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RESEARCH ON THE EFFECTS OF DIFFERENT SHAFT COUPLING TYPES ON STEAM TURBINE ROTORS IN THERMAL POWER PLANTS

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ABSTRACT

Theshaftcoupling using for a steam turbine rotor is an indispensable element for its smooth operation. Mechanical couplings connect the turbine shaft to other rotating equipment such as generators. They facilitate the transmission of torque between the turbine shafts or from the turbine to the connected machineryand connect these two devices together precisely.

The shaft coupling in the thermal power plant is a critical mechanical interface that links separate rotor sections such as high-pressure (HP), intermediate-pressure (IP), low-pressure (LP), and the generatorinto a unified, high-speed rotating shaft in large-scale utility thermal power plants. This paper presents comprehensive research on the operational impact of different predominant coupling configurations: rigid flange, semi-flexible, and flexible gear couplings etc. The structural characteristics, torque transmission capabilities and thermal expansion management of each type are thoroughly analyzed. Furthermore, the study evaluates the direct consequences of coupling-related anomalies: such as thermal misalignment, loose fitted bolts, and dynamic unbalance. The findings provide critical reference data for power plant maintenance engineers to optimize shaft alignment, mitigate forced outages and ensure the long-term structural integrity of utility-scale steam turbines.

KEYWORDS: Steam Turbine, Shaft Coupling, high-pressure (HP), intermediate-pressure (IP), low-pressure (LP), Generator, Shaft Alignment.

1. INTRODUCTION

In modern large scale thermal power plants, the steam turbine-generator set serves as the primary prime mover thatconverts thermodynamic energy into rotational mechanical energy. To achieve output capacities scaling from 300MW to 1000MW, these machines employ an extensively long shaft line, often exceeding 50 meters in length or more. For optimal manufacturing, transport, and maintenance logistics, the original equipment manufacturers (OEMs) take partition this immense shaft assembly into independent rotor sections, typically comprising high-pressure (HP), intermediate-pressure (IP), low-pressure (LP), generator.

The shaft coupling acts as the definitive mechanical link these distinct segments into a singular, cohesive dynamic. Operating at high continuous speeds of 3000 or 3600 rpm, the coupling must reliably execute three critical operational functions:

- *Torque Transmission:* Transmit massive, continuous mechanical work from the turbine blades directly to the generator rotor.
- *Load Bearing:* Withstand harsh transient axial thrust forces and dynamic radial loads under both normal and severe electrical fault states (e.g., generator short-circuits).
- *Thermal Expansion Management:* Accommodate severe axial and radial structural growth as materials transition from cold standstill to pass over initial steam working temperature.

Despite being entirely static components once fastened, shaft couplings represent the most dynamically sensitive elements within the entire rotor assembly. Minor geometric misalignments, poor bolting preloads, or improper type selection will be discussed to ensure for plant safety and small economic losses.

2. CLASSIFICATION AND ANALYSIS OF COUPLING TYPES

Based on mechanical design and self-aligning capabilities, steam turbine shaft couplings are categorized into main types as follows:

2.1. Rigid flange coupling

The Rigid flange coupling(Figures 1) is the most prevalent coupling configuration, used almost exclusively at main intersections (HP-IP-LP-Generator) in modern high-capacity utility power plants (300MW or more).

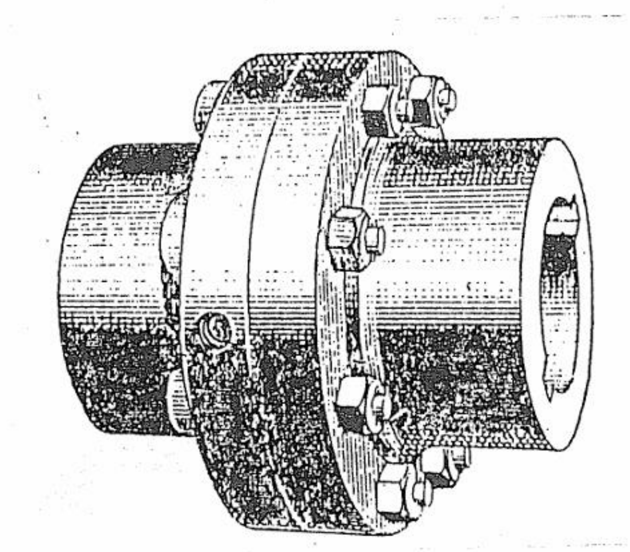

Figure 1. a rigid shaft coupling.

