TECHNICAL REPORT

ISO/TR 10809-1

Second edition
2023-02

Cast irons —

Part 1: Materials and properties for design

Fontes —

Partie 1: Matériaux et propriétés pour la conception

Reference number
ISO/TR 10809-1:2023(E)

© ISO 2023



COPYRIGHT PROTECTED DOCUMENT

© ISO 2023

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

© ISO 2023 – All rights reserved

Contents

Page

Foreword ..... **v**
Introduction ..... **vi**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **1**
4 Why use cast irons as an engineering material? **5**
4.1 General 5
4.2 Why use grey cast iron? 5
4.3 Why use spheroidal graphite cast iron? 5
4.4 Why use ausferritic spheroidal graphite cast iron (austempered ductile iron, ADI)? 6
4.5 Why use malleable cast iron? 6
4.6 Why use compacted (vermicular) graphite cast iron? 6
4.7 Why use austenitic cast iron? 6
4.8 Why use abrasion-resistant cast iron? 7
5 Overview **7**
5.1 General 7
5.2 Recent changes in standardization 7
5.3 General microstructure of cast iron 9
5.4 Section sensitivity and the effects of relevant wall thickness on material properties 11
5.5 Understanding hardness 11
5.6 Heat treatment 12
5.7 Welding 13
6 ISO 185, Grey cast irons **13**
6.1 Overview 13
6.2 Effect of structure on properties 16
6.3 Metal composition and carbon equivalent 16
6.4 Graphite form, distribution and size 16
6.5 Section sensitivity 19
6.6 Effect of alloying elements 19
6.7 Heat treatment 20
6.8 Choosing the grade 20
7 ISO 1083, Spheroidal graphite cast irons **21**
7.1 Overview 21
7.2 Effect of structure on properties 22
7.3 Metal composition and carbon equivalent 22
7.4 Graphite form and size 22
7.5 Relevant wall thickness in spheroidal graphite iron 24
7.6 Effect of alloying elements 24
7.7 Matrix structure and resultant properties 24
7.8 Influence from strain rate and temperature on properties for ferritic, ferritic-pearlitic and pearlitic grades 26
7.8.1 General 26
7.8.2 Influence from pearlite content at constant silicon level 26
7.8.3 Influence from silicon content in fully ferritic matrix 27
7.9 Special case of impact-resistant grades 29
7.10 Heat treatment 30
7.11 Choosing the grade 31
8 ISO 17804, Ausferritic spheroidal graphite cast irons (ADI) **31**
8.1 Overview 31
8.2 Heat treatment process 34
8.3 Effects of alloying elements 35

© ISO 2023 – All rights reserved

8.4 Graphite form and size 35
8.5 Matrix structure and the resultant properties 36
8.6 Influence from relevant wall thickness on mechanical properties 36
8.7 V-notch impact energy grade 36
8.8 Abrasion-resistant grades 36
8.9 Machinability 37
8.10 Choosing the grade 37

9 ISO 5922, Malleable cast irons 38
9.1 Overview 38
9.2 Metal composition and carbon equivalent 40
9.3 Heat treatment 41
9.3.1 General 41
9.3.2 Blackheart malleable irons 41
9.3.3 Whiteheart malleable irons 42
9.4 Graphite form and size 42
9.5 Mechanical property requirements and the influence of structure 42
9.6 Impact properties 43
9.7 Section sensitivity 43
9.8 Choosing the grade 43

10 ISO 16112, Compacted (vermicular) graphite cast irons 44
10.1 Overview 44
10.2 Compacted graphite iron — intermediate properties 45
10.3 Effect of structure on properties 46
10.4 Metal composition and carbon equivalent 46
10.5 Graphite form and size 46
10.6 Section sensitivity in compacted graphite iron 47
10.7 Matrix structure and the resultant properties 47
10.8 Heat treatment 47
10.9 Choosing the grade 48

