

涡轮轴发动机振动监测技术研究

空军第 1 研究所 李喜发

【摘要】介绍了某型涡轮轴发动机的振动特点,针对其空中、地面的振动频谱分布情况,提出了实施振动监测的方法。结合部队外场的实际情况,利用单片微机研制出适合外场地面、空中使用的振动监测仪,收到了较好的效果。

主题词: 涡轮轴发动机 振动 监测
分类号: V235.12

1 某型涡轮轴发动机振动频谱的特点和分析

近几年来,某直升机先后多次发生因发动机空中振动大而停车的故障。此涡轮轴发动机是引进型机种,长期来国内尚未进行其地面、空中的频谱分析,发生故障后,我们进行了地面、空中振动监测和频谱分析,发现其特点:

(1) 发动机自由涡轮,燃气涡轮两者振动频谱的地面重叠和空中分离。地面、空中的振动频见图 1、图 2(图 1 $X = 0.684\text{kHz}$, $Y = 31.4819\text{mv}$; 图 2 $X = 0.6964\text{kHz}$, $Y = 44.3848\text{mv}$; 图 1、图 2 转速均为 80%,传感器号为 573)。该涡轮轴发动机由于其自身特点,自由涡轮转速在燃气涡轮转速增至大约 67% 时基本稳定,以后 N_g 再增加,自由涡轮转速基本不变,因此,在地面维护开车时 N_g 一般小于 85%,两者的振值由于速比的不同,在地面难以分开,而空中 N_g 一般大于 90%,两者振值从频谱上看,明显分开。

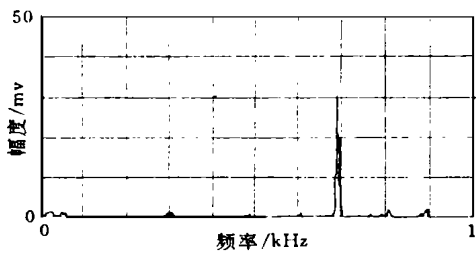


图 1 地面振动频谱

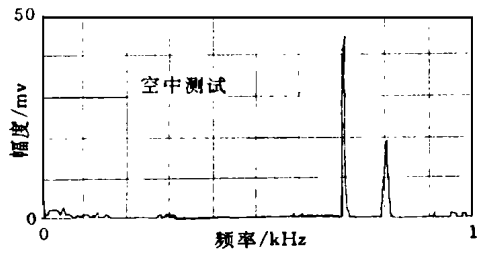


图 2 空中振动频谱

(2) 机载测振系统空中监测的目标是燃气涡轮,故要求系统在空中能分出自由涡轮和燃气涡轮引起的振动,而在 $N_g = 90\%$ 附近,两者的振动基频相差不大,对测振系统的滤波措施要求更高。

(3) 直升机自身振源多,干扰强,而该涡轮发动机体积小、转速高、温度高,故对测振传感器及系统提出更高要求。

2 某型涡轮轴发动机振动监测方法

针对此涡轴发动机振动特点和外场实际需要,采用了以压电测振系统为基础,以振动速度为监测参数,选用 8031 单片微机为核心,配以模拟电路和数字电路,组成此涡轴发动机的振动监测系统。方案的特点如下。

(1) 采用了既测振动总量,又测自由涡轮和燃气涡轮振动分量的综合监测方案,根据本发动机的振动特点及规定的振动限制值是总量限制,见图 3。因此,作为此涡轴发动机的振动监测设备,必须能测出发动机的振动总量,以便与法国规定的限制值协调,便于外场使用。但根据空中振动的频谱分析,由于自由涡轮、燃气涡轮空中振动基频分量非常突出,故在测总量的同时,也测出了两涡轮的分量,便于外场振动故障的快速诊断。

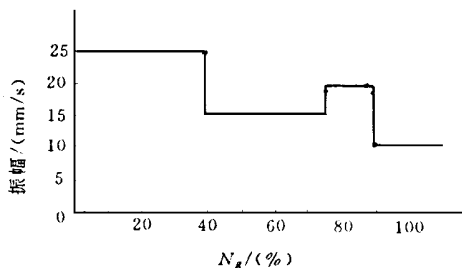


图 3 某型涡轴发动机的振动限制值

(2) 采用了 Intel 51 序列的 8031 单片微机,实现空中振动值的显示、存贮和报警,存贮的数据,不怕掉电。

3 主要技术指标及应用情况

(1) 采用压电测振传感器,其灵敏度为 $10 \pm 0.5 \text{ PC/g}$; 横向灵敏度优于 3%; 频率范围 $5 \sim 5 \pm 5 \text{ kHz}$; 安装谐振频率 25 kHz; 长期工作温度 350°C 。