The rigid shaft coupling consists of two flanges that are either integrally forged with the shaft or shrink-fitted onto the shaft, and are tightly fastened together with bolts arranged in a circle (Figures 2)

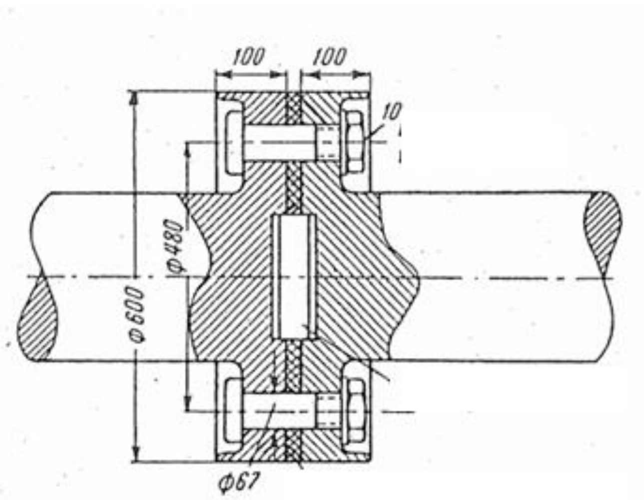

Figure 2. Cross-section of a rigid shaft coupling.

The rigid coupling flanges are forged integrally with the ends of each rotor section. The two flanges are clamped tightly together using a set of high-tensile fitted bolts. A male-female spigot register at the geometric center locks the shafts radially to ensure exact concentricity.

- **Advantages:** Provides absolute and rigid torque transmission with zero mechanical backlash. Mechanical lifespan is equal to the rotor itself, that is requiredfor no routine maintenance (such as lubrication). It transforms the shaft line into a continuous beam and optimize the journal bearing layout.

- **Disadvantages:** Completely incapable of absorbing any misalignment. It demands extremely stringent cold alignment tolerances during industrial overhauls (radial and axial runout are generally restricted to less than about 0.02 mm).

This Coupling HP to IP rotors, IP to LP rotors, and LP to generator rotors across OEM designs such as GE, Siemens, Alstom, and Mitsubishi companies.

2.2. Semi-flexible / Semi-rigid coupling

The semi-flexible shaft coupling is used to connect the turbine shaft to the generator shaft (Figure 3). Between flanges 1 and 2 is an elastic corrugated section 3. This allows for a slight angular and radial misalignment of the shafts during operation. However, this coupling does not compensate for axial misalignment.

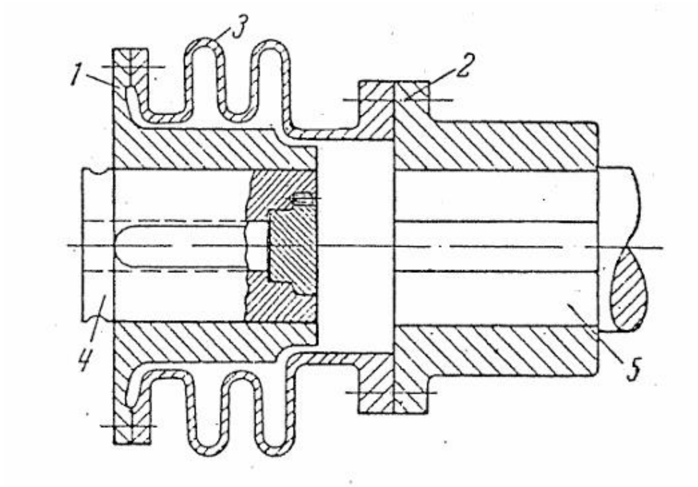

Figure 3. Semi-flexible / Semi-rigid coupling.

