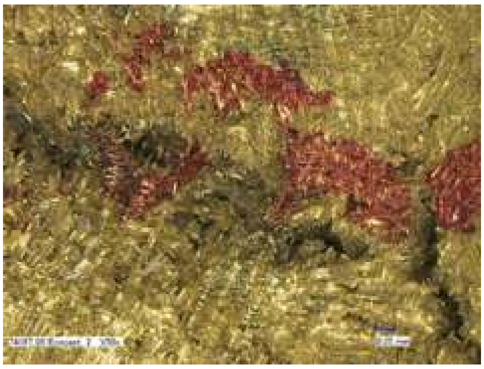


Fig.12-18. Enlarged view using microscope of the defect area inside the blind hole, showing a dendrite-like as-solidified surface.

Conclusions

Object	**Defect**	**Probable Origin**
Object – drain valve	Surface cracks	Hot cracking / hot tearing
	Surface bulge	Unclear. Defect in mould ?
Object 2– drain valve	Blue surface contamination	Fluoride compounds. Contamination of surface after machining.
	Surface cracks	Shrinkage cavities directly underneath the surface
Object 3– cone	Surface defect at center blindhole	Shrinkage cavities

Experimental Work on Possibilities to Predict Casting Defects in LPDC Brass Castings

Introduction

The aim of this study was to enable the cutting down of the production cost for water taps. In the production 0.5mm of brass needs to be ground off from the surface for removing the surface defects and the aim was to decrease that down to 0.2 mm. Close to one hundred casting were cast in the sequences of 10 pieces to assure statistical sampling and approximately steady die temperature.
The die was cleaned by air blowing after the cores were set in and by steel brushing after every sequence. The die was also heated up on the furnace riser tube before each sequence to avoid cold shots and to equalize casting conditions between sequences. Before every sequence the initial coating was produced by spraying before the first dipping. If graphite marks appeared during the casting sequence a small brush was pressed softly against die surface where the marks had appeared and this made the marks to disappear. One half of the gating system is shown in Fig 13-1.

Fig. 13-1. Gating system used in the castings.

The casting die was equipped with eight thermocouples to measure mould and melt temperature during casting cycle. The casting parameters were varied in the following parameter window: casting temperature: 1010°C - 990°C, cast valve time: 7.0s - 9.0s, waiting time: 1.5s - 2.5s, dipping time: 1.7s - 2.2s and carbon -% in dipping solution: 12% - 25%.

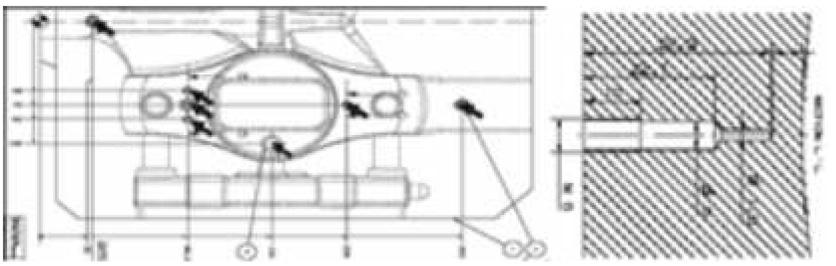
Table 13-1. The casting parameters used for different casting sequences.
The varied parameters are shown in bold.

Nr of set	Temp °C	Valvetime s	Wait time s	Diptime s	Carbon %	Pressure bar
1	1010	7.0	1.5	1.7	12	430
2	1010	9.0	1.5	1.7	12	430
3	1010	7.0	2.5	1.7	12	430
4	1010	7.0	1.5	2.2	12	430
5	990	7.0	1.5	1.7	12	430
6	990	9.0	1.5	1.7	12	430
7	990	7.0	2.5	1.7	12	430
8	990	7.0	1.5	2.2	12	430
9	990	7.0	1.5	1.7	25	430

Each casting in the sequence was marked by scraping on the large sand core an individual identification mark of the sequence. Then the sequence of each casting could be determined even after grinding and polishing it from outside. After cutting off the gating system and risers at castings where sent to labratory. Only the right hand side castings were polished while the left hand side castings were left as-cast. An exception was the last casting of each sequence, which was cut to halves along the parting line. After that the upper part of casting was cut again to two halves in opposite direction, normal to the parting line as shown in Fig. 13-2.

Fig. 13-2. Example of the cutting of the last casting in each sequence.

