Preface

This book is intended to act as a guide for students and practicing engineers for fatigue design of dynamically loaded marine structures. Fatigue of structures is a broad and complex area that requires more background than can be included in design standards. Many papers on fatigue of structures are published each year, and different design approaches have also been issued. However, due to the nature of the fatigue phenomena and scatter in test results, it may be difficult for engineers to obtain a good overview of what is found to be a good recommended fatigue assessment methodology.

The purpose of this book is not to give a complete overview of different design approaches, but rather to provide the reader with a sound background for the most common recommendations in design standards for fatigue assessment of marine structures. The content of this book is colored by the experiences by the author, and it may be relevant to consider this textbook in relation to the Standards with which the author has been most heavily involved, including the Recommended Practice DNVGL-RP-C203 Fatigue Design of Offshore Structures and DNV-RP-C206 Fatigue Methodology of Offshore Ships. However, similar content can also be found in a number of other design standards, such as: ISO 19902 (2007), API RP2A (2014), AWS (2010), BS 7608 (2014), Eurocode 3 (EN 1993–1–9, 2009), and IIW (Hobbacher, 2009). Thus, this book might best be considered as providing background for fatigue assessment of welded structures on a broad basis.

Based on the author's main background experience, a number of DNVGL standards are referenced. As these documents can be downloaded for free from the Internet, they are also useful reference documents for students studying fatigue of marine structures.

Much of this book is related to fatigue capacity of steel structures. The book may be seen as complementary to the Naess and Moan's book, *Stochastic Dynamics of Marine Structures*. Thus mainly the fatigue capacity of marine structures is considered in this book. The dynamic loading may be due to different sources such as waves, wind, rotors on wind turbines, dynamic response, vortex-induced vibrations, pile driving, and loading and unloading of content. Although this book will be easier to read and understand if the reader has a sound background in structural mechanics, the derivation of equations and the examples are presented in sufficient detail that it should be also possible to understand for engineers whose background is not rooted in structural engineering. A number of relevant examples are also included for the purpose of education of students.

A number of other test books on fatigue are recommended for a more basic learning about fatigue. Rather than repeating content that has already been well presented elsewhere, the author concentrates on engineering practice based on his own experiences in this book. Other textbooks on fatigue include (listed in alphabetical order by the author): Almar-Naess (1985), Collins (1993), Dowling (1998), Fischer (1984), Forrest (1962), Gurney (1979), Gurney (2006), Haibach (2006), Lassen and Recho (2006), Macdonald (2011), Maddox (1991), Marshall (1992), Nussbaumer et al. (2011), Pilkey (1997), Radaj et al. (2006), Radaj and Vormwald (2013), Schijve (2009), Sines and Waisman (1959), Sors (1971), Stephens et al. (2001), and Wardenier (1982). Books related to fatigue based on fracture mechanics include: Anderson (2005), Broek (1986), Carlsson (1976), Hellan (1984), Knott (1973), Liebowitz (1968), and Taylor (2007).

Although our understanding of the fatigue phenomena has improved over time, the assessment procedures are still strongly related to laboratory fatigue test data. Therefore, some of the author's experiences related to laboratory testing are included in the first section of this book. Careful review of these sections will enable the reader to obtain a better understanding of the remaining part of the book.

Most of the terminology used in this book is defined at first use, and the index may be useful in this respect. Some expressions are used more frequently than others; one example is the term "fatigue strength," which can be defined as magnitude of stress range leading to a particular fatigue life. Fatigue life or the number of cycles to a failure under the action of a constant amplitude stress history may also be denoted "fatigue endurance." A "fatigue strength curve" or "S-N curve" is defined as the quantitative relationship between the stress range (S) and the number of stress cycles to fatigue failure (N), used for fatigue assessment of a particular category of structural detail. Thus, the expression "fatigue strength" needs to be associated with some number of cycles to be fully meaningful. The same comment may be made with respect to expressions as "fatigue resistance" used in some design standards and "fatigue capacity" used by designers to characterize the resistance against fatigue failure in structures. Thus also these expressions may be interpreted as resistance or capacity in relation to an S-N curve. Both the term "fatigue strength" and "fatigue capacity" are used in this book to characterize resistance against fatigue. Normally the word "capacity" may be considered to be more general than "strength" and include more influencing parameters when comparing this also with other failure modes than fatigue for structures. For example, the wording "fatigue strength" is used to describe the resistance to fatigue failure in a single fatigue test or of, for example, a single bolt, and "fatigue capacity" is used to describe the fatigue resistance of a bolted connection where the fatigue capacity is dependent on more parameters such as surface conditions of plates, friction coefficient, and pretension of the bolts. In some literature the S-N curves are also denoted as Wöhler curves.

See Sections I.4 and 4.11.1 for definition of characteristic and design S-N curves. When the accumulated number of cycles is divided by a reference value, such as the characteristic number of cycles to failure as derived from an S-N curve, the wording "fatigue damage" is used. Fatigue damage accumulates with time when a structure is subjected to dynamic loading. Fatigue endurance is similar to fatigue life, which may be measured often in terms of years. Fatigue endurance can be observed during laboratory fatigue tests or can be calculated based on a defined design procedure. The calculated values normally differ from fatigue test data or observed values; therefore, the term "calculated" is often inserted in front of fatigue life in order to make this difference more clear.

In design standards for offshore structures the notation SCF is used for a linear elastic stress concentration factor (see Section 3.2.1 and Chapter 8). In design standards for sailing ships K is used as notation for the same stress concentration factor; see, for example, the IACS common rules from 2013. In this book SCF is used as notation for stress concentration factor, and it should not be mixed with the stress intensity factor used in fracture mechanics analysis that is denoted by K – see Section 16.2.

Some items are presented in more than one section of the book. However, where this occurs, cross-referencing has been used to improve readability.