TECHNICAL REPORT

ISO/TR 13393

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Welding consumables — Hardfacing classification — Microstructures

Produits consommables pour le soudage — Classification des rechargements durs — Microstructures

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 13393 was prepared by the *International Institute of Welding*, Commission II, *Arc Welding and Filler Metals*, which has been approved as an international standardizing body in the field of welding in accordance with Council Resolution 42/1999.

Requests for official interpretations of any aspect of this International Standard should be directed to the ISO Central Secretariat, who will forward them to the IIW Secretariat for an official response.

Introduction

Hardfacing is the deposition of a given type of alloy onto a substrate, in view of protecting this substrate against various types of degradation known under the name of wear. The science that deals with wear and wear mechanisms is called “tribology.”

In this sense, this Technical Report does not cover the surfacing processes and alloys that are commonly known under the name of “cladding technologies”, which more specifically address the protection of substrates against corrosion.

Hardfacing can be carried out by means of a large variety of alloys.

The selection of the optimum alloy to resist a given combination of wear factors is not necessarily an easy task. This task can, however, be facilitated by giving consideration to those attributes of alloys that are dominant in determining their behaviour and their properties.

In this sense, the microstructure of the alloys, which itself is determined by a composition and a thermo-mechanical history, certainly can be accepted as an attribute of major importance and significance.

It is the purpose of this Technical Report to propose a classification system of hardfacing alloys based on compositions and microstructures.

Since most of these alloys exist under the form of consumables that can be used with a variety of welding processes, no specific reference is made to these processes in the rest of this Technical Report.

Welding consumables — Hardfacing classification — Microstructures

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This Technical Report proposes a system for classifying hardfacing microstructures deposited by fusion welding processes.

2 Proposed classification/designation system

The designation system indicates the type of consumable (electrode; tubular cored electrode, wire or rod; solid wire or rod; or powder), the use of the consumable for hardfacing, the alloy base (iron, nickel, copper, cobalt, or tungsten carbide), and the microstructure type. Designations of microstructure types for the various alloy bases are given in Clauses 3 and 6. Definitions and examples of the microstructure types are given in Clauses 5 and 7. The designation scheme for a hardfacing deposit is given below:

E	**H**	**XX**	**XXX**
Electrode	Hardfacing type	Alloy base	Microstructure
T = tubular-cored electrode		**Fe** = iron base	
S = solid wire or rod		**Ni** = nickel base	
P = powder		**Cu** = copper base	
		Co = cobalt base	
		W = tungsten carbide base	

