NOTES ON THE DESIGN OF MACHINE ELEMENTS: FOR USE IN CONNECTION WITH UNWIN'S MACHINE DESIGN, PART I

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649658909

Notes on the Design of Machine Elements: For Use in Connection with Unwin's Machine Design, Part I by John H. Barr

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

www.triestepublishing.com

JOHN H. BARR

NOTES ON THE DESIGN OF MACHINE ELEMENTS: FOR USE IN CONNECTION WITH UNWIN'S MACHINE DESIGN, PART I

Trieste

NOTES

ON THE

DESIGN OF MACHINE ELEMENTS

FOR USE IN CONNECTION WITH UNWIN'S
MACHINE DESIGN, PART I.

BY JOHN H. BARR,

Professor of Machine Design, Sibley College.
Cornell University.

ITHACA, NEW YORK,
1901.

PREFACE.

These notes were prepared to accompany Professor W. C. Unwin's Elements of Machine Design, Part I. Taken in connection with this text-book, they form an outline of the course in the Design of Machine Elements as given to the Junior class of Sibley College, Cornell University.

The arrangement of the topics indicates the order in which the subjects are discussed, so that these notes serve as a syllabus of the lectures as well as a commentary on the text-book. In order that this double function may be fulfilled, numerous headings of articles are inserted accompanied simply by references to Professor Unwin's book. When it has seemed desirable to supplement or qualify the statements of the text-book, comments follow the appropriate references. The treatment of certain topics is quite independent of the text-book, and references to the authorities used are generally given in connection with the discussion of such subjects.

A short list of Reference Books is added to suggest the sources of fuller information and data. These books are arranged in classes, as an indication of their general scope, but they overlap to a considerable degree.

The preparation of these Notes has extended over a period of two or three years, advanced sheets having been printed and distributed to the classes from time to time. The conditions under which they have been issued has necessarily resulted in errors and imperfections, and many of these are apparent.

I desire to acknowledge my great obligation to the numerous writers and investigators consulted. I am especially indebted to Professor Dexter S. Kimball and Mr. William N. Barnard for their helpful criticism and careful reading of the manuscript and proof.

JOHN H. BARR.

Ithaca, New York,
March, 1901.

REFERENCE BOOKS.

Materials of Engineering.

Materials of Construction — R. H. Thurston
Materials of Construction — J. B. Johnson

Mechanics of Engineering.

Mechanics of Engineering — I. P. Church
Mechanics of Materials — Mansfield Merriman
Applied Mechanics — J. H. Cotterill
Mechanics of Machinery — A. B. W. Kennedy
Machinery and Millwork — W. J. M. Rankine

General Design.

The Constructor — F. Reuleaux
Machine Design — A. W. Smith
Machine Design — J. F. Klein
Machine Design — F. R. Jones

Special Subjects.

Friction and Lost Work — R. H. Thurston
Machinery of Transmission — J. Weisbach
Gearing — Brown & Sharp Mfg. Co. (Beale)
Kinematics, or Mechanical Movements — C. W. MacCord
Teeth of Gears — George B. Grant
Rope Driving — J. J. Flather

Practice.

Mechanical Engineer's Pocket-Book — Wm. Kent
Mechanical Engineer's Pocket-Book — D. R. Low
Manual of Machine Construction — John Richards
Transactions of American Society of Mechanical Engineers.
Transactions of American Society of Civil Engineers.
Transactions of American Institute of Electrical Engineers.
Transactions of American Institute of Mining Engineers.
Transactions of Institution of Civil Engineers (Great Britain).
Transactions of Institution of Mechanical Engineers (Great Britain).
Engineering Periodicals.
Trade Publications.

I.

STRAINING ACTIONS IN MACHINES.

1. **Forces acting on Machine Members.**—[Unwin, § 16, page 22.]

To the forces specified by Unwin, may be added: (7) Magnetic attraction, as exerted between members of electrical machines.

2. **Nature of Straining Actions.**—The character of the straining action and of the stress which results from a given load depends upon the direction and point of application of the load force, (or forces), and upon the form, the position, and the arrangement of the supports, of the member. A given load may produce tension, compression, shearing, flexure, or torsion; or a combination of these. Of course tension and compression cannot both exist at the same time between any pair of molecules, or particles. Flexure is a combination of tensile and compressive stresses between different sets of molecules; or, as it is often expressed, in different fibres, of the same body. Torsion is a special form of shearing stress. Owing to the frequent occurrence of flexure and torsion it is convenient to treat these as elementary forms of stress.

The stresses due to tension, compression and flexure are essentially molecular actions normal to the planes separating adjacent sets of interacting molecules: that is, the stresses increase or decrease the distances between these molecules along lines connecting them.

