

环形金属橡胶减振器

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【摘要】 研究开发出一种用于转子支承系统的新型阻尼器—环形金属橡胶减振器(RM RD)。在转子实验器上的实验研究表明,它具有优越的阻尼减振性能和线性特性。与挤压油膜阻尼器(SFD)比较,RM RD 减振效果更好而且能承受更大的不平衡力载荷。作为一种干摩擦阻尼器,RM RD 能在高温或低温下长期工作,因而特别适用于作低温环境下工作的火箭发动机的液氢和液氧涡轮泵转子减振器。

主题词: 减振 转子 阻尼器

分类号: O 328

1 前 言

挤压油膜阻尼器(SFD)是一种效果较好的阻尼器,并且得到了广泛的应用。设计不当或不平衡量过大会引起 SFD 的高度非线性使转子系统过临界状态时出现双稳态或锁闭^[1],因此使用范围受到了限制。此外,航天液体火箭发动机的高压液氢,液氧涡轮泵由于工质的低温和低粘度不可能采用 SFD 或其它阻尼材料。因此很希望能找到一种能在超低温下工作的阻尼器。环形金属橡胶减振器(RM RD)是我们设计的一种新型减振器。它是由细金属丝经过螺旋成型,拉长,缠绕毛坯,模压等几道工序制成。其内部结构是金属丝相互交错勾联形成的类似橡胶高分子结构那样的空间网状结构,在受到振动位移时可耗散大量能量而起到阻尼作用。环形金属橡胶减振器可安装在轴承外环与轴承座之间。我们的实验充分证明了采用环形金属橡胶减振器不仅可以有效地解决非线性问题,它的减振性能也超过了 SFD;而且因为环形金属橡胶减振器完全是由金属丝制成,所以它可以在高温和超低温下正常工作。

2 RM RD 与 SFD 在转子不平衡响应实验中的性能对比

实验所用转子为刚性转子,由电机带动,其间有增速器和联轴器。转子的一端为刚性支承,另一端为减振器支承。本实验中所用的减振器为环形金属橡胶减振器和挤压油膜阻尼器(SFD)+弹性支承,实验的目的是对上述两种减振器的性能进行比较。

转子和减振器(RM RD/SFD+弹性支承)的结构参数。转子参数:转子在左端轴承处的当量质量为 7.3 kg。RM RD 参数:重量为 99.7 g;宽度为 25 mm;外径为 91 mm;内径为 75 mm;金属丝直径为 0.1 mm;螺旋丝直径为 1.1 mm;轴向模压成形压力为 30000 N;滑油压力为 0;刚度为 $4.5 \times 10^6 \text{ N/m}$ 。SFD 参数:油膜环外径为 94 mm;油膜间隙= $0.375\% \times \text{油膜环内半径}$ 为 $0.375\% \times 80/2$, $0 = 0.15 \text{ mm}$ 油膜环长度与油膜环外径比为 0.25 mm;鼠笼式弹性支承刚

度为 $2.1 \times 10^6 \text{ N/m}$; 滑油温度为 $16\text{ }^\circ\text{C}$ 。

表 1 RM RD 和 SFD 转子系统临界转速时的不平衡响应实验结果

参 数	RM RD 转子系统				SFD 转子系统		
左端轴承处的等价不平衡量($\text{g} \cdot \text{cm}$)	44	66	88	110	17.6	30.8	39.6
临界转速(r/min)	7600	7500	7500	7500	4800	5100	5300
临界转速时的振幅(mm)	0.042	0.061	0.082	0.099	0.04	0.08	0.09
临界转速时不平衡量引起的不平衡力(N)	278.70	407.12	542.82	678.54	44.47	87.85	121.98

由上述实验数据可以得出如下结论:

(1)RM RD 的减振效果大大超过 SFD。其原因是金属橡胶(MR)是一种大阻尼材料,金属丝之间的相互摩擦和碰撞消耗掉大量能量。因此RM RD 表现出很好的阻尼特性。

(2)RM RD 没有明显的非线性。由图 1 可知:在某一小工作范围内,RM RD 动态特性中位移与所受外力的关系基本上为线性;RM RD 的刚度基本上可以认为是定值。

(3)RM RD 在大不平衡量时表现出色。在大不平衡量时 SFD 常出现双稳态,锁闭等严重问题。如前面所述,RM RD 不存在这一问题,其刚度为常数,阻尼效果又很好,这样RM RD 注定会在大不平衡量时有出色表现。从上面数据可以看出: SFD 在 121.98 N 的离心力作用下振幅已达 0.09 mm ;而RM RD 在 278.70 N 的离心力作用下振幅仅为 0.042 mm 。