This system utilizes a short intermediate cylindrical sleeve (spacer) or a series of laminated flexible steel membrane discs bolted between the two main rotor flanges.

- Advantages: Accommodates minor angular flexibility. When the massive LP rotor experiences natural catenary deflection or when the turbine foundation settles unevenly, the semi-flexible assembly absorbs the bending moment without transmitting overwhelming mechanical stresses to adjacent journal bearings.
- Disadvantages: More complex design compared to rigid couplings, it has higher manufacturing cost and periodic in-service non-destructive testing to detect metal fatigue in the flexible plates.

It is primarily located at the component junction between the final low-pressure (LP) turbine bearings and the generator rotor, or between the generator and the exciter rotor where thermal and mechanical deltas are high.

2.3. Gear coupling

The flexible shaft coupling as gear couplingin the figure 5allows for relative displacement of the shafts caused by installation misalignment and thermal deformation during turbine operation. This coupling is installed on turbine-generator sets with four or more bearings, where the coupling is located in the space between two bearings.

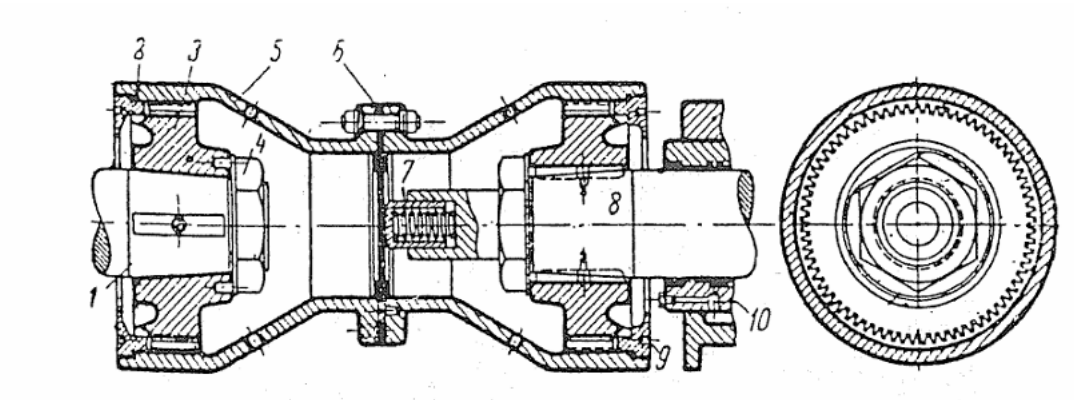

Figure 4. Cross-section of a gear coupling.

One shaft end needs to be processed with external crowned gear teeth which mesh inside an internal toothed sleeve integrated with the mating shaft. This assembly mandatorily requires continuous pressurized lubrication sourced directly from the turbine lube oil main header.

- Advantages: Permits significantly higher radial and angular misalignments compared to rigid or semi-rigid configurations. Critically, it allows for free axial floating dissipation between the rotors and it also isolate axial expansion reaction forces.
- Disadvantages: The meshing teeth are prone to mechanical wear and milling. Malfunctions in oil lubrication or oil contamination breaks down the protective oil film, producing operational instability. It cannot support large axial thrust loads.

It cannot be normally used for the shaft of the large-scale turbine. Gear couplings are exclusively applied on small independent turbines, boiler feed pump turbines (BFPT), auxiliary fan drives, or the mechanical interface connecting the rotor to the turning gear (barring gear) assy.

2.4. Flexible coupling

The flexible shaft couplingis used to connect the shafts of a double-casing turbine. It not only dampens shocks during torque transmission but also allows the rotors to displace significantly in the axial direction, as well as when the rotors are misaligned, which commonly occurs during operation even though the machine has been fully assembled.

