Axel Rossmann

Machine Elements
Identifying and Solving Problems

Under Special Consideration of Lightweight Design

for

- Students
- Designers/Engineers
- Operators
- Quality assurance
- Maintnence and servicing
- Investigators
- Consultants/Experts

Translated from the German by the Author.

Volume 1C: Erosion (particles, liquids, cavitation). Corrosion (SCC). Embrittlement by (hydrogen, solid metal, liquid metal). Tribology (galling/seizing). Wear (fretting, slippage). Metal fire. Dust explosion. Electrical and magnetic effects.

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1st Edition
(Series 1.0 Letter)

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ISBN 978-3-00-054731-7

Foreword

This four-volume book series is intended as **extension of the standard books**, used for the dimensioning and og machine elements. It is attended to aspects wich get more and more importance for components of modern machines. A concer is the application orientation, i.e. the practice relevance. For this

the awareness of the problems is more important than the mere knowledge.

Energy efficiency, protection of resources and environment redsult in higher looads/stresses, utilisation of material strength and reduction of weight. Correspondent the demands at the machine elements and its safety increase. This, the design/construction of the machine elements, is the task of the standard books. Anyway **problems and failures during operation** must be expected. Unknown, respectively disregarded operation loads /conditions and component properties show first with application specific **operation experience**. Hopefully in time in appropriate **tests and proofs**. To **avoid** in the future failures and to find **remedies** for problems of compnents which are already assembled or even in service, the **sourcing/identification of the causes** is essenti-al. This is a step, which is not focus in the standard books for the design of machine elements. This shall be complementd with this book-series. The literature about failure analysis is expecially oriented at materials. Thereby prior-ranking are investigation methods, its analysis and case studies. So an **assessment of the failure mode and the correlation to the failure mechanism** takes place. However, this are only partly aspects of a systematic problem/failure analysis. It is merely a matter of a so called **collection of facts**, belonging a multitude of further fields like operation data and atmosphere as well a chronologigical sequences. Here the designer and the practitioner are needed. They demand in cases of a extensive problem clarification also laboratory investigations.

Based on the causes of clarified problems and failures is the **experience and with this the awarness of problems**. This again requires experience. Helpful is a **systematic problem analysis**. Therein the determination of the facts, the development of the hypothesis and as last step the review of the hypothesis on the basis of the facts.

To **identify and the correct interpretation of first signs of a failure** should be aspired. This can only be realized at the right area/position of the component. For this the knowledge of the **failure mechanisms and the failure modes** of the concerned macjine elements is reqired. So **weak points respectively faults of the design** can be identified. The application specific **know how** and **know why** increases, this is an important competitive advantage.

Against the assumption, the **computer and calculation programs** available today, would guarantee already the safety of the machine elements concerning operation problems, rather the opposite can be observed. The point is firstly, to **identify all relevant effects**. For this summaries of typical concerned components shall serve. Rising requirements respctively reduced safety distances demand the consideration of **effects**, which are **hardly acessible a calculation**. Because of this these and its mechanisms have been especiallyemphasized. Typical are production specific **faults and weak points** as well as **operation influences** in the form of wear, corrosion and aging. Combinations further aggravate the task. A calculation can be oly as good, as it is component specific, lifetime and safety relevant. So the operation realistic testing often will be essential. For this, which detracts the calculation applies: „The engine will tell us“. Here, the understanding of this „language“ of a machine should be promoted. But keep also always in mind, if the machine „remains silent“, the possibility of an outage may be dangerously near if there have been changes to increase the performance or if there have been repairs.

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The purpose of the special form of this book.

Motivation: Interesting and surprising headings of the illustrations.
Draw interest: Fast to understand illustrations of typical machine elements with features related to the content. typischer Maschinenelemente mit inhaltsbezogenen.
Meaningfulness and necessity shall be recognized during sudies.
Relevancy to practice with the reference to the general own technical experience. The concerned matter should promote already the one another interest, of the learner/student and the industry
Explanations to find as simply as possible in the text with the help of cross-linking (with descriptions in the illustrations).
Suitable for practical use. Also afer the sudies this booh schall seve as a adviser. For this, it supports especially the identification of design relevant influences.
Possibility of deepening of the knowledge with the help of literature references.

