

分析机匣—支承—转子系统动态响应的子结构迭代法*

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【摘要】 为分析机匣—支承—转子系统的动力特性,发展了一种子结构迭代—传递矩阵方法。利用这一方法使得对复杂转子系统的分析大为简化。与传统的整体传递矩阵方法相比,可大为节省机时,简化公式推导。理论证明与计算实例都表明,该方法具有收敛快、稳定性好的特点。

主题词: 子结构 迭代法 矩阵法分析 系统结构
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对机匣—支承—转子耦合系统^[1,2]动力特性的分析是发动机设计及故障分析的基础^[3]。利用有限元法可实现这一分析,但其公式推导繁琐,计算量较大。为此,本文提出了一种子结构迭代—传递矩阵方法。将机匣—支承—转子耦合系统分离成独立的机匣—支承子结构和转转子子结构。首先求得转转子子结构的稳态响应,将其作为激励通过支承施加在机匣上。由此所引起的机匣响应反过来又通过支承作用在转转子子结构上。每次求得的响应只是真实响应的近似解。但经反复迭代最终收敛于系统响应的精确解。由于每次响应计算只是针对自由度低的子结构进行,因此即使经几次迭代,计算速度仍比整体传递矩阵法快。理论分析表明,此方法在仅除几个不稳定点之外的转速区域都是收敛的,而一般的稳态响应计算都满足收敛条件。

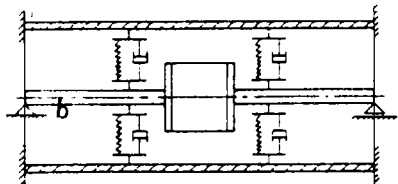


图 1 机匣—支承—转子系统模型

1 子结构迭代—传递矩阵法的原理

如图 1 所示,机匣与转子通过支承的弹性与阻尼相互耦合。现将此系统分离为图 2 所示的机匣子结构和转转子子结构。利用传递矩阵法首先

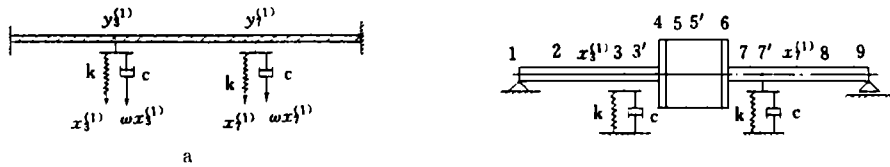


图 2 机匣子结构和转转子子结构(a)机匣子结构(b)转转子子结构

计算出图 2 所示的转子子结构在各个截面处的稳态响应(例如不平衡响应),以此作为转子响应的第一次近似解。

设截面 3 处和 7 处(即机匣与转子耦合截面)第 1 次近似响应为 $x_3^{(1)}$ 和 $x_7^{(1)}$ 。将此响应施加在耦合弹簧 k 和阻尼 c 的一端。在此作用下,利用传递矩阵法可以求出机匣各个截面处的响应,并以此作为机匣响应的第 1 次近似解。

第 2 次迭代时,解除转子子结构中耦合弹簧 k 和阻尼 c 的一端的固定约束,而代之以机匣第 1 次近似响应 $y_3^{(1)}$ 和 $y_7^{(1)}$,如图 3 所示。

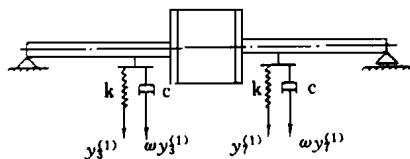


图 3 转子子结构受到机匣子结构的激励

同样利用传递矩阵法依次计算出转子子结构和机匣子结构的响应,由此得到相应的二次近似解。按第 2 次迭代过程进行反复迭代,转子和机匣的响应都将收敛于一相应的稳定值。实际计算时只需迭代 2、3 次就能得到。

