

非同心型挤压油膜阻尼器的 试验和理论研究

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摘 要

本文介绍非同心型挤压油膜阻尼器在非对称模型转子和燃气涡轮发动机上的试验和理论研究。挤压油膜阻尼器能有效地抑制和减小传递到支承结构上的振动力。理论与试验结果是吻合的。本文推荐非同心型挤压油膜阻尼器设计方法。

一、引 言

过大的机械振动会严重地降低航空发动机的寿命、可靠性和总体结构完整。在比较轻薄的旋转动力机械中,因转子不平衡引起的同步激振对系统动力响应影响最大。减小振动的一种有效方法是采用合理设计的挤压油膜阻尼器。

挤压油膜阻尼器有同心型和非同心型两类。后者无定心弹簧,阻尼器造价低,占空间小,在相同工作条件下减振特性优于前者^[1]。但是,这种阻尼器通常使得转子中心涡动轨道不是同心圆,因而在理论处理上比较复杂。以往对非同心型挤压油膜阻尼器的理论和试验研究多半针对单质点对称柔性 Jeffcott 转子^[2,3],尽管取得了具有重要参考价值的研究成果,但毕竟与常用的燃气涡轮转子结构差异太大。

本文致力研究更接近真实燃气涡轮发动机结构的、非对称多质点柔性转子模型和双转子航空发动机,其挤压油膜阻尼器采用非同心型。本文论述了非同心型挤压油膜阻尼器试验和理论研究结果,推荐了这种阻尼器的设计方法。

二、挤压油膜阻尼器在模型转子上的试验研究

非对称模型转子安装在两个带非同心型挤压油膜阻尼器的滚动轴承上,试验装置和力学模型如图1所示。用支承座外传振动大小表征阻尼器减振效果^[4]。试验结果表明:有利的油膜间隙值有一个特定的下限,当间隙小于该特定下限值时,振动比不带阻尼器时还要大,甚至转子无法强迫通过临界转速;当油膜间隙稍大于该特定下限值时,振动则骤然变小,阻尼器获得较好的减振效果;油膜间隙在较大范围增大时,振动值基本保持不变;但过大的油膜间隙会使振动增大(图2)。一定的油膜间隙只能适应一定的转子不平衡度,油膜间隙大的阻尼器能适应的不平衡度范围也相应增大。转子不平衡度较大时,油膜间隙必须相应放大,但是,