(2) 记录仪通道数 8 路。其中 6 路用于记录发动机振动信号,2 路用于监测转速。滤波器带宽。总量 $100 \sim 1000 \text{ Hz}$,带内不平坦度小于 0.2 db,低端衰减 20 db/OCT,高端衰减 35 db/OCT; 自由涡轮分量带宽 $693 \pm 10 \text{ Hz}$,低端衰减 25 db/OCT,高端衰减 100 db/OCT; 燃气涡轮分量带宽 $777 \sim 1000 \text{ Hz}$,低端衰减 100 db/OCT,高端衰减 35 db/OCT。两路转速信号分别来自发动机转速表传感器,经限幅,光电转换形成闸门时间,作为判断存贮振动信号的时限。有广频信号输出,便于分析和诊断故障。有自校装置,便于外场使用。通过了军标要求的电磁兼容试验,能与机载设备电磁兼容。

本系统研制成功后,先后在外场进行了数十次地面、空中现场实测和记录,证明系统性能稳定,工作可靠,取得满意效果。其中在外场地面测试中,发现两架直升机的振动值超标,工厂当即决定发动机返场修理,排除了故障隐患,保证了飞行安全。

(责任编辑 王震华)

new trainer engine. This study shows that due to short average flight time, a great difference exists between the mission duty cycles of the trainer engine and the design requirements of Engine Structural Integrity Standard (MIL-STD-1783).

Key words Training aircraft Aircraft engines Loading spectrum

A FINITE ELEMENT METHOD FOR COMPUTING DYNAMIC COEFFICIENT OF HYDRODYNAMIC JOURNAL BEARINGS

Wang Dongwei and Zhu Jun

(Inst. of Lubrication and Bearings, Xian Jiaotong University, Xian 710049)

ABSTRACT A finite element method is presented for computing the oil-film dynamic coefficients of hydrodynamic journal bearings. Once the integral equations of the four functions, $\hat{q}_p/\hat{\alpha}_{xc}$, $\hat{q}_p/\hat{\alpha}_{yc}$, $\hat{q}_p/\hat{\alpha}_{xc}$, $\hat{q}_p/\hat{\alpha}_{yc}$, are gotten, their matrix expressions can be obtained immediately. Integrating them over the film domain, we can get the eight oil-film dynamic coefficients. Then it is possible to solve the Reynolds equation only once.

Key words Matrices Hydrodynamic journal bearings Finite element methods

AN INVESTIGATION ON VIBRATION MONITORING TECHNIQUE FOR A TURBOSHAFT ENGINE

Li Xifa

(First Air Force Research Institute, Beijing 100076)

ABSTRACT The Vibration characteristics of the turboshaft engine on ground and in flight are considered. According to the distribution of the vibration frequency spectrum, a method is presented to display and record vibration velocity value of the turboshaft engine on ground or in flight. A vibration monitor made of INTEL 51 series 8031 single chip microcomputer has eight channels. Six channels are employed to record vibration signals and the other two channels to measure engine rotating speeds. The system operation performance has been proved by a large amount of measurements on fields and airborne measurements.

Key words Turboshaft engines Vibration Monitoring

A STUDY ON MOTION BEHAVIOURS OF PARTICLES THROUGH TURBINE CASCADE

Yi Jinghai

(Shanghai Jiaotong University, Shanghai 200030)

Shi Feng and Xu Zhong

(Xi'an Jiaotong University 710049)

ABSTRACT A high speed camera is used to photograph the motion process of particles through turbine cascade. The effects of particle size and initial position on the particle trajectories and velocities are analyzed. The particle trajectories and velocities are also computed with the Lagrangian method under conditions of flow with and without boundary layer. Comparison between computational and experimental results shows that it is necessary to consider the effect of the boundary layer for the smaller particles, but it is unnecessary for the larger particles when the Lagrangian method is used to compute the motion behaviours of particles.

Key words Plane cascades Solid particles High-speed photography