CHAPTER 4.2

FLEXIBLE ROTOR BALANCING

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ABSTRACT

Developments which led to modern flexible rotor balancing techniques are described. The theory of flexible rotor balancing is outlined, and the theoretical basis for Modal balancing, and for Influence Coefficient balancing, is presented. In both instances, the publications from which the source material for this section was obtained are identified, with discussion. Certain other balancing techniques are also discussed. Recent developments toward the establishment of criteria for appropriate levels of residual unbalance in flexible rotors following balancing operations are included. The state-of-art for flexible rotor balancing is summarized, and the work which remains is identified.

4.2.1 Development of Flexible Rotor Balancing

The earliest reference to flexible rotor balancing appears in the patent awarded to Linn in 1928, reference [1], in which a sequential process for correcting the whirl modes of flexible rotors in bearings is described. Figure 1 shows the title sheet of the Linn patent, which refers to a steam turbine rotor in end bearings, to demonstrate the proposed process. The next development appeared in a paper by Thearle [2] concerning a vector method for two-plane balancing of the rotors of a three-bearing turbine-generator set. The application of a proposed method is described in detail, but without mention of whether or not the operating speed is beyond any bending critical speed of the unit. The method proposed is in effect a trim balancing procedure, intended to obtain an improved final balance condition for the three-bearing shaft assembly, over the two-plane balance results.
achieved separately for the individual rotors. Two other early papers, by Kroon [3] deal with the theory of rigid rotor balancing. These papers also include certain practical details for field balancing of turbine-generators.

Grobel [4] is a discussion of practical flexible rotor balancing for large turbines and generators. The importance of accurate manufacturing methods to minimize inherent unbalance is stressed. Special problems arising from the generator windings, from thermal instability of the turbine rotor, and from the buckets around the turbine circumference are mentioned. An empirical trial-weight balancing method is described for the first three bending modes of the rotor, indicating that since Thearle's earlier paper improved techniques had become necessary to account for flexible rotor effects in larger machines. Details of residual vibration in installed units are given. The paper contains an interesting description of the practical aspects of turbine-generator balancing at that time (1953).

Moore and Dodd [5] is a detailed practical discussion of the Modal balancing technique applied to turbine-generator rotors. Only single-span rotors are considered, not entire units. The vibrations arising from each mode are first described, and then the Modal balancing technique and its application is described in detail, in relation to the suppression of these vibrations. An interesting example of a pump rotor which responded strongly in its second and third modes simultaneously at operating speed is described. The problem of separating and balancing mixed modes is discussed, with detailed numerical values. Recognition of the cause of this problem and its solution resolved persistent difficulties with this unit.

Another recent practical contribution is due to Lindsey [6] who described an empirical 'one-shot' method for the balancing of large turbine-generator rotors. The method is most effective when the interaction from adjacent spans is minimal, and where the whirl ellipse is circular. In essence, the method is a procedure for balancing single-span rotors in their first three modes without regard to adjoining spans. It relies on collected previous experiences with similar units. The method could probably be adapted to more general balancing of other types of supercritical rotors. This paper presents an outline of the method, but gives no theory nor supporting details of its performance.

4.2.2 Theory of Flexible Rotor Balancing

The theory of flexible rotor balancing was begun by Weldahl [7] who outlined the principles of modal balancing and their application to the three-plane balancing of an end-bearing