SPRINGS
Troubleshooting and Failure Analysis

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Foreword

In Carlson's *Spring Designer's Handbook,* comprehensive data are contained covering detailed specifications of spring materials, examples of spring design problems, more than 100 curves of recommended design stresses, and a brief description of manufacturing methods. Included also are tables of spring characteristics, design data, tolerances, photographs of equipment, and similar information. That book is extremely helpful to engineers, metallurgists, spring designers, manufacturers, instructors, and students.

This book, *Springs: Troubleshooting and Failure Analysis,* explains the troubles encountered with spring materials, spring designs, and spring manufacture. Data on failure analysis are described in various chapters, and a detailed summary of metal fatigue and failure analysis is included in a separate chapter.

The troubleshooting of the problems encountered with both design and manufacture has been given for each type of spring, so designers can become more aware of the problems of manufacturing and thereby reduce the tendency to make special expensive designs.

Thus, the volume should be considered as a sequel to *Spring Designer's Handbook* and a complimentary work. Both books are recommended to all spring designers, spring manufacturers, wire mills, engineering instructors, and students of machine design.

Douglas V. Suckow, President
Alfred & William Spring Co., Inc.
Union, New Jersey

Preface

Troubleshooting is merely another name for problem solving. The process means different things to different people. Spring designers and engineers are concerned with stress analysis, design, and mechanical properties of materials. Metallurgists are interested in chemical properties, grain structure, processing, and heat treatment. Plant managers troubleshoot problems of manufacture and production. Spring manufacturers are concerned with all these problems and many others, including problems with materials, premature breakage, shock loading, high and low temperatures, and a variety of conditions that reduce fatigue life.

The purposes of this book are (1) to describe troubleshooting in all its phases in order to be of assistance to engineers, metallurgists, spring manufacturers, and the product manufacturer, who is the ultimate consumer; (2) to describe the process of failure analysis and explain how to avoid or reduce problems so that better spring designs can reduce failure and increase fatigue life; and (3) to include methods of manufacture, technical data, curves, and tables in an endeavor to help all persons concerned with spring design and manufacture to become more aware of the problems intimately associated with manufacturing operations.

Troubleshooting the problems of production is complicated due to the wide variety of shapes, styles, and classifications of springs, which is in the hundreds, and the variety of sizes, in the millions. Each purchase order entering a spring manufacturing plant must be thoroughly studied for correctness of design, availability of material, most economical manufacturing method, proper sequence of manufacturing operations, classification of quality control, method of inspection and testing, type of finish, method of heat treatment, method of packaging, and several other equally important operations.

Prior to the publication of my technical paper "Fatigue Testing of Springs," printed in the May 1969 issue of *Springs* magazine, there were only a few technical papers covering fatigue testing of springs and no books describing failure analysis. In the late 1970s a few books on the general subject of failure analysis excited interest, perhaps due to the shocking accidents that occurred with commercial aircraft.

All design data in this book is presented both in the inch-pound system with stresses in pounds per square inch (psi) and in the metric system (SI) with stresses in megapascals (MPa), with dimensions in both inches and millimeters. All values in both systems have been rounded off as much as possible to make them more generally suitable for use in design formulas.

The author gratefully acknowledges the opportunities he has had in design, research, and development as a design engineer and as spring supervisor of the Otis Elevator Company for 12 years, as chief engineer of two different spring manufacturing companies for 7 years, as a member of spring committees of the Americal Society of Mechanical Engineers and the American Society for Testing and Materials for many years, and as a consultant to the Spring Manufacturer's Institute and to hundreds of spring manufacturing companies and product manufacturers for over 30 years.

This lifetime of interesting work now makes it possible to help others in this field.

The author is grateful to Graham Garratt, Vice President of Marcel Dekker, Inc., for suggesting that I write this book and for his encouragement and suggestions, and to several engineers and representatives of manufacturing companies who suggested that a book of this nature was needed. I am especially grateful to my wife Ruth for typing and proofreading the manuscript.

Harold Carlson

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The publications and cooperation of many manufacturing companies have helped to make the writing of this book possible. A few of the more prominent companies who have cooperated or furnished publications are the following:

Associated Spring Corp.
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Sleeper & Hartley Corp.
Techalloy Co.
Tinius Olsen Testing Machine Co.
Torin Corp.
U.S. Baird Corp.
United States Steel Corp.
Wafios Machinery Corp.
Wheelabrator-Frye, Inc.

Introduction

All professions and most industries have special languages of their own. The medical profession uses Latin. The engineering profession uses the Greek alphabet. Musical compositions contain Italian and French words. Lawyers use a combination of several languages, and sailors truly have a very special language.

Foreign terms are not used to baffle us; they are used to simplify and reduce unnecessary verbiage. Obviously, it is much easier to say *modulus of elasticity* than it is to take a whole paragraph to describe the intended meaning each time the term is used. Even a garage mechanic uses simplified terms that baffle the laity but are understood by all mechanics.

In the early days of steel making, the Bessemer converter was the only method used to produce low-carbon and mild steel rods that could be drawn into steel wire for mattress springs. This was done by pouring molten pig iron directly from the blast furnace into a pear-shaped Bessemer converter and regulating the carbon content by controlling the blast of compressed air blowing up through the charge, which reduced the carbon and the impurities. This early wire was called B wire (for Bessemer) or BB for a higher carbon content to obtain higher tensile strength. This was the first method for producing steel spring wire and was used until the open-hearth method was invented.

With the advent of the open-hearth process the ability to control the carbon content became practicable, the B designation was continued, and other terms were used even though Bessemer steel was no longer in vogue.

The terms used and their proper meaning follow:

MB: Medium-hard Bessemer, carbon 0.60 to 0.70 percent; now covered by ASTM A 227, Class II, and SAE 1065
HB: Hard Bessemer, carbon 0.75 to 0.85 percent; now covered by ASTM A 679 and SAE 1080
XHB: Extra hard Bessemer, carbon 0.85 to 0.98 percent; seldom used but covered by SAE 1090

All these designations are now obsolete, but the letters MB and HB are still extensively used, are well understood by the wire mills, and may continue in use for many years to come. The two straight high-carbon spring steel designations MB and HB are popular spring steels, and the letters are easier to remember than ASTM or SAE numbers.

Incorrect interpretations of these letters are often used; they cause no harm, and actually provide a better understanding of the steel grades. They could be called a modern interpretation and are as follows:

MB: Medium-carbon basic steel, 0.60 to 0.70 percent
HB: High-carbon basic steel, 0.75 to 0.85 percent
XHB: Extra-high-carbon basic steel, 0.85 to 0.98 percent

MB steels are often used with prefixes, such as OTMB, meaning oil-tempered MB spring steel, and HDMB, meaning hard-drawn MB spring steel. Even though these terms are considered obsolete, they may continue to be used for many years.

Standard steel specifications no longer specify the acid method of making steels because all methods today use only the basic method.

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