11 ISO 2892, Austenitic cast irons 48
11.1 Overview 48
11.2 Effect of structure on properties 49
11.3 Chemical composition and its effect 50
11.4 Effect of composition on carbon equivalent 51
11.5 Graphite form and size 51
11.6 Heat treatment 51
11.7 Choosing the grade 52

12 ISO 21988, Abrasion-resistant cast irons 53
12.1 Overview 53
12.2 Effects of structure on properties 55
12.3 Chemical composition 56
12.4 Unalloyed and low alloyed cast irons 56
12.5 Nickel-chromium cast iron 56
12.6 High chromium cast iron 56
12.7 Influence of chemical composition on properties and performance 57
12.8 Section sensitivity 58
12.9 Heat treatment 58
12.10 Choosing the grade 59

Bibliography 61

© ISO 2023 – All rights reserved

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 25, *Cast irons and pig irons.*

This second edition cancels and replaces the first edition (ISO/TR 10809-1:2009), which has been technically revised.

The main changes are as follows:

— Clauses 4 to 10 have been reordered in line with microstructural similarities between cast iron types;

— the Bibliography has been updated.

A list of all parts in the ISO 10809 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

© ISO 2023 – All rights reserved

Introduction

Worldwide cast-iron production is in excess of 74 million metric tonnes per annum.[13] It is manufactured in a wide range of alloys and has applications in all sectors of world production and manufacture. Its use spans many industries, including automotive, oil, mining, etc.

The purpose of this document is to assist the designer and engineer in understanding the family of cast iron materials and to be able to utilize them with a more complete knowledge of their potential, among the wide range of other engineering materials and fabrication methods now available. A considerable amount of the data provided are metallurgical, but it is usually the metallurgical aspects of the cast irons that create misunderstandings when these materials are specified. Metallurgy is not one of the scientific disciplines commonly taught to engineering students, so the material properties of cast irons are not often well understood. Thus, such students often have a lack of knowledge regarding the fundamentals underpinning the material properties of cast irons.

© ISO 2023 – All rights reserved

Cast irons —

Part 1:
Materials and properties for design

1 Scope

This document provides information about cast iron materials so that users and designers are in a better position to understand cast iron as a design material in its own right and to correctly specify cast iron for suitable applications.

This document suggests what can be achieved, and what is not achievable when cast irons are specified as well as the reasons why. It is not designed to be a textbook of cast iron metallurgy. It is intended to help people to choose the correct material for the right reasons and to also help to obviate the specification or expectation of unrealistic additional requirements, which are unlikely to be met and which can be detrimental to the intended application.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
alloying
addition of elements such as copper, nickel and molybdenum to enhance hardenability

3.2
annealing
heat treatment (3.17) that breaks down *iron carbide* (3.21) and *pearlite* (3.26) to produce *ferrite* (3.12)

3.3
ausferrite
cast iron matrix microstructure, produced by a controlled thermal process, which consists of predominantly acicular *ferrite* (3.12) and high carbon *austenite* (3.5)

© ISO 2023 – All rights reserved

3.4
austempering
<of spheroidal graphite cast iron> *heat treatment* (3.17), consisting of heating the castings to a temperature at which *austenite* (3.5) starts to form during heating and holding a sufficient time for carbon diffusion into the austenite, followed by cooling at a rate sufficient to avoid the formation of *pearlite* (3.26), and transforming the matrix structure for a time and temperature (above the *martensite* (3.23) start temperature) sufficient to produce the desired properties

Note 1 to entry: This process produces a microstructure that consists predominantly of acicular *ferrite* (3.12) and high carbon austenite. This microstructure is called *ausferrite* (3.3). Examples of ausferritic microstructures are given in ISO/TR 945-3.