3 Summary of the designators for iron-base microstructures

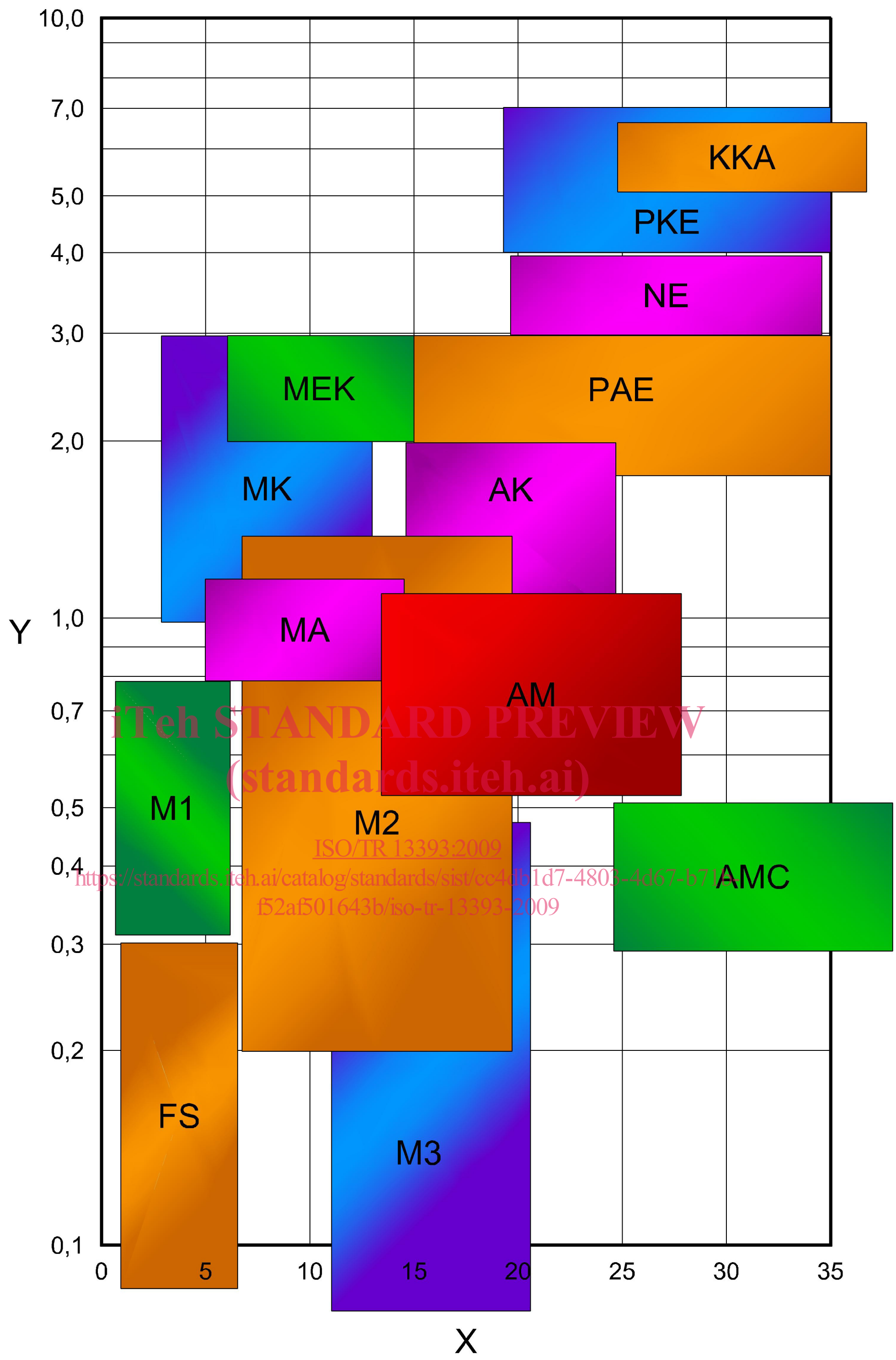
Most of the currently known Fe-based hardfacing alloys fall into one of about 17 typical microstructural categories. These types of microstructure are listed in Table 1, which also gives the proposed corresponding designators for covered electrodes. For convenience, only the E (electrode) form is shown, but it is understood that T (tubular-cored electrode), S (solid wire or rod), or P (powder) may be substituted for E.

Table 1 — Iron-base hardfacing deposit microstructure types

Hardfacing deposit designation	Microstructure type
E-H-Fe-FS	Mostly ferritic steel with second phase
E-H-Fe-M1	Low-alloy martensitic steel
E-H-Fe-M2	Tool steel martensite with secondary hardening
E-H-Fe-M3	Stainless steel martensite
E-H-Fe-M4	Maraging steel martensite
E-H-Fe-MA	Approximately equal amounts of martensite and austenite
E-H-Fe-MK	Martensite with alloy carbides
E-H-Fe-MEK	Martensite with austenite-carbide eutectic
E-H-Fe-A	Austenitic stainless steel with little or no ferrite
E-H-Fe-AF	Austenitic stainless steel with more than 30 FN
E-H-Fe-AM	Austenitic manganese steel with low or no chromium
E-H-Fe-AMC	Austenitic manganese steel with chromium nearly equal to manganese
E-H-Fe-AK	Austenitic manganese steel containing alloy carbides
E-H-Fe-PAE	Primary austenite with austenite-carbide eutectic
E-H-Fe-NE	Near-eutectic austenite-carbide iron
E-H-Fe-PKE	Primary chromium carbides with austenite-carbide eutectic
E-H-Fe-KKA	Primary chromium carbides with alloy carbides and austenite-carbide eutectic