The primary straining effect in shearing and torsional actions is displacement of adjacent molecules, between which the stress acts, tangentially to the planes separating such molecules. In uniform shear, the interacting molecules move, relatively, with a rectilinear translation. In torsional action, the adjacent molecules, each side of the plane of stress, have a relative rotation about an axis.

3. **Ultimate or Breaking Strength.**—[Unwin, § 17, pages 23–24; also Table I, pages 40–41.] See, also, the table given on

AVERAGE VALUES OF STRENGTH OF MATERIALS.[1]

Material.	Per Cent. Carbon	Stress at Elasticity Limit. Tension.	Stress Ultimate Tension.	Stress at Elasticity Limit. Comp'n.	Stress Ultimate Comp'n.	Stress Ultimate Shearing.	Modulus of Elasticity. Shearing.	Modulus of Elasticity. Tension.
Bessemer and Siemens-Martin Steel.	0.15	42,000	63,000	39,000		48,000	9,000,000	30,000,000
	0.20	47,000	68,000	43,000		53,000		
	0.50	48,000	80,000	46,000		57,000		
	0.70	53,000	89,000	53,000		60,000		
	0.80	57,000	103,000	63,000		68,000		
	0.96	69,000	118,000	71,000		83,000		
High grade wrought iron		28,000	56,000	28,000		40,000	9,000,000	28,000,000
Common wrought iron		22,000	40,000	22,000		32,000	9,000,000	28,000,000
Crucible or tool steel		58,000	116,000	58,000			12,400,000	31,000,000
Malleable cast iron			35,000					
Steel castings		29,000	47,000	29,000				19,000,000 to 31,000,000 Average 25,000,000
Cast iron			10,000 to 35,000 Average 20,000		56,000 to 145,000 Average 90,000	18,000 to 20,000	7,000,000	13,000,000

[1] Taken from Constructive Materials of Engineering, A. W. Smith.

page 2; taken from Professor A. W. Smith's Constructive Materials of Engineering.

4. General Idea of the Factor of Safety.—[Unwin, § 17, pages 23-24.]

The working stress in a member must be less than the ultimate strength of the material, because:

(a) Members of structures and machines are not made to be broken in ordinary service.

(b) Materials employed in engineering usually take a permanent deformation, or set, before rupture occurs.

(c) There is always liability of defects in the material and imperfections in workmanship.

(d) In many cases there is danger of stress greater than the normal working stress from an occasional excess of load, or from accidents which are not foreseen or computed in advance of their occurrence.

It is generally essential that a part be not only strong enough to avoid breaking under the regular maximum working load, but also that it shall not receive a permanent set; for a machine member ordinarily becomes useless if it takes such set after having been given the required form. In many cases a temporary strain, even considerably below the elastic limit, would seriously impair the accuracy of operation, and in such cases the members often require great excess of strength to secure sufficient rigidity. It follows from these considerations that the working stress should always be below the elastic limit and it must often be much lower than the elastic strength

The elastic strength of many of the common materials of construction is not much above one-half the ultimate strength, and the proper allowance for defects, overloading and other contingencies depends upon the conditions of the particular case. It thus appears that the working stress should never be as great as one-half, and it should seldom exceed one-third, of the working strength of the material In structures liable to little variation of load and to no shock, the working stress may be from one-third to one fourth the ultimate strength, with such comparatively homogeneous and ductile materials as wrought iron, mild steel, etc. With brittle materials, as cast iron, hard steel, etc. (which are more subject to hidden defects and are less reliable generally), a greater margin is required for safety. If the conditions are such that the material is apt to deteriorate seriously, a suitable decrease of computed working stress should be made.

The effect of a suddenly applied load (shock or impact) is to produce a stress in excess of that due to the same load applied gradually, and where such impulsive application of the load is to be expected, an appropriate reduction of the ordinary working stress should be made to provide for this action. Experience and experiment have shown that the repeated variation or reversal of stress affects the endurance of a material, sometimes causing a piece to break under a load which it has often previously sustained. The theory of this gradual deterioration is not very completely developed as yet; but enough has been learned to show that the working stress must be reduced as the magnitude of the variations of stress and the number of such variations increases.

The quotient of the ultimate stress divided by the working stress is called the "*factor of safety.*" The Table [Unwin, page 24] gives some general values of the factor of safety for a few of the common materials with constant stress, varying stress of one kind, reversal of stress, and shock. Various writers have given such tables, and a comparison of the factor of safety recommended by different authorities shows a very wide range. See Thurston's Text Book of the Materials of Construction, page 342; Merriman's Mechanics of Materials, page 18, and many others. All such general values should be looked upon simply as suggestions; for the proper factor of safety can only be determined by careful study of the conditions of the particular case in hand. It is frequently proper to use different factors of safety for different members of the same structure or machine. Different materials and the methods of working these materials make some parts more liable than others to hidden defects. Certain members may be subject to considerable variation, or even to reversal of stress, or to shock; while other members carry a load which varies much less. A later article will treat more fully of