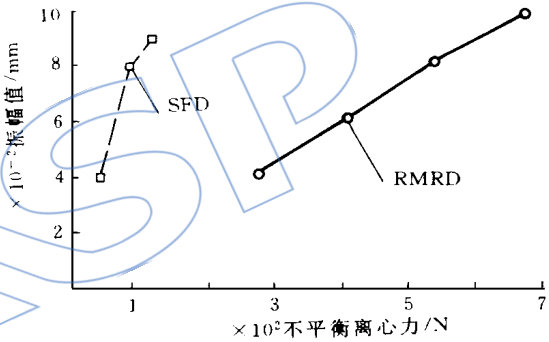


图 1 RM RD 和 SFD 转子系统对不平衡量的振动响应

(4)SFD 表现出硬特性而RM RD 表现出软特性。从图中曲线的凸凹走向可以看出,SFD 的动态特性是一条凸曲线而RM RD 的动态特性基本上是一条变化不大的凹曲线。也就是说RM RD 具有不明显的软特性,SFD 具有硬特性。软特性更有利于转子加速时通过临界状态。

3 夹紧对 RM RD 性能的影响

上面所采用的数据是从众多的数据中抽出的一组。在实验中我们发现对RM RD 性能影响较大的参数有很多,这些参数的变化有可能引起RM RD 性能的较大变化。以下仅考察安装对RM RD 性能的影响。实验中所用的RM RD 是在一个环形腔内由轴向加压力成形的。对于前面所提到的RM RD 试件,当轴向压力为 30000 N 时,RM RD 的长度为 21 mm ;轴向压力去掉后,RM RD 的长度变为 25 mm 。可以由此推断,对于工作中,从轴向对RM RD 夹紧时,夹紧长度的不同必然会影响RM RD 的性能。这里定义夹紧率为: $CR = \text{夹紧后长度} \times 100\% / \text{模压成形时的最小长度}$ 。从图 2(b)数据可以看出:夹紧率是一个很重要的参数。夹紧率增大时RM RD 内部金属丝之间的相互挤压作用加强,摩擦力加大,RM RD 的阻尼增加,所以转子过临界时的振幅降低了。在 $88 \text{ g} \cdot \text{cm}$ 不平衡量作用下, $CR = 75\%$ 时的振幅大约为 $CR = 0\%$ 时振幅的一半;从图 2(a)还可以发现 CR 增大时转子的临界转速也略微增大了,这是RM RD 的刚度和阻

尼都增大的结果。相比而言,刚度的变化要小得多。所以尽管临界转速也增大了,但变化不大。此外实验所用的 RM RD 的临界转速随不平衡量的增大而降低,这就是说这个 RM RD 试件具有软特性。这可以使转子加速时更易于通过临界状态。

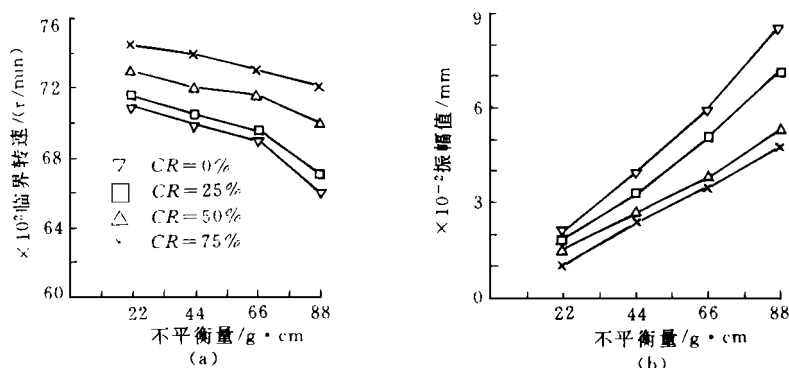


图 2 加 RM RD 减振器的转子的临界转速(a)和过临界转速时的振幅(b)随夹紧率的变化

由此可以得出如下的结果: 对 RM RD 实施夹紧可以提高 RM RD 的减振效果。但是应当注意的是,任何作法都不可以过分。对于某些 RM RD 减振器, CR 过大将导致刚度大大增加,有时还会引起 RM RD 减振器性能的巨大变化。在实验中就发现过这样的现象: 某些软特性的 RM RD 减振器在 CR 较大时表现出硬特性,而且其性能呈现出恶化的趋势。