不平衡度的增大是有限度的。

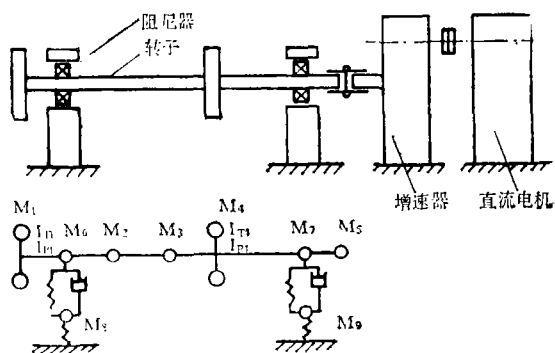


图 1 模型试验转子与力学模型

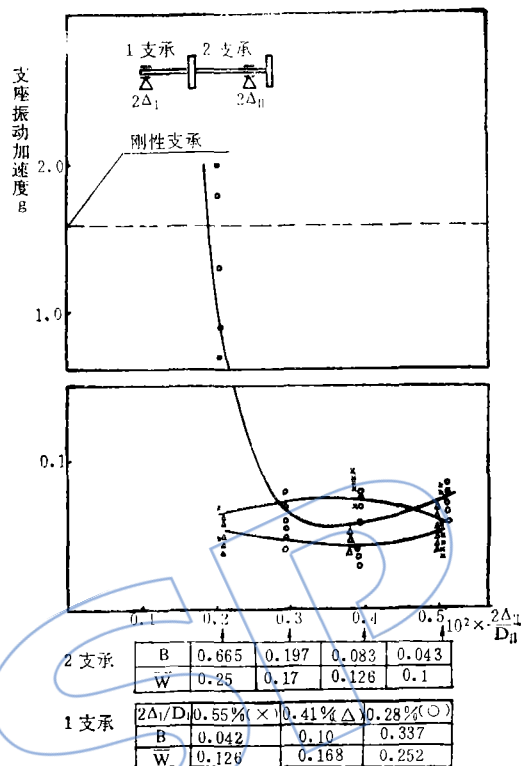


图 2 振动加速度与油膜间隙关系

三、挤压油膜阻尼器在航空发动机上的试验研究

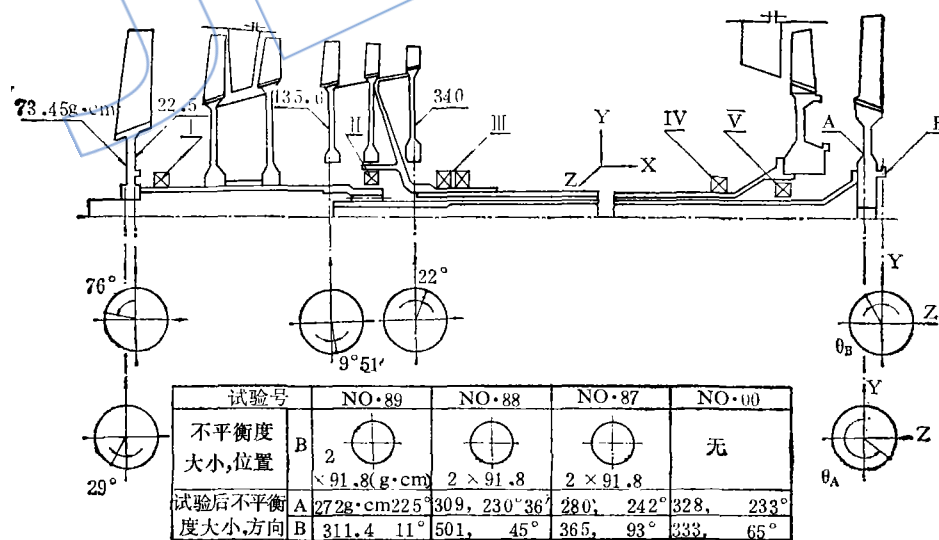


图 3 试验机与不平衡度试验检测数据

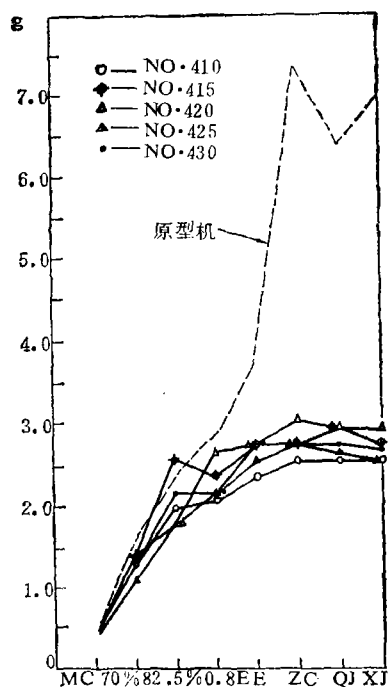


图 4 IV 支承带阻尼器时涡轮水平振动

试验机是一台振动很大的双转子燃气涡轮发动机(图 3), 振动源主要来自低压涡轮转子, 通过Ⅳ号支承传递到机匣。整机动力响应试验研究表明^[4], 仅在Ⅳ号支承设置非同心型挤压油膜阻尼器时, 涡轮机匣处振动值相对原型机(不带阻尼器)降低了 60% 以上(图 4)。由于涡轮振动减小, 对压气机部件的激振也相应降低, 致使压气机外传振动大为下降。当Ⅰ、Ⅳ两支承同时带非同心型挤压油膜阻尼器时, 其振动水平和减振规律与前者基本一致。具有合适参数的挤压油膜阻尼器可在转子很大不平衡度范围内保证转子稳定工作, 并得到满意的减振水平。

四、非同心型挤压油膜阻尼器理论研究与设计

对接近真实燃气轮机结构特征的、支承在非同心型挤压油膜阻尼器上的非对称转子——支承系统力学模型(图 1)进行了动力响应理论分析^[5,6]。分析结果指出: 传递性随轴承参数 B 的减小而降低, 大的 B 值会导致传递性接近于刚性轴承情况; 两个盘处的无因次振幅随 B 的减小而减小, 但在低速区伴有加大的相反结果。减振效果愈好的挤压油膜阻尼器具有愈大的轴颈振幅, 要使阻尼器起到良好的减振作用, 必须保证轴颈在轴承内有自由运动的可能性, 尽管这种运动量不大。在挤压油膜阻尼器工作最有效的区域内, 轴颈存在最大的运动。随着重力参数 $\bar{W}$ 增大, 轨道逐渐地沉至间隙圆底部, 太大的 $\bar{W}$ 值会使轨道拉长以致带尾巴(图 5)。不平衡度参数 U 对动力响应影响呈现非线性特性, 过大的 U 有时会产生非协调轨道(图 6)。

本文推荐挤压油膜阻尼器设计参数如下^[1]:

$$B = \mu R L^3 / m \omega_c C^3 = 0.1 - 0.2$$

$$\bar{W} = g / C \omega_c^2 = 0.05 - 0.1$$

式中 μ ——油的绝对粘度 ($\text{kg} \cdot \text{s} / \text{cm}^2$)[⊖], R ——轴承半径 (cm), L ——承载长度 (cm), m ——轴颈参振质量 ($\text{kg} \cdot \text{s}^2 / \text{cm}$), ω_c ——第一阶弯曲临界转速 ($1/\text{s}$), C ——油膜半径间隙 (cm), g ——重力加速度 (cm / s^2)。推荐值与试验结果吻合较好(图 2)。

⊖ $1 \text{ kg} \cdot \text{s} / \text{cm}^2 = 98066.5 \text{ Pa} \cdot \text{s}$