2 子结构迭代—传递矩阵法与整体传递矩阵法的比较

为检验子结构迭代—传递矩阵法的精度及可靠性,针对图 1 所示的机匣—支承—转子系统,利用传统的整体传递矩阵法进行了计算。所取的传递截面与利用子结构迭代法计算时的相同,计算结果如图 4 所示。由图 4 可见,仅经 3 次迭代算得的结果就基本与整体传递矩阵法的

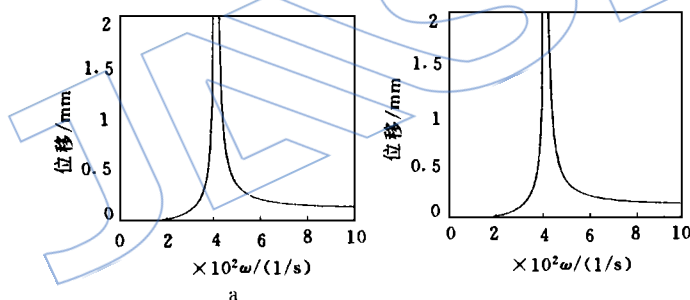


图 4 子结构迭代—传递矩阵法与整体传递矩阵法的比较

(a) 子结构迭代—传递矩阵法 (b) 整体传递矩阵法

相同。本法所用时间则为 652 s (HP9826 小型计算机),而后者要用 811 s。

可见,本法算得的结果可靠并具有收敛快、所需机时少的优点。如果分析更为复杂的机匣—支承—转子系统,则该方法的优点将更为突出(收敛性的理论讨论省略)。

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of P_p^*/P_s^* , but the corrected momentum coefficient K_m in the mixing pipe goes up. The mass flow rate coefficient μ of the primary nozzle increases slightly as the entrainment ratio goes up. The theoretical analysis has been done for the above conditions by application of aerodynamics. The comparison between the analysis and the experiment shows a good agreement.

Key Words Jet nozzles Ejectors Supersonic velocity Performance Analysis

SUBSTRUCTURE ITERATION FOR ANALYZING DYNAMIC BEHAVIOUR OF A CASING- SUPPORT- ROTOR SYSTEM

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ABSTRACT

In order to investigate the dynamic behaviour of a casing- support - rotor system, an approach associated with substructure iteration and transfer matrix is developed. With help of the approach, the dynamic response analysis of a complex rotor system is simplified and the computation time is lessened. The convergence and stability of the approach are verified with a simple model.

Key Words Substructure Iteration methods Matrix method System architecture

STUDY ON REDUCTION FACTOR OF FATIGUE STRENGTH AND DISPERSION COEFFICIENT OF LIFE IN SEAM WELDED JOINTS

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ABSTRACT

The purpose of this work is to study low cycle fatigue life of engine cases. A welded test piece has been designed according to reality of cases, using material of 1Cr18Ni9Ti in order to get fatigue function survey of seam welded joints. From tests S- N curve and P- S- N curve are obtained. Then the reduction factor of fatigue strength and dispersion coefficient of fatigue life for the seam welded joints are achieved with statistics analysis methods. Compared with a smooth test piece, the fatigue strength of the seam welded joints is obviously less than smooth test piece, but dispersion coefficient of fatigue life is better.

Key Words Welding joints Fatigue strength Life time

A BROKEN FILM CALIBRATION SYSTEM OF DYNAMIC PRESSURE MEASUREMENT

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ABSTRACT

The investigated calibration system of dynamic pressure measurement with response frequency less than 1 kHz includes two parts: a broken- film dynamic pressure signal generator and an acquisition- analysis system. Many experiments were carried out for investigating frequency components produced by the signal generator of different lengths, which indicated that the signal generator, under first- order resonant frequency, can produce sufficient frequency components (0.5- 1.5 kHz) as exciting resources. Moreover, the calibration system was used for dynamic calibration of three pressure probes of different lengths with a pressure sensor respectively. Meanwhile a particular way is adopted to obtain precise frequency response characteristics only by measuring the pressure probe output. It is shown that the calibration system is simple, reliable, and applicable.