4 Identification of iron-base alloy microstructural groups in a carbon/alloying elements diagram

A convenient and systematic way to correlate composition and microstructures of hardfacing alloys consists in using a diagram such as that given in Figure 1. On the ordinate, the mass fraction of carbon is plotted as a percentage using a logarithmic scale. On the abscissa, the total amount of alloying elements, also plotted as a percentage, is represented. Alloying elements include Cr, Mn, Si, Mo, Ni, Nb, V, W and Ti. These are the most commonly encountered alloy elements in Fe-based hardfacing alloys. In this diagram, based on compositional ranges and corresponding microstructures that are known for most of the alloys currently being used in practice, the domains which correspond to the types of microstructure listed in Table 1 have been delineated. It should be noted that these delineations are to be taken as guidelines, not absolutes. Transitions from one type to another type of microstructure are often progressive, and therefore, at least with alloys that are characterized by borderline compositions, a certain degree of overlap is to be expected in practice. Note that composition ranges for microstructure types A, AF and M4 are not included in Figure 1 because their mass fraction of carbon is below 0,1 %.



Key

X alloy, percent

Y carbon, percent

Figure 1 — Map of composition ranges for hardfacing microstructures

5 Description of the iron-base alloys belonging to the different microstructure groups

5.1 General

For each group, the following pages contain some general information as to the following topics:

- typical chemical composition ranges;
- as-welded microstructure;
- typical as-welded hardness range;
- typical response to post-weld heat treatment;
- impact resistance (as a qualitative judgment);
- metal-to-metal wear resistance (as a qualitative judgment);
- resistance against abrasive wear;
- corrosion resistance;
- high-temperature resistance;
- machineability;
- typical applications;
- typical microstructure illustrations.

5.2 Fe-FS Group (ferrite with second phase)

See Table 2.

Table 2 — Fe-FS Group

Typical composition:

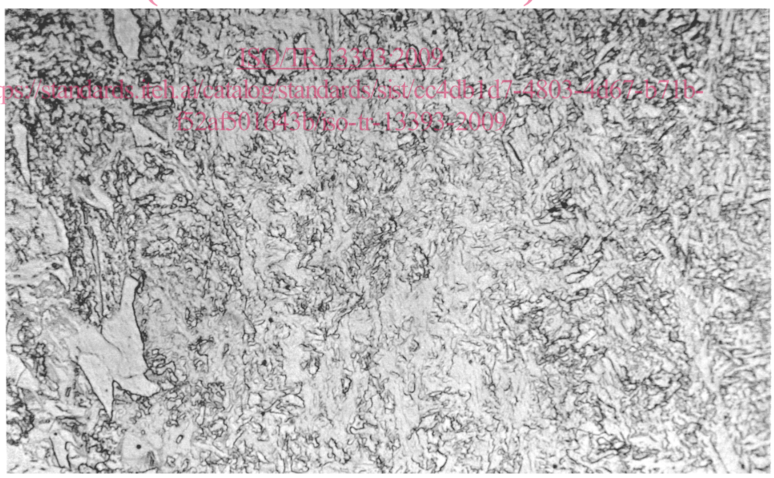
- Up to 0,3 % C
- Up to 6 % alloying elements

Microstructure: Predominantly ferrite with small amounts of pearlite, bainite, martensite

Main characteristics:

- Hardness (as deposited): Generally expressed in HB, ranging from 200 HB to 400 HB, function of mass fraction of C
- Machineable in the as-welded condition, PWHT improves machineability
- Excellent impact resistance
- Good metal-to-metal wear resistance
- Low to moderate abrasion resistance (function of hardness)
- Hardness drops if heat treated
- Deposits rust
- Typical example: 0,25 % C, 3 % Cr

Applications: Build-up to return worn parts to original size, metal-to-metal wear as in pulleys, idlers, gears



Deposit made with preheating at 200 °C, cooled slowly, resulting in a hardness of 20 R_C.

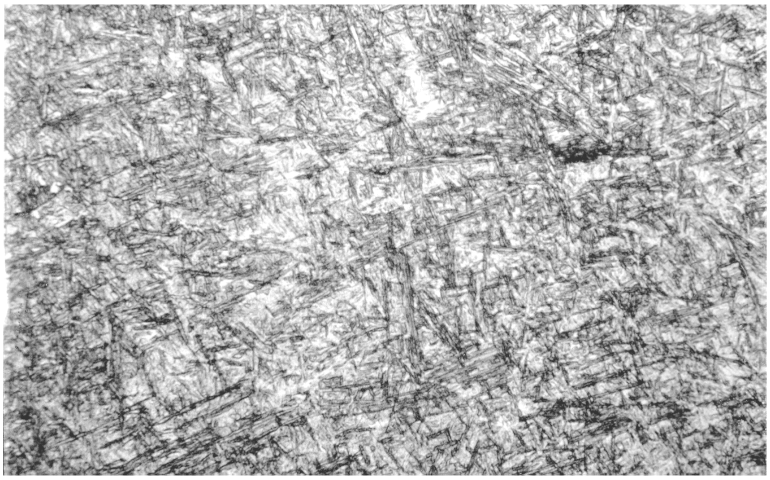
Microstructure is primarily ferrite with a little second phase.

