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Book Reviews

Design of Machine Elements, 6TH ED., by M. F. Spotts, Prentice-Hall Inc., Englewood Cliffs, N.J. 07632, 1985, 710 pgs., $41.95

Reviewed by H. Saunders

The latest (6th) edition of M. F. Spotts's book on design is an excellent, most read book for those interested in machine design. The proper usage and application of machine design are basic to the development of all mechanical and electrical instruments, high and low speed machinery, and transportation equipment tempered by experimental findings and/or practical experience. Design calculations also estimate the stress or deformation in given parts so that equipment can safely carry imposed loads and last for its expected life. The text includes calculations and experiments of tension, compression, torsion and fatigue life; consideration of natural properties like surface conditions, fillets, notches, manufacturing tolerances and heat treatment. As Mr. Spotts states, "The object of this book is to give training in the making of design calculations for the mechanical elements in universal use."

The initial chapters introduce the topics of machine design and the prime purpose of design calculations, fundamental principles, and working stresses. The fundamental principles treated concern tension stresses, center of gravity, force, mass, inertia and the bending of beams; the principles of superposition, deflection of beams, shearing stresses, Mohr's Circle and St. Venant's Principle. Then the focus shifts to stresses, beginning with the stress-strain diagram then continuing with maximum shear theory in one and two dimensions and, Mises-Hencky Theory (distortion energy theorem). Stress concentration factors are discussed for fillets in flat and round bars, plus grooves in flat and round bars; and the endurance limit of materials. This leads to the concept of ductile materials with complete stress reversal, plus alternating stresses in the Goodman diagram. This section concludes with consideration of the Miner-Palmgren (MP) rule, factor of safety, brittle materials subjected to fluctuating loads and steady stress. Included is a modified Goodman diagram.

Covered in Chapter 3 are the torsion and power transmitted by a circular shaft, application of maximum shear theory and the Mises-Hencky theory applied to shafting. Applications are made to keys, couplings in shafts and crankshafts and to their respective stress concentration factors. The fundamental critical speed equations for rotating shafts are furnished. This follows with the deflection and torsion of nonuniform shafts and to the slope of shaft influenced by elastic energy. The chapter concludes with consideration of the torsional moment carried by composite sections and their walled tubes.

Chapters 4 and 5 enunciate the use of various springs and screws. Springs are helical, leaf, belleville and rubber. Their material properties are presented with mention of fatigue, the buckling of compressive springs, and the vibration and surging of helical springs. Design considerations for helical extension springs and helical springs with torsional loading conclude this topic.

The treatment of screws indicates their different kinds of threads, and the effect of initial stress. Power screws and the torque required to produce a proper clamping force are treated. Last, Spotts considers the friction of screws, locknuts and the relaxation of screws in high temperature service.

Belts, disks, plate and cone clutches, disk brakes and chains provide the topics for Chapter 6. Included are the prime concern for the proper design equations for band brakes, block brakes with short shoes, pivoted brakes with long shoes and brakes with pivoted symmetrical shoes; then follows the treatment for chains. Equations are given for them, with consideration, expounded to horsepower capacity, galling of roller chains, and lubrication.

The next chapter studies welding and riveted connections. The strength of fusion welds, eccentrically loaded welds related considerations are thoroughly explained. Rules are offered for the design of fluctuating loads, and for procedures in welding such as, cold welds, atomic hydrogen welds, resistance welding, soldering and brazing. The design of riveted joints under the influence of central and eccentric loading and stresses in their cylindrical shells conclude this topic.

Chapter 8, studying lubrication, begins with Newton's Law for shear stresses in oil films, continues with Petrof's bearing equation, load carrying, and the load and function curves for journal bearings. The chapter treats power lost in friction due to heat and by self-cooled bearings, then turns to the design for film temperature and minimum film thickness, measurement of viscosity and its index. It treats various types of bearing materials: bronze, copper, lead, cast iron and sintered or porous metals. The construction of bearings is reviewed, and bearing loads, specifying clearances and grooves, and elastic matching. This latter concerns whether to seat the bearings closer together or use a larger diameter shaft. The chapter ends with a discussion of the "classical rules of dry friction," boundary (shear film) lubrication and mixed or simplified lubrication.

Ball and roller bearings provide the natural focus for the next chapters. Types of ball bearings are reviewed; then the effects of axial loads are mentioned. A short discussion of the Miner-Palmgren equation follows, although this equation must be used with caution. Spotts then reviews the design of bearings using different confidence levels, their mountings and materials, and the design considerations for unground ball bearings made on automatic screw machines. He concludes with a consideration of contact stresses between cylinders.

The next two chapters, 10 and 11, take up the subject of gears. The design equations for spur gears are considered first,

then the basic velocity law, kinematics of involute gear teeth, and pitch and cycloidal curves of gear teeth. Manufacturing methods for gears are reviewed, including gear finishing methods. Backlash and gear force determination are reviewed, including the load on gear teeth from transmitted power. A consideration of dynamic load equations leads into bending capacity of gear teeth, the Lewis factor for spur gear teeth, tooth capacity in contact stress, contact stress determination of bearing loads, the number of teeth in contact and last, the speed ratio of gear trains. Chapter 10 concludes with an interesting discussion on internal or annular gears, types of gear tooth failure, and the use of floating gear trains for speed reducers.

The following chapter takes up questions of gear design, starting with the design of level gears, including beam strength, beam loads and dynamic loads which cover wear. Then follows the design of special level gears, worm gears and horsepower capacity, geometric relationships, and the thermal capability of worm gears. Spotts reviews helical gears and their types, determined by pitch diameter, formative number of teeth, dynamic loads and wear loads, tooth loads, and load capacity. There is a great deal of useful information here condensed into a few pages.

The design of machine elements concludes with a review of assorted machine elements, including a consideration of the properties of engineering materials. The first topic concerns stresses, first for a thick cylinder, then those stresses generated by press fit and shrink fit. Stresses caused by flywheels with rims are reviewed including, solid rims containing center holes. Spotts then turns to torque impacts on a flywheel attached to a shaft. He reviews stresses caused by a moving weight on the end of either a bar or a beam, then turns to the cover design of gaskets for static loads, forces, and the fatigue life of wire ropes and stresses in circular and rectangular curved beams. Last, before turning to materials, Spotts lightly touches on different cams, both polydyne and plate, and stresses in both circular and rectangular flat plates.

Spotts initiates the discussion of machine materials by reviewing the tensile test and its findings concerning yield strength, elastic limit, proportional limit, and stress-strain curves. The good and bad points of carbon and alloy steels are brought forth. Additional topics encompass carburizing, nitriding, flame and strain hardening, corrosion and its prevention, and wear of materials. He concludes with the composition and mechanical properties of nonferrous materials like copper alloys and aluminum alloys, and with coating alloys.

Although this is an excellent, thorough book, there are some minor failings. For example, a short introductory section on finite elements and its applications, would have been helpful. Another area for improvement would be the provision of a more detailed section on analysis applied to compressor and turbine blades. A thorough section on random fatigue of metals would have helped too. These are minor comments in an otherwise able and comprehensive text.