

教练机发动机使用任务循环推导

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【摘要】 在大量的外场统计和空测的基础上,对某教练机发动机的外场使用载荷进行了分析研究,推导出了其使用任务循环,并与 MIL-STD-1783 进行了对比分析,为国产同类新型教练机发动机的设计任务循环的预测奠定了基础。

主题词: 教练机 航空发动机 载荷谱
分类号: O231.9

1 典型飞行科目的空测与任务混频

为了预测某新型教练机发动机的设计任务循环,对现役某同类教练机发动机的外场使用情况进行了空测与调查,在此基础上推导了发动机的使用任务循环。根据飞行训练大纲,该教练机的飞行科目有 65 种,按文献[1]中的原则,选取了 7 个飞行科目进行空测,这 7 个科目包括起落、特技、仪表、航行、攻击,以及夜航等飞行练习,全面反应了该机的飞行训练特点。为了获得准确的任务混频,调查了近 5 年来累积总架次为 217822,总时间为 103271.6 小时的飞行训练,经统计和计算后的结果如表 1 所示。它真实地反映了外场使用情况。

表 1 飞行任务混频

序 号	1	2	3	4	5	6	7	总计
典型练习	5# -1	5# -2	10#	15#	127#	67#	32#	
架次(次)	19695	44313	17019	43576	3737	45445	44037	217822
每架次平均时间(分)	4.93	19.72	25.97	28.83	28.30	49.67		
100 小时任务混频	19.08	42.93	16.48	42.21	3.62	44.02	42.66	211

2 使用任务循环的推导

使用任务循环是由飞行任务混频和实测的飞行任务剖面推导出来的混合循环,包括 0-最大-0、慢车-最大-慢车、巡航-最大-巡航三类循环,为此应给出发动机最大、慢车和巡航三个特征功率状态下的转速变化范围。根据发动机的特性,取以下转速范围表示特征功率状态:(1) 最大状态:转速 $\geq 11200\text{ r/min}$; (2) 慢车状态:空中为 $4000\text{--}8680\text{ r/min}$,地面为 $2500\text{--}4000\text{ r/min}$; (3) 巡航状态:转速为 $8680\text{--}11200\text{ r/min}$ 。为了统计方便取转速剖面为 A: $0\text{--}2000$; B: $2000\text{--}4000$; C: $4000\text{--}8680$; D: $8680\text{--}11200$; E: $11200\text{--}11600$ 。用计算机程序进行处理,取循环无效幅值为 250 r/min 。表 2 为大于或等于中等功率以上的时间的统计结果总计 1089.96 分;对 7 个剖面乘上任务混频后的混合循环,其中删去全部为零的各行和各栏,见表 3。

发动机使用任务循环包括有^[2]:使用寿命和寿命参数两大部分。由发动机飞行任务剖面和

飞行任务混频的统计结果, 参考大纲的要求, 各项指标计算如下:

表 2 大于或等于中等功率以上的时间($T_{\max}$)的统计结果

练习号	5# -1	5# -2	10#	15#	127#	67#	32#
$T_{\max}$ (分)	0. 833	3. 33	7. 87	10. 07	2. 30	1. 67	6. 90
任务混频	19. 08	42. 93	16. 48	42. 21	3. 62	44. 02	42. 66
小计(分)	15. 90	143. 12	129. 70	425. 05	8. 33	73. 51	294. 35
总 计	1089. 96 分= 18. 17 小时						

(1) 设计使用寿命: 总的飞行时数: 以 100 小时寿命为一个计算单位, 进行计算分析其它各参数。飞行总次数: 根据飞行任务混频统计为 211 次。所以每架次的平均起落时间为 100 小时/211= 28. 44 分。地面工作时间与运转次数: 根据发动机的地面检查试车程序^[2]知一次地面试车时间为

表 3 剖面雨流计数统计结果(次数)

初	终		
	C	D	E
A	0	0	211
C	450	1037	1076
D	0	383	357

7 分钟, 其中包括: 0-最大-0, 慢车-最大-慢车各 1 次, 大于等于中等功率状态时间为 0. 5 分钟。地面运转次数: 根据外场使用的统计结果, 为飞行次数的 5% 左右, 即为 $211 \times 5\% = 10. 55 \approx 11$ 次。地面工作时间: 根据对实测飞行剖面统计, 结果为每个起落 3 分钟; 地面试车一次为 7 分钟, 共 11 次, 所以总的地面工作时间为 $3 \times 211 + 7 \times 11 = 710$ 分钟= 11. 83 小时。