4 结 论

(1) RM RD 具有很好的减振性能, RM RD 动态特性近似线性,比 SFD 适用范围更广。(2) 而 RM RD 对安装的要求很低,轴承轴线相对于支座轴线倾斜 $1^\circ \sim 3^\circ$ 的时候,位于轴承和支座之间的 RM RD 仍可以正常工作。(3) RM RD 对供油要求不高,在无油的情况下它也可以长时间正常工作。作为一种干摩擦阻尼器,它的性能是稳定的。(4) RM RD 特别适用于高、低温环境,其性能受温度的影响不大。可以在低温下和较高的高温下长时间正常工作。

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CALCULATION OF THERMAL RATE IN ANALYZING THERMAL STRESSES

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ABSTRACT The real- time monitoring of rotor life consumption makes urgent demands on exact real- time calculation of the thermal rate in analyzing thermal stresses. In order to eliminate the data fluctuation in temperature sampling and meet the demands of real- time calculation, the zone linear regression is adapted to accomplish the data filtering of thermal rate curves instead nonlinear regression, and the time subdomains are so divided, that the later one covers as much as possible the data of former one except first sampling data. As a result, a recurrence formula of the regression has been worked out. The exactness of the formula has been verified by numerical simulation. The convergence and filtering efficiency of the method are very well.

Key Words Thermal rate Thermal stress Regression analysis

RESEARCH ON BENDING FATIGUE LIFE PREDICTION METHOD OF AIRCRAFT GEARS

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ABSTRACT The limitations of the conventional bending fatigue life prediction method for aircraft gears are investigated and the applicability of local stress- strain approach to the gear bending fatigue life analysis is researched. Some valuable conclusions have been drawn from comparison between the computational results and experimental data.

Key Words Gears Lifetimes Prediction technique

EFFECTIVENESS OF AN ADVANCED HYBRID SQUEEZE FILM DAMPER ON NONSYNCHRONOUS RESPONSE SUPPRESSION

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ABSTRACT The effectiveness of an advanced Hybrid Squeeze Film Damper (HSFD) without the retainer springs on suppressing the nonsynchronous response of the rotor system was studied theoretically. A flexible rotor supported on the orifice- compensated HSFD is taken as an example. It is shown that the HSFD is able not only to improve obviously the highly nonlinear behaviours of the conventional squeeze film dampers, but also to enhance its capability of nonsynchronous response suppression greatly.

Key Words Rotors Dampers Non- linear Dynamic properties

A RING- LIKE METAL RUBBER DAMPER

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ABSTRACT A new kind of rotor damper, Ring- like Metal Rubber Damper (RMRD), has been invented. Its application to a rotor rig shows that RMRD has excellent damping property and linear characteristics. RMRD has better damping effects and can with-

stand larger unbalanced load than Squeezed Film Damper. As a kind of dry-friction damper, RMRD can work under very high or low temperature for a long period of time. It is especially suitable for High Pressure Liquid Hydrogen (Oxygen) Pumps of rocket engines working under very low temperature.

Key Words Rotors Dampers Absorbers

AN INVESTIGATION ON IGNITION PERFORMANCE OF A CATALYTIC IGNITER AT HIGH ALTITUDE

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ABSTRACT An experimental investigation on performance of a catalytic igniter made of platinum/rhodium catalyst has been conducted in a turbofan engine afterburner. Its ignition delay was measured under the conditions: the static pressure of 0.04- 0.115 MPa; the inlet total temperature of 673- 773 K; the velocity at the lip of igniter cone $\lambda = 0.20$ - 0.36. The investigation simulates the operation of the engine's afterburner when aircraft flies at an altitude of 18000 m and the Mach number of 1.0. The experiments on performance of the igniter for igniting of 1100 runs at normal pressure were also conducted to verify the longevity of the catalytic igniter.

Key Words Catalytic ignition Afterburners Aircraft engines

ANN- BASED OBSERVER FAILURE DETECTION

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ABSTRACT An Artificial Neural Network (ANN) - based observer failure detection method is presented, which uses ANN's self-learning ability instead of analytical computation of the observer design to get the redundancy relationship of the system. In order to deal with the failure detection of model uncertainty system, the failure detection of the control system sensor of a given aeroengine has been simulated with the presented method. The simulation shows that this method not only has the advantage of the observer failure detection method, but also has no need for the precise model of system. It is useful to the failure detection of the model uncertainty system.

Key Words Neural networks Failure Detection Observer

ANN- BASED MMAF FAILURE DETECTION

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ABSTRACT Artificial neural network (ANN) and Multiple Model Adaptive Filter (MMAF) are combined in a new failure detection method- ANN- based MMAF, which uses ANN's self-learning ability instead of analytical computation of the filter design. Numerical simulations of an aeroengine have been performed to detect the sensor failure of the control system. The results show that this method not only can detect the failure of the system with an uncertain model, but also has self-learning ability for the unknown failure pattern.