Digital photos where taken from the raw casting surfaces before any material removal. New photos were taken after polishing at the same places. During each sequence, one thermocamera picture was taken from the die halves after casting removal and after dipping to solution.
Eight thermocouples (TC) were used, one in riser tube and seven in the die, for measuring the temperature history during the casting cycle. The last casting had also one TC inserted into one of the cores.
The thermocouple locations and TC attachment system are shown in Fig 13-3.



Four of the TCs were inserted so that the end of the TC was 5 mm from the die surface as shown in Fig 13-3. Three TCs adjacent to each other were set on the left hand side to distances 5, 10 and 15 mm from the surface surface in order to produce required data for the inverse modelling of the heat transfer coefficient transfer coefficient. The lowest TC in the middle of Fig 13-3. was inside a stamp where the pro-duction information usually is. It was also set only 2 mm from the stamp surface and as the stamp is upraised when compared to surrounding die surface the response to temperature changes was better and temperatures higher than temperatures from the rest of the TCs. The TC set into the riser tube was protruding a few millimetres into the tube.

This caused problems with the measurement: the measured temperatures were too low due to the boundary layer effect in the tube and the measuring head collected solidified metal.
The study included also a simulation part, which aimed for studying the eventual correlations between simulation results and defects. Because the dipping process cannot be simulated with any available casting simulation program, the defects caused by graphite accumulation and moisture cannot be predicted directly. The influence of coatings can be taken into account using the heat transfer coefficient (HTC). The results from this study were used also for validating the simulation model for shrinkage defects and boundary conditions. For validating the HTC values virtual thermocouples were set in casting simulations to exactly same locations where the actual thermocouples were in the real casting experiments. Afterwards, the simulated temperature curves were compared to those actually measured.

Results

At first the as-cast surfaces were visually inspected and the types of defects were classified according to the categories shown below. An example of a graphite wake defect before and after grinding is shown in Fig. 13-4.:

Impact Mark

- Deep, sharp and clean marks on the surface.
- Caused by hot castings hitting each other when piling them to a container.

Graphite Sphere

- Black dot on the surface, local defect.
- Small graphite particles in solution or coating surface.

Graphite Wake

- Long, shallow mark on the casting surface; reminds a crack but the edges are not sharp.
- Dip coating is running down when the die is raised and turned from the coating bath.

Graphite Flow Marks

- The same as previous, but marks are accumulating in sequential cycles.
- If the wake is large enough, it will not disappear during next dip but will be growing.

Graphite Accumulation

- Some graphite will remain in definite places in the die cavity where it cannot flow away easily.
- Local defects in corners of the cavity.

Graphite Mark

- Group of small holes on the casting surface.
- Caused by a cold die or wet coating during filling.

Slag Defect

- Slag in the melt, light brown or white marks, not containing graphite or sand.

Fig. 13-4. A graphite wake type surface defect before and after grinding.

The result from the inspection was that all the surface defects were related to graphite coating except those caused by the improper handling of castings (impact marks) and slag. Typical die casting surface defects such as cracking, cold shot marks or incomplete filling were not detected. This indicates that a too narrow process parameter window was used in the casting experiments. When the defects were analysed closer no clear connection between the process parameters and surface defects were found except in the last sequence where the graphite content was increased from 12% to 25%. In this sequence graphite accumulation caused graphite wakes on every casting.
One investigation method was to compare thermocamera pictures taken from the mould during casting sequences yielding defected components to pictures taken during sequences without defects. Due to the small number of thermocamera pictures the sampling was quite small. Two cases are compared in Fig. 13-5, where the sequence 5 had graphite pearls only in the first two pieces and sequence 6 had graphite pearls in castings 7, 8 and 9. Temperature values measured from casting 8 in the sequences 5 and 6 are given in Table 13-2.

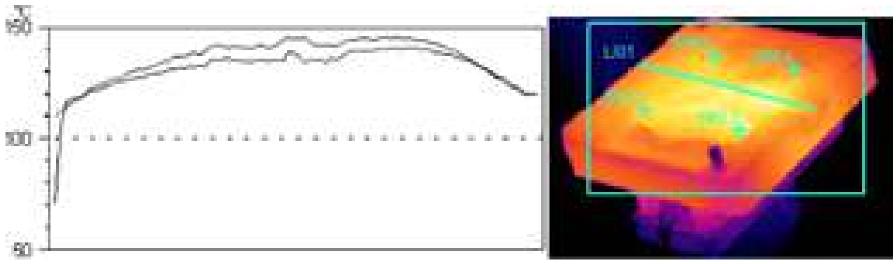


Fig. 13-5. Temperature profiles measured with thermocamera from the mould centreline (LI01) during casting sequences 5 (lower) and 6.