[SOURCE: ISO 17804:2020, 3.3]

3.5
austenite
cast iron matrix microstructure, formed in cast irons immediately upon solidification that at lower temperatures transforms into *ferrite* (3.12), *pearlite* (3.26), *ausferrite* (3.3) and/or *martensite* (3.23), unless the austenite is stabilized at lower temperatures by either sufficient *alloying* (3.1) with nickel in austenitic cast irons, or by carbon enrichment in the austenite phase during the *austempering* (3.4) of ausferritic cast irons containing sufficient silicon to prevent formation of *bainite* (3.6)

3.6
bainite
cast iron matrix microstructure that can form if a white iron with low silicon content is *austempered* (3.4)

Note 1 to entry: Ausferritic cast irons contain sufficient silicon to prevent the formation of bainite.

3.7
carbon equivalent
formula based on the carbon and silicon contents of molten cast iron by thermal analysis

3.8
compacted
stubby form of graphite flakes providing material properties in between those of the grey and spheroidal graphite irons

3.9
ductility
elongation measured on the tensile test piece following testing

Note 1 to entry: It is expressed as a percentage.

3.10
eutectic
point at which elements are present at a level where the lowest solidification temperature is reached

3.11
eutectic cell
solidification mechanism in grey cast iron where cells form, each with its individual internal graphite structure

Note 1 to entry: These ultimately coalesce to form a uniform material.

© ISO 2023 – All rights reserved

3.12
ferrite
cast iron matrix microstructure formed during slow cooling of *austenite* (3.5), provided that *pearlite* (3.26) is not rapidly forming to consume the austenite

Note 1 to entry: The formation of ferrite is promoted by both slower cooling and higher silicon content. The latter results in considerable substitutional solution strengthening of the ferrite. A new kind of ferrite, also interstitially solution strengthened by medium carbon contents, is formed during *austempering* (3.4) into ausferritic microstructures.

3.13
graphite flake
two-dimensional appearance of the *graphite form* (3.14) in grey cast iron, when looking at the material structure through a microscope

3.14
graphite form
descriptor of graphite shape, which can define material properties

Note 1 to entry: It is shown in ISO 945-1.

3.15
graphite size
size of the free graphite, whether in the form of flakes, nodules, temper nodules or vermicular graphite

Note 1 to entry: It can be quantified using the relevant cast iron type standard, and will have an effect on the mechanical properties of the final product.

Note 2 to entry: It is classified in accordance with ISO 945-1.

Note 3 to entry: Fine graphite normally provides better properties than coarse graphite.

3.16
hardening
heat treatment (3.17) that generally produces *martensite* (3.23) in the *matrix* (3.24)

3.17
heat treatment
thermal process that removes internal stress or enhances properties

3.18
hypoeutectic
composition below the *eutectic* (3.10)

3.19
hypereutectic
composition above the *eutectic* (3.10)

3.20
inoculation
technique of adding inoculant to molten iron to enhance the graphite growth

3.21
iron carbide
iron and carbon in a combined form

EXAMPLE Fe3C.

3.22
iron-chromium carbide
complex carbide principally found in abrasion-resisting irons

© ISO 2023 – All rights reserved

3.23
martensite
cast iron matrix microstructure formed from cooling any *austenite* (3.5) not previously transformed at higher temperatures into *ferrite* (3.12), *pearlite* (3.26), *bainite* (3.6) and/or *ausferrite* (3.3)

Note 1 to entry: In contrast to these transformations relying on the diffusion of carbon and thus depending on both temperature and time, the formation of martensite is diffusionless and is dependent only on temperature.

3.24
matrix
structural phases surrounding the graphite in graphitic cast irons and carbide in abrasion-resisting irons

EXAMPLE *Ferrite* (3.12), *pearlite* (3.26), *ausferrite* (3.3), *austenite* (3.5) and *martensite* (3.23).

3.25
nodularity
assessment of the proportion of spheroidal graphite particles in a cast iron sample

Note 1 to entry: Nodularity is generally expressed as a percentage.