The flexible coupling consists of two flanges mounted on the shaft ends of the rotors. Along the circumference of the flanges, there are rows of teeth. A serpentine steel spring 1 is placed between the teeth in the figure 5. The spring is divided into individual segments for easy assembly. A casing 2 is used to retain the spring and protect against dust.

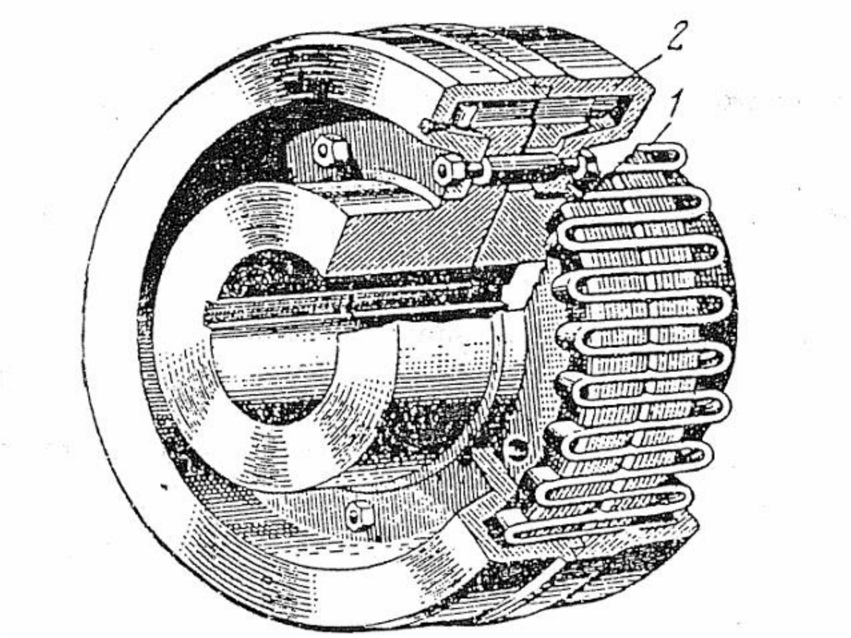

Figure 5. a flexible coupling.

The teeth must be shaped to allow the spring to bend easily. Under normal load, force is transmitted through the long free lengths of the spring with high elasticity. When the overload, the pivot point of the spring on the teeth shifts will be leaving. It is only a short free length with a stiffness that increases proportionally to the high load.

3. TECHNICAL STANDARDS AND SHAFT ALIGNMENT PROTOCOLS

During comprehensive plant overhauls, measuring and correcting the core rigid coupling centering configurations is the primary activity regulating system operational vibration.

3.1. The two mainly alignment metrics

Using reverse indicator dial gauges or digital field laser scanning alignment systems, maintenance engineers must correct work to the following limits:

- **Radial misalignment (Rim):** The offset distance between the geometric centerlines of the coupling flanges. Regulatory specifications typically dictate a maximum limit is less than

0.02 mm.

- **Angular misalignment (Face):** The parallel gap deviation across the flange faces (commonly referred to as flange gaping). Technical codes dictate a maximum specification is less than0.015 mm calculated across the coupling flange diameter.

3.2. Coupling bolt tightening methodologies

Rigid coupling bolts (fitted bolts) transit extremely severe rotational shear stresses. Hence, standard torque wrenches are abandoned in favor of high-accuracy preload techniques:

- **Thermal expansion tightening (Hot boting):**The central heating rods are inserted into the cored bore of the hollow bolt body. The heat induced by axial thermal elongation is pre-calculated and it is allowed the nut to be seated gently by hand to the mark position. Upon cooling process, the metal contractsis established immense design clamping forces.
- **Hydraulic pre-tensioning:** Specialized ultra-high pressure hydraulic fixtures extend over the protruding bolt threads. Simulated hydraulic fluid pressures mechanically stretch the bolt studs. Field engineers spin the nut to its position and then discharge the oil system pressures.