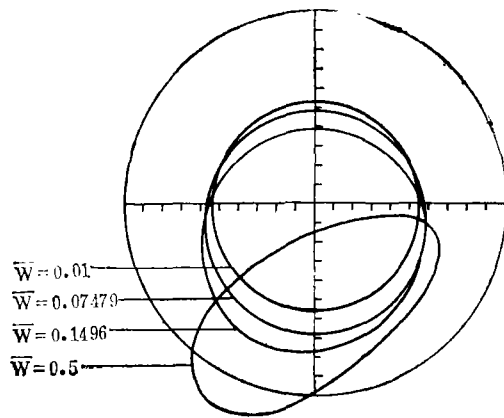


图5 No1盘轨道随重力参数 $\bar{W}$ 的变化 ($\bar{B}=0.0706081$, $U=0.2$, $\Omega=1.0$, $\bar{C}_d=0.01$, $\bar{C}_\theta=70.0$, $\bar{W}$ ——改变)

五、结 论

1. 只要小心地选择挤压油膜阻尼器的特性参数, 有可能使传递到支承结构上的力和转子振幅减至最小。挤压油膜阻尼器具有极大的减振潜力。一般地说, 只要合理设计阻尼器, 减振水平可达60%以上。

2. 由大量理论计算结果归纳得出的挤压油膜阻尼器设计参数推荐值, 在模型转子和航空发动机上得到了较好的验证。

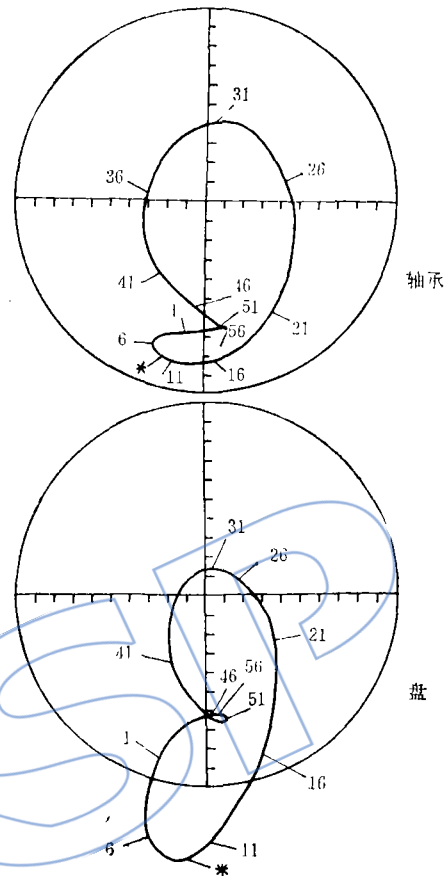


图6 非协调轨道 ($B=0.1018$, $\bar{W}=0.1067$, $U=0.3$)

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INVESTIGATION ON STEADY-STATE RESPONSE OF A DUAL-ROTOR SYSTEM WITH INTER-SHAFT SQUEEZE-FILM DAMPER

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Abstract

An analysis of the steady-state unbalance response of a dual-rotor gas turbine engine with a nonlinear flexible intershaft squeeze-film damper is implemented using a simplified transfer matrix method with rotating coordinates.

The simplified transfer matrix method is convenient for evaluation of the critical speed and the steady-state response of the rotor system with various supports, shaft coupling, intershaft bearing, etc. The rotating coordinates are simpler than the fixed Cartesian coordinates for calculation of oil film force generated by the centralized squeeze film damper. The nonlinear characteristics of the squeeze film damper are calculated by using iteration method.

The introduction of a flexible intershaft squeeze film damper into the rotor system is effective in reducing amplitude response and bearing loading, especially at the location of the intershaft bearing and adjacent rotor bearing supports.

EXPERIMENTAL AND THEORETICAL INVESTIGATION ON AN UNCENTRALIZED SQUEEZE-FILM DAMPER

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Abstract

The squeeze-film dampers on model rotors and a real jet are studied experimentally and theoretically. It shows that it is possible to minimize the unbalance forces transmitted to the surrounding structure and the disc amplitude and to bring great potential of damper attenuation capability into full play if only the parameters of an uncentralized squeeze-film damper are chosen carefully. Generally speaking, the optimum damper design will achieve a reduction in

vibration of 60% or more.

A design method of uncentralized squeeze-film dampers is also recommended, which gives the bearing parameter $B = 0.1$ to 0.2 and the gravity parameter $W = 0.05$ to 0.1 . The theoretical results and the experimental data have been found in good agreement.

LOW CYCLE FATIGUE LIFE TESTING RESEARCH OF AN AEROENGINE CASE

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Abstract

This paper presents in detail the method of low cycle fatigue life testing research on engine cases in connection with the following aspects: the determination of standard cycle load, testing samples and the design of its connection, stress testing and cycle testing under the synchronously loaded conditions at several points of a fully-sized case, the determination of approved cycle life and usage life.

MASS TRANSFER EXPERIMENTAL STUDIES ON THE FILM COOLING EFFECTIVENESS OVER THE CONVEX SURFACE WITH DOUBLE-ROW DISCRETE HOLES

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F.K.Tsou

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Abstract

The distribution of film cooling effectiveness for staggered double-row discrete holes has been measured extensively over the whole area of convex surface. It has been found that whether or not the blowing ratio of first row is equal to