(2) 寿命参数: 0-最大-0 循环: 等于飞行总次数与地面运转次数之和, 即 $211 + 11 = 222$ 次。慢车-最大-慢车循环: 空中飞行该项取自表 3, 为 1076 次循环; 地面检查试车乘上混频后为 11 次, 共计 $1076 + 11 = 1087$ 次。巡航-最大-巡航循环: 空中飞行时, 该项取表 3, 即 357 次循环; 地面检查试车无此类循环, 所以共 357 个巡航-最大-巡航循环。

加力燃烧室点火次数和加力工作时间: 该发动机无加力, 故这两项为零。

最大状态工作时间由两部分组成: ① 飞行剖面的统计值见表 2, 为 18. 17 小时; ② 地面检查试车为 $0. 5 \times 11 = 5. 5$ 分= 0. 0916 小时, 总计为 $18. 17 + 0. 0916 = 18. 26$ 小时。

以上综合结果见表 4, 在表中同时也列入了结构完整性大纲中教练机的相应项数据。从表 4 可见, 该发动机的使用任务循环与结构完整性大纲中的教练机的规范要求相差很大, 以 100 小时为计算单位, 0-最大-0 循环相差近 3 倍。其主要原因在于平均起落时间比 MIL-STD-1783 中的 1. 33 小时要短得多, 从而导致在规定的时间内 0-最大-0 循环比 MIL-STD-1783 多, 这是现阶段该类教练机的外场使用的一个重要特征之一。

表 4 发动机使用任务循环

使用 任务 循环	使 用 寿 命				寿 命 参 数			
	小 时		任 务		0-最大-0	慢车-最大-慢车	巡航-最大-巡航	等于或大于中等功率的时间 (小时)
	飞 行	地面工作	飞 行	地面工作				
	100	11. 83	211	11				
1783 大纲	18000	5400	13500	1500	15000	150000	150000	3600

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RELIABILITY DESIGN OF TURBINE PART VIBRATION

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ABSTRACT

This paper presents a reliability design method of turbine part vibration, based on conventional vibration design method for turbine parts. The method considers excitation force frequencies, natural frequencies and vibration responses of turbine parts as random variables according to actual conditions. The reliability for the vibration design of parts is estimated by means of probabilistic design. Methods for determining the distribution parameters of design magnitudes are given together with reliability calculation models for distancing from resonance and limiting vibration response. Reliability design methods of rotors and bearings as well as blades are elucidated with some practical examples.

Key words Turbomachines Reliability design Parts Vibration

A STRESS INFLUENCING MATRIX METHOD FOR CALCULATING BENDING ROOT STRESSES OF HELICAL GEARS

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ABSTRACT

A method of the stress influencing matrix is proposed for calculating bending stress courses on teeth root of the helical gears. The stress influencing matrix of mesh nodes on the surface of the gear teeth and on nodes of its contact lines is established by using 2-D interpolation and then is multiplied by the load distributing matrix on the nodes. Therefore, the bending stress courses on the gear teeth root are obtained. By means of generating the flexibility matrix on the gear teeth root the finite element calculation of this method is only needed once to obtain the distributing conditions of loads on the working surface of the gear teeth and distributing conditions of the bending stresses on root surface of the gear teeth for whole meshing period. The calculated results are compared with the experimental data. It is proved that the method of the stress influencing matrix is as accurate as the finite element method, but can save computer memory and calculating time to a great extent.

Key words Helical gears Bending stress Finite elements Matrices

TECHNICAL NOTES

DERIVATION OF MISSION DUTY CYCLES FOR A TRAINER ENGINE

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ABSTRACT

The main objective of this study is to establish a method for deriving engine mission duty cycles. Seven typical training profiles of a trainer engine are recorded. The flight mission mix is obtained from statistics of the trainer engine operations on fields. Based on the typical flight mission profiles and the mission mix, the mission duty cycles of the trainer engine are derived which can be used as a design load requirements for a

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

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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

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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

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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