American Welding Society

The Practical Reference Guide to Welding Metallurgy

Key Concepts for Weldability

THE PRACTICAL REFERENCE GUIDE to WELDING METALLURGY— Key Concepts for Weldability

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AUTHOR'S NOTES

For many, the metallurgical aspects of welding are not well understood and many of the books and technical articles dealing with the subject are sometimes difficult to master because the lay person does not have the technical background necessary to digest them. Generally, what welding personnel need is a basic understanding of the metallurgy of welding that is sufficient to aid in solving many of the day-to-day problems of fabrication or repair welding.

To that end, I have approached the subject less stringently than most, and have offered some basics that will aid the non-metallurgist in understanding why problems occur, and how to avoid them. While it is necessary to touch on the science in several areas, I have endeavored to limit it to the minimum needed for a practical understanding. I cover the effects of the various elements that make up our alloys, specifically from the weldability standpoint. The effects of cooling rates and the resulting structures are also covered from the mass effect and hardenability standpoints—a perspective I feel will be very helpful in understanding and solving many of the common welding problems.

I hope this Guide will be helpful to all, especially those non-metallurgists who have a need to avoid welding problems so often caused by overlooking the metallurgical considerations.

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Introduction

Knowledge of welding metallurgy can be beneficial to almost every aspect of fabrication, inspection, and failure analysis. Too often, problems occur repeatedly because the metallurgical aspects are not sufficiently understood (note Figure 1), and as the old saying goes, "*When you continue the exact same practices, why should you expect different results?*"

While the subject of metallurgy, and its subset welding metallurgy, encompasses a very large technical base, there are several basic issues that can be studied and implemented to aid in avoiding problems associated with fabrication and repair welding. These basic issues will be discussed in simple terms and hopefully with an approach that will enable a non-metallurgist to grasp and apply them in order to avoid common welding problems.

Since carbon and low-alloy steels are used predominantly in many industries, these alloys form the basis for much of this metallurgical review. An understanding of the steel basics can then lead to other alloy groups including austenitic stainless steels, copper and aluminum alloys, and the high alloys that include the nickel alloy groups. These families of alloys will also be discussed, but to a much lesser degree.

Definitions

A discussion of metals requires the first step to be a review of several basic definitions. Many definitions used in this guide are from Webster's. A metal is defined as "*Any of a class of chemical elements generally characterized by ductility, malleability, luster, and conductivity of heat and electricity.*" Examples of metals include gold, iron, aluminum, and silver. Metals can be found in their natural elemental state, such as the case with gold and silver, or combined with other elements such as oxides, sulfides, sulfates, etc. These combined forms of metals are referred to as "ores," and the elemental metal must be first extracted, or separated from, the other constituents before combining them in desired alloy forms.

An alloy is defined as "*A metal that is a mixture of two or more metals, or of a metal and something else.*" The phrase "something else" in the definition can refer to the combinations of metals with ceramics, called "cermets," or various other combinations. Some metal alloys occur naturally while others are combined in furnaces by intent to develop particular mechanical or physical properties. Examples of very common alloys include carbon steel, a mixture of primarily iron and carbon, and the austenitic stainless steels that are primarily mixtures of iron, chromium, and nickel. The man-made alloys also contain many other elements that may affect their properties; these will be discussed later.

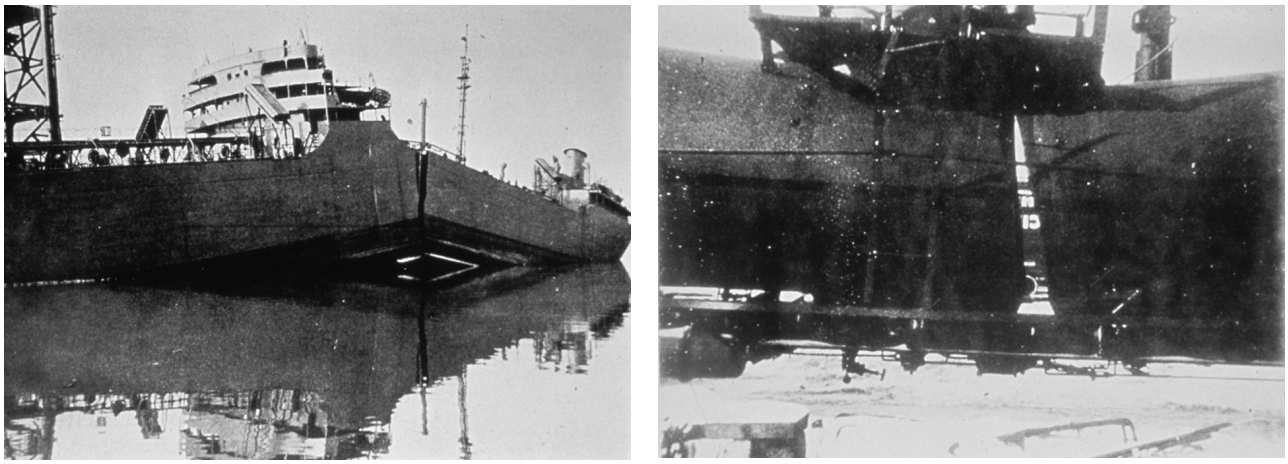

Figure 1. Liberty ship failures from the World War II era: massive hull fractures due to a combination of poor-quality steel, less-than-adequate welding procedures, and low temperatures in the North Sea.