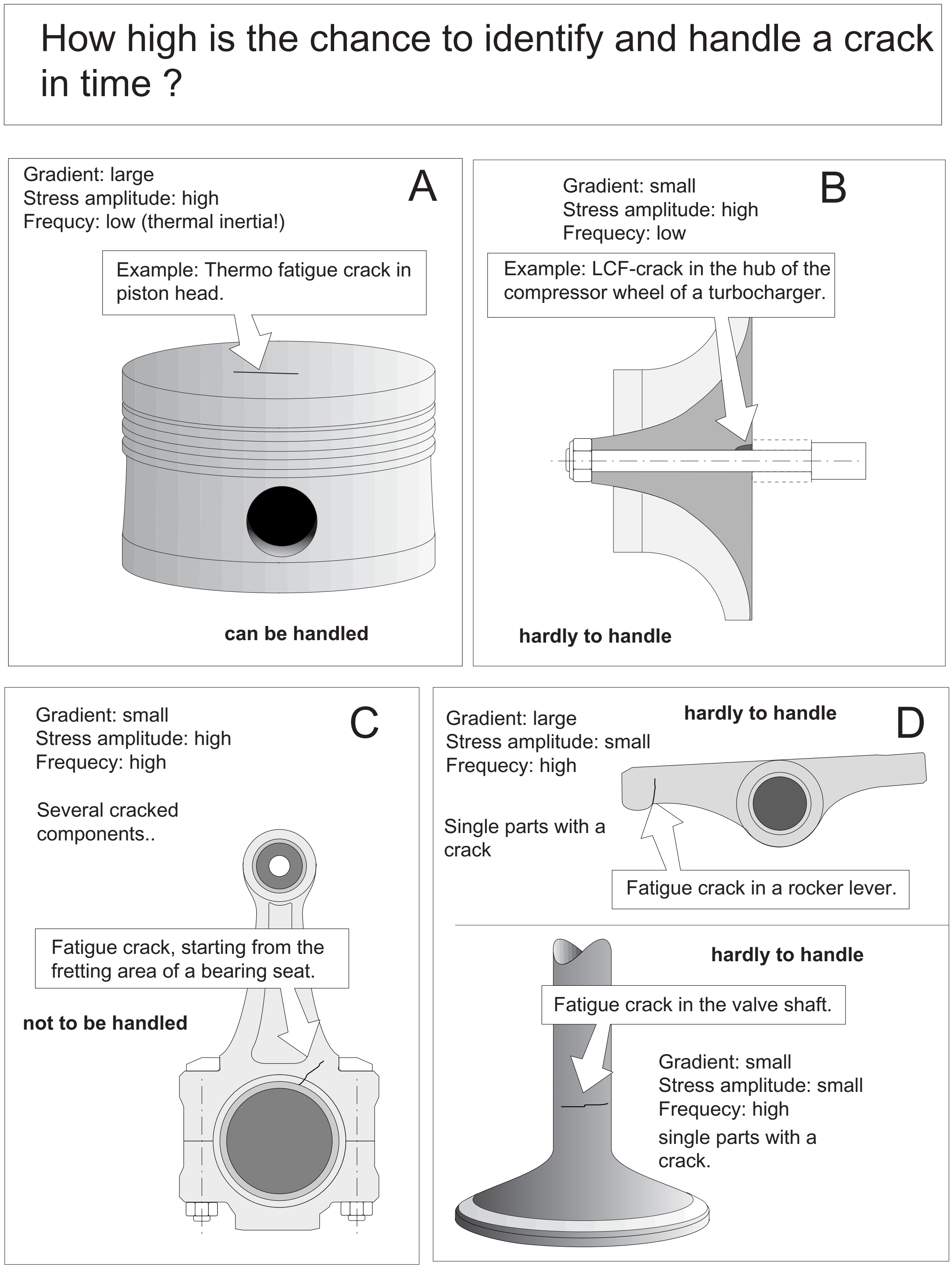
About the layout:

At the beginning of every chapter in a 'running text' a summary is given. The technical content however in based predominant on illustrations/**pictures with detailed explanations** in an **assigned text**. This is a situation similar to a lecture. Emphasized is also the evaluation by the 'lecturer'. This shall illustrate problems of the subject matter and last not least convey a feeling of personal contact.

To achieve those goals a **network** was chosen. It links the illustration descriptions with **hints at other pictures** and so enables to immerse oneself in the matter without fatiguing searching. This is espacially useful for technical terms and failure mechanisms. Bibliographic references (literature at the end of each chapter) should, if requested, serve the consolidation of knowledge. Thereby it is also a matter of 'web-contents' which can be reached directly by the specified addresses in the 'literature'.

A very extensive **index** at the end of the book is intended for the use asgeneral reference work in practice. As Pdf file this can be excellent used also in portable electronic devices with a **search engine** in the Reader ®.

Example:
Ill. 1-0 *(corresponding to Ill. 4.3-22, Lit. 4.3-21): The **evaluation of the risk** for its minimizing at acute failure cases is of high importance for a whole concerned fleet of similar engines/ components for the measures to be initiated. To this belongs the identification of concerned components, The **specification of inspection intervals**, the definition of the processes to be used und the development respectively introduction of remedies. For this approach the chance must be estimated to **intercept** the (incipient) crack in time before the failing of the component (mostly the fracture, Ill. 4.3-24). This enables the exchange of the defective component. In the scetches A,B,C and D the risk of a fracture in spite of a crack monitoring, is assigned typical load features.*
Criteria:
- ***Stress gradient*** *(see Ill. 4.3-1)*
- ***Stress amplitude*** *(LCF, HCF, see Ill. 5.4-5)*
- ***Mean stress.***
- ***Stress concentration*** *(influence of existing notches and incipient cracks).*
- ***Fracture toughness*** *of the material (Ill. 4.3-4 and Ill. 4.3-8)*
- ***Load frequency****: At high frequencies in a most shortly time (e.g., seconds) due to the many*



Ill. 1-0

load cycles very much damage is accumulated and the temporal crack growth gets uncontrollable.

- ***Number of cracked components** (see Ill. 4.3- 20 and Ill. 4.3-21).*
- ***Experiences** with failure relevant components.*

I am especially indebted to my editor, documentalist Reinhard Glander,

and for technical consultations and corrections:

Mister A.o.Univ.-Prof. Dipl.-Ing.Dr.techn. Heinrich Hochleitner for the review with the emphasis for the understanding of the reader for the behaviour of the machine elements.
Mister Dr. Andreas Marn for the review with the emphasis for ‘vibrations’ of machine elements.
Mister Reinhold Gräter für expert discussions woth the emphasis for practice related materials engineering and materials behaviour/properties.
Mrs. Dipl Ing. Katrin Friedberger for the review with the emphasis of materials science and failure analysis.

Contents

of this volume 1B on hand is marked with a grey background.

Materials Behaviour

'Mechanical' Loads

Operation Influences

Operation Influences.