Point	Sequence 5 casting 8 (°C)	Sequence 6 casting 8 (°C)
SP01	132.2	135
SP02	138	145
SP03	126	128
SP04	117	116

Table 13-2. Temperatures measured from points SP01, 02, 03 and 04 Fig. 13-3) from casting sequences 5 and 6

Despite the small sampling an indication can be found that higher die temperatures can cause the formation of graphite pearls. This suggests that continuous temperature monitoring and process control may lead to better casting surface quality.

Useful experimental information was obtained by interviewing the experienced machine operators. Mostly this information deals with the coating behaviour during the process. First of all the operators have noticed at that the sprayed coating has a repulsive type interaction with the dipped coating but this combination is the best they have at the moment. This combination quite often causes the graphite marks.

It seems that the moisture does not evaporate properly during the few first cycles and that the light brushing is needed for tampering the coating. The graphite coating seems to grow quite steadily during normal production and that was visible even during short sequences comparable to those used in this study.

Some defects that appeared in the first casting of a sequence were visible for 3-5 shots and then disappeared. This might indicate that the coating layer builds up and finally collapses after certain growth.

What has been obvious also in the production is the influence of the shape of the cast piece, i.e. the shape of the die cavity. In the dipping the die is lowered into the graphite solution by turning the die halves around. This causes the solution to flow along the die cavity surface and one parameter is the velocity of this flow. Based on the cavity shape some improvements have been enabled by altering the dipping speed, not necessarily the overall dipping time. This is a factor, which is extremely difficult to study and to optimise. Other factors that certainly have an influence on defect formation but are difficult to investigate are caused by the actions of the operator: how fast the cores are set in, how well the die is cleaned and how quickly the die is dipped after taking the piece out.

RESOURCES

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THE HISTORY OF BRASS

Brass was being used together with copper since the discovery of copper. During the last millennium, brass is started to be used separately from the copper for the special engineering purposes. In the beginning, copper and tin were being used together and kitchenware such as pots and pans made of bronze were being produced. The ancient Egyptian civilization knew copper very well and it was shown by the symbol ankh in the Egyptian hieroglyphs, which is also the symbol of eternal life. Ancient Egyptians were appreciating the long physical life of copper and copper alloys. Tin was obtained more easily and as a result of this bronze was used more in daily life. Since brass resembled gold, it was used for visual purposes. Ancient Greeks called brass “oreichalcos” which is formed by the words “oros” (mountain) and “chalcos” (copper). Then names the brass as a type of white bright copper.

Romans called brass “aurichalum” and were using it in the production of golden colored helmets and jewelry. They were using alloys with 11-28% of zinc in order to produce valuable accessories from the bright golden colored brass. They had determined the alloy with the best ductility for metal work and ornamentation as the composition with 18% zinc. This is very close to the 20/80 gilt metal which is used for the same works today.

It was in the 18th century that it was discovered that zinc melts at 420°C and boils at 906°C, and that the zinc oxide forming can be purified by taking the slags with the wood charcoal. When pure zinc was not available, smithsonite ore, which is found in the nature as the zinc-carbonate crystal and copper was being melted in the crucible in order to produce brass. When the heat melted the ore and liquid metal is produced, the copper was remaining as unmelted. Zinc vapor was penetrating from the surface of the copper and was converting into brass form. Afterwards, the ally was re-melted in order to provide homogeneity.

In the Middle Ages, still pure zinc could not be obtained. Brass was produced from calamine mineral, which is a zinc ore and which contains zinc oxide and very little amount of iron oxide in its structure. Thin brass plates were laid in between the stone floor laying in the church monuments and this way the remembrance of death was emphasized. In general, zinc ratios of 23-29% and sometimes the addition of lead were being used. At the same time, brass was started to be recycled and re-melted.

Use of brass materials in the production of wool spread more with the industrial revolution. Afterwards, the needle trade gained importance. In the needle production, little amount of lead and tin were added in order to facilitate cold forming with 15-20% zinc ratio. The simple production qualities of brass, easy processing capability and corrosion resistance provided it to become the standard metal in the production of many moving parts. Now, large or small, all watches, marine direction finding devices were started to be produced of brass.

In the beginning, the brass wires were being drawn manually and brass plates were pressed. In 1697 the first rolling benches started to shape the brass. Needles were being produced of brass plates of 30 kg. Rolling mills were turned by the water power. Before drawing the wires, the materials were being heated with intermediate thermal process. These systems were used until the mid 19th century.

Ms60 brass was started to be used after the year 1832 and this spread the brass plates which were cheap and had easy hot processing capability. It replaced copper and was used to cover the ship boards in order to prevent them from getting wormy.