[SOURCE: ISO 945-4:2019, 3.5]

3.26
pearlite
cast iron two-phased lamellar matrix microstructure composed of alternating layers of *ferrite* (3.12) and cementite (Fe3C), formed by a eutectoid reaction during slow cooling of *austenite* (3.5) not previously transformed into ferrite

Note 1 to entry: The formation of pearlite is promoted by both faster cooling and lower silicon content.

3.27
quenching
rapid cooling of previously austenitized castings to prevent formation of *ferrite* (3.12) and *pearlite* (3.26), cooled either in a salt bath for subsequent *austempering* (3.4) into *ausferrite* (3.3) or in oil to form *martensite* (3.23)

3.28
relevant wall thickness
section thickness of the casting, agreed between the manufacturer and the purchaser, to which the determined mechanical properties apply

[SOURCE: ISO 185:2020, 3.2, modified — “thickness” added before “section”.]

3.29
section sensitivity
change in material properties that occurs due to variations in the solidification and cooling rates of cast iron poured into different wall section thicknesses

3.30
spheroidal graphite
graphite in spheroidal graphite iron that is present as spheroids as opposed to flakes

3.31
stress relieving
low-temperature *heat treatment* (3.17) that removes stress without affecting structure

3.32
tempering
heat treatment (3.17) that enhances properties or relieves stress after *hardening* (3.16)

© ISO 2023 – All rights reserved

3.33
temper carbon
graphite form (3.14) found in malleable iron with the appearance of "ragged" spheroids, also known as "temper carbon nodules"

3.34
trace elements
elements that are present in small amounts

EXAMPLE Copper, nickel, molybdenum, vanadium, titanium.

Note 1 to entry: Such elements can also be added for *alloying* (3.1) purposes.

4 Why use cast irons as an engineering material?

4.1 General

The first questions that the designer and engineer will probably ask are:

— Can I use a cast iron?

— Should I use a cast iron?

— Which type and grade are applicable?

— What are the advantages?

General information on the cast iron types currently standardized in International Standards is given in 4.2 to 4.8.

4.2 Why use grey cast iron?

Grey cast iron is sometimes called "flake graphite cast iron" or "lamellar graphite cast iron". It provides the largest worldwide tonnage of all cast irons produced, mainly because of its wide range of uses within general engineering, its ease of casting and machining, and its cost advantage. The material has the highest thermal conductivity and vibration damping capacity among the range of cast irons, which is why it is used in applications where these properties are important. Typical examples are automotive parts such as brake drums, discs, clutch plates, and cylinder blocks and heads. Grey iron lacks ductility, but for parts where requirements for ductility and impact resistance are low or unimportant, a huge range of applications can be found. These include, for example, the manufacture of machine tools such as lathe beds, where slideways can easily be surface hardened and the self-lubricating properties of the material are advantageous. This highly versatile material can be considered for a potential application unless there are ductility requirements, or the design requires ultimate strengths in excess of 350 MPa.

4.3 Why use spheroidal graphite cast iron?

Spheroidal graphite cast iron, also known as "ductile iron" or "nodular graphite iron", has the benefit of ductility as well as strength, which is why it is often considered to be a material superior to grey iron. Its main disadvantage in this respect is that it does not have as high thermal conductivity as grey iron and is not normally used where this property is important. A large number of spheroidal graphite iron grades are available to the designer, based on the fact that as tensile strength increases, ductility decreases. Thus, the designer has the opportunity to utilize different combinations of tensile/ductility properties, depending upon the application. The lower-strength grades with high ductility also have good impact properties at low temperatures and, for this reason, spheroidal graphite iron is increasingly being used to produce cast parts to replace steel fabrications. Large tonnages of spheroidal graphite iron are used to produce centrifugally cast pipe for water and sometimes gas transportation, but the majority is used in general engineering applications where its considerably higher tensile properties, compared with grey iron, are of advantage.

© ISO 2023 – All rights reserved