Photomicrograph provided by The Lincoln Electric Company, USA.

Microstructure of Type FS Deposit, ×650, 2 % Nital (alcoholic nitric acid) etch

(*continued*)

Table 2 (*continued*)



Deposit made without preheating, and allowed to cool rapidly, resulting in a hardness of 35 R_C.

Microstructure is heavily bainitic.

Photomicrograph provided by The Lincoln Electric Company, USA.

Microstructure of Type FS Deposit (same electrode as above), ×650, Nital etch

5.3 Fe-M1 Group (low-alloy martensite)

See Table 3.

Table 3 — Fe-M1 Group

Typical composition:

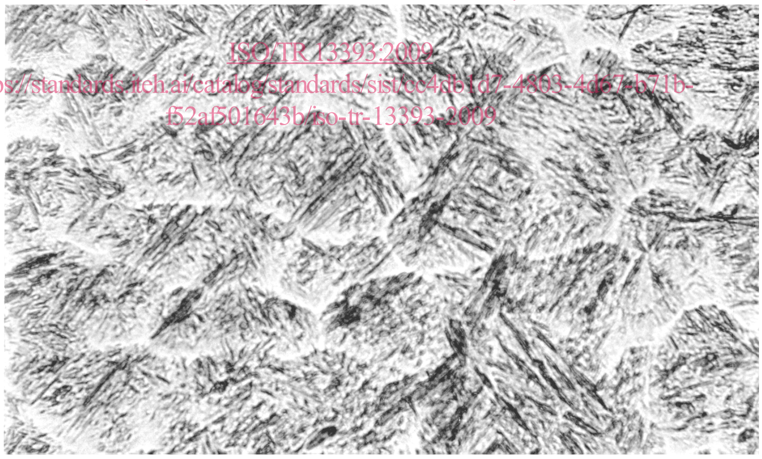
- 0,3 % to 0,8 % C
- Up to 6 % alloying elements

Microstructure: Predominantly martensitic

Main characteristics:

- Hardness: 450 HB to 600 HB, 45 R_C to 60 R_C, function of mass fraction of C
- Generally not machineable as-welded, grinding only. PWHT can soften enough to make deposit easily machineable
- Good impact resistance
- Excellent metal-to-metal wear resistance
- Improved abrasion resistance compared with FS group, function of hardness
- Hardness drops if heat treated
- Deposits rust
- Typical example: 0,5 % C, 5 % Cr, 0,5 % Mo

Applications: Metal-to-metal wear, as in transfer rolls or guides



Microstructure is predominantly blocky martensite, with white retained austenite around the former grain boundaries.

Photomicrograph provided by The Lincoln Electric Company, USA.

Microstructure of Type M1 Deposit, ×650, 2 % Nital

5.4 Fe-M2 Group (tool-steel martensite)

See Table 4.