4. COUPLING MALFUNCTIONS AND TURBINE SUPERVISORY INSTRUMENTATION (TSI) SIGNALS

The TSI run real-time continuous evaluation of coupling situations via vibrations sensors integrated on adjacent journal bearing.

Operational incidents	Cause	TSI data	Solutions
Thermal misalignment	Incapable of expanding along sliding slots.	Radial vibration amplitude spikes as load increases. Harmonic analysis display spectrum dominated by a rigid 2x running frequency peak (100 Hz for 50Hz machines).	Examine system pedestal sliding keys; re-inject temperature-resistant industrial graphite lubrication. If unresolved, emergency sequence shutdown
Loose coupling bolts	Intense vibratory torque counter-reversal during severe generator phase short circuits process or insufficient initial bolt clamping force.	Radial vibration jumps instantaneously comprising unstable mechanically impacting waveforms noted on real-time scopes.	Immediate manual tripping emergency sequence shutdown to defend shafts against total journal breakage and rotor warping.
Coupling dynamic	Incorrect sequential positioning of fitted	Radial vibration escalates smoothly relative to rotor	Perform real-time field balancing calculations

unbalance	bolts during overhaul re-assembly. Each fitted bolt contains individual adjusted corrective gram masses to compensate runout.	up-barring speed. Spectrum plots show single independent voltage peak at 1x speed frequency (50 Hz).	and fit designed compensating weight block attachments into pre-machined radial slots on the flange edge.

5. CONCLUSION

The shaft coupling, although constituting a completely static component post re-assembly, operates as the most dynamically sensitive interaction element within the steam turbine-generator group. The long-term reliability of the entire unit depends inherently on strict compliance with stringent cold alignment technical standards, where radial misalignment (Rim) and angular misalignment (Face) must not exceed a tight threshold of 0.015 mm to 0.02 mm. Precision control of these geometric metrics, combined with advanced bolt preloading methodologies such as thermal expansion tightening or hydraulic tensioning that will serve as the core foundation to fully neutralize rotational shear stresses and forced bending moments.

Current technological developments emphasize a major shift toward utilizing rigid integral couplings to maximize torque transmission efficiency and eliminate routine lubrication maintenance. Concurrently, the deployment of 3D automated thermal matrix laser scanning systems embedded with live thermal expansion simulation algorithms represents the definitive technological key for engineering teams to maintain absolute control over rotor structural integrity. Implementing these synchronized solutions effectively eliminates the risks of operational misalignment, safeguards the journal bearings, and optimizes the equivalent availability factor of utility-scale thermal power plants throughout their operational lifecycles.

6. REFERENCES

1. TiêuchuẩnKỹthuậtvậnhànhNhàmáyđiện - TậpđoànĐiệnlựcViệt Nam (EVN).
2. Tuốc bin hơinước. Lý thuyếtvàcấutạo, Pham Luong Tue,NXBĐạihọcBách Khoa Hà Nội, 2005.
3. Gland Seal Steam of GE / Alstom / Doosan / Toshiba on web.
4. Shi Qingli, Wen SheJiao.Application of thermal test in thermal power plants [J].Qinghai Electric Power, 2004, 23 (4): 4-10.
5. Lv Kai, Wang Hongyu, Zhou Jia, etc.Study on characteristics of electrothermal coal for

cogeneration units [J].Thermal Power Generation， 2018, 47 (5)：7-12

6. Ji Ansen.Results and Analysis of Thermal Performance Test of Unit #12 in Wuhu Power Plant before Overhaul [J].Anhui Electric Power Technical Information, 2000, 000 (002)：7-10.
7. Zhang Guangcai, Zhou Ke, Lu Fen, etc. Discussion on deep peak shaving technology of coal-fired units [J].Thermal Power Generation, 2017, 46 (9)： 7-15.
8. Wang Wei.Analyze the application of thermal test in thermal power plants [J].China Science and Technology Wealth, 2012, 000 (014): 214-214.
9. Li Hening.Optimal operation of electric heating combined system based on new energy consumption [D]. Shenyang University of Technology.