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INFLUENCE OF VARIATIONS IN THE STIFFNESS OF BEARINGS IN HIGH POWER STEAM TURBINES

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ABSTRACT

The logic of programmed maintenance was not always at the base of the design choices made 50 years ago, above all due to the use of technologies quite different from those of today. The result is that today's technician can be in charge of equipment which, while still functioning, has suffered the wear or deterioration of material to the extent where, at least in certain fields of operation, components of the system have been "modified". The present study was motivated by direct experience with "dated" steam turbine installations (more than 30 years in operation). In particular, reference is made to an industrial plant where a variation in the critical velocity, due to wear and malfunctioning, has provoked damage to important components of the machine.
A preliminary examination of the case in question regarded an analysis of those factors that may impact on the critical velocity, and the development and validation of a suitable model of the machinery. It was then possible to evaluate the variation in first two values of the critical bending velocity in relation to parameters (play in bearings and loss of lubricant) which were found during the maintenance phase to differ from the original design parameters.
In the case of large steam engines for the production of energy, the operation of the machine over long periods of time can lead, for different reasons (deterioration of material, wear, etc.), to variations in the values of the critical velocities with respect to the original design values provided by the manufacturer. If these variations are not evaluated and taken into account, it is possible that operating conditions of extreme seriousness arise, especially in the phase of system start-up. In steam systems for the production of electric energy, in fact, the first critical velocity is often below the operating speed of the shaft and the second a little above.
In general, variations in parameters regarding the stiffness or the mass of a system may lead to conditions which differ from the original design conditions and, consequently, may give rise to situations which are unsafe for both the equipment and for the personnel in charge of its operation.
It is well known that in such installations, the start-up phase, which follows every shut-down (whether programmed or not), must respect a definite procedure of activation according to a precise protocol defined by the manufacturer.
The programmed velocity ramp has the aim of smoothly bringing the machine up to nominal operating speed, allowing the machinery to gradually take up the play resulting from thermal variations.
In general, it takes about 6 hours to arrive at connecting the turbine to the electric network, and during this period the machine must never continue running at speeds close to the critical velocities.
If for some reason (a series of maintenance interventions, not easily detected break down of a component, deterioration of materials due to elevated number of thermal cycles, etc.) there are modifications in the physical or geometric parameters of the entire system which may affect masses or stiffnesses, the critical velocities may vary. If such variations involve the lower critical velocities, it is possible that conditions of resonance are generated, also during the start-up phase. In this phase, in fact, following the velocity ramp indicated by the manufacturer (Figure 1), there is the risk of remaining at shaft speeds close to the modified critical velocity.
In the norms adopted by the American Petroleum Institute (API), the second edition of API 612 "Steam Turbine Specifications" prescribe a margin of separation such as to "position" the critical velocities at least 20% above and 15% below the constant velocity of rotation.
In the present study of a real case where the turbine shaft was damaged precisely during the start-up phase, the values of the new critical velocities are defined on the basis of modifications to the system found during a subsequent intervention to check the set-up of the machine.
The first phase of the study was to construct and validate a suitable model to simulate the behavior of the entire system (supports-bearings-shaft). The first two critical velocities of the system were known: these had been provided by the manufacturer and, furthermore, verified over many years of operation.

In a second phase, this model was used to evaluate the effect of variations in the stiffness of the bearings, produced by varying the play and loss of lubricant.
Finally, it was possible to calculate the value of the new first critical velocity on the basis of the real parameters found during a maintenance intervention which differed from the original design parameters. On checking the operation of the machine, in fact, it was found that in the first two bearings (high pressure zone) there was a loss of lubricant due to the failure of a pipe in the oil inflow circuit, and an increase in the play 0.2 mm greater than the design values.

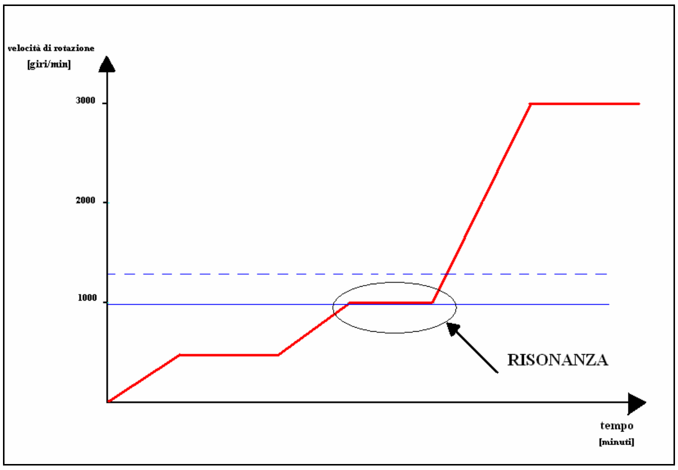

Figure 1: Graph of start-up. Original critical velocity (broken line), hypothesized critical velocity following variations in operating conditions (unbroken line)