Table 4 — Fe-M2 Group

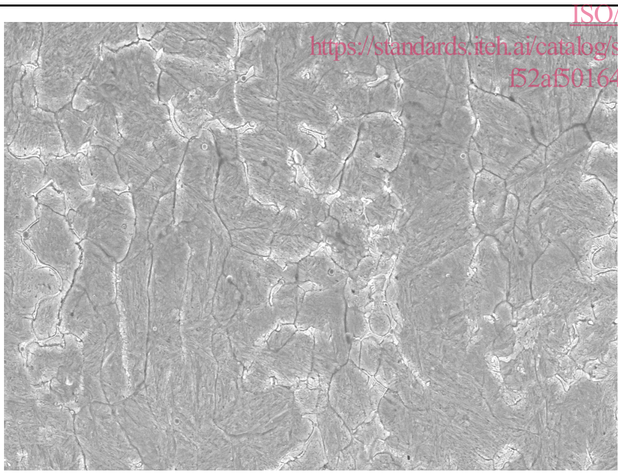
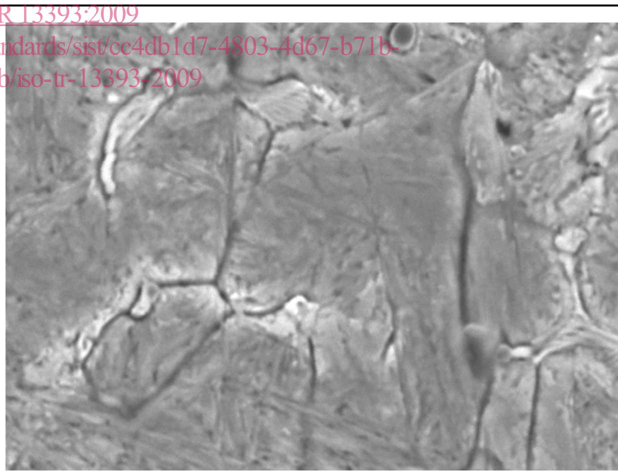
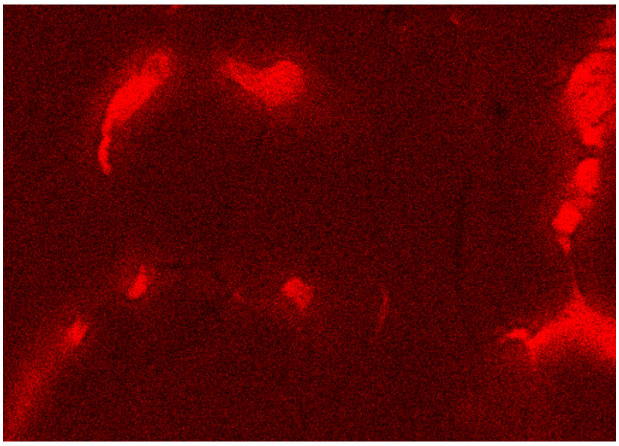
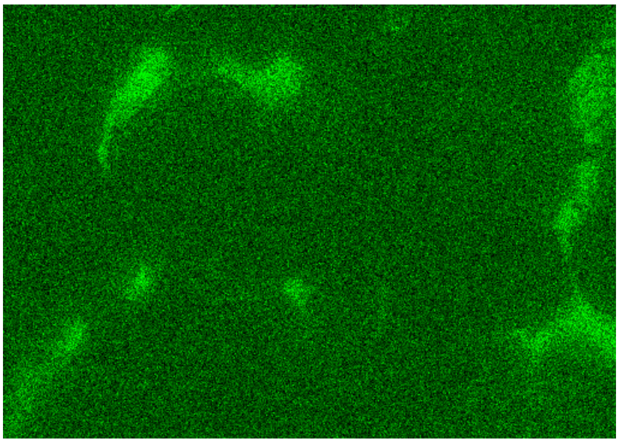
Typical composition: — 0,2 % to 1,5 % C — 7 % to 20 % alloying elements, essentially Mo, W, Cr, V
Microstructure: High-alloyed martensite with complex alloy carbides
Main characteristics: — Hardness: Ranging from 45 R_C to 60 R_C (as deposited) — Generally not machineable as-welded, grinding only. PWHT can soften enough to make deposit easily machineable — Fair impact resistance, decreases with increasing mass fraction of carbon — Good abrasion resistance — Maintain or even increase the hardness after heat treatment at temperatures up to 550 °C or higher — Maintain the hardness at high service temperature — Good thermal shock and thermal cycling resistance — Deposits rust — Typical example: 0,7 % C, 3,75 % Cr, 6,0 % Mo, 1,8 % W, 1,1 % V
Applications: Tool steels for hot/cold shears and dies, hot metal-to-metal wear, work rolls in the metals-processing industries
 SEM Image, ×1 000  SEM Image, ×5 000 Photomicrographs provided by The Lincoln Electric Company, USA. (*continued*)

Table 4 (*continued*)



SEM Image, Mo Distribution, ×5 000



SEM Image, V Distribution, ×5 000

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