国际科技合作课题论文集

SELECTED PAPERS IN SCIENTIFIC AND TECHNICAL INTERNATIONAL COOPERATION PROGRAM

中国航空航天研究院
CHINESE AERONAUTICS AND ASTRONAUTICS ESTABLISHMENT

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目　录

CONTENTS

原苏联民航飞机结构强度要求的演变

俄罗斯中央空气流体动力研究院（TsAGI）
O.S.Bykov ，V.L.Raikher，Yu.A.Stuchalkin

摘　要

本文回顾了原苏联民航适航性条例（NLGS）的发展和形成过程，并与美国和欧洲共同体的民航适航性条例 FAR 和 JAR 进行了比较。特别对 NLGS 与 FAR 中有关规定的差别进行了分析和讨论。

原苏联中央空气流体动力研究院（TsAGI）的奠基人 N.E.Zhukovsky 教授领导的委员会早在 75 年前就制定了一整套满足待验证的飞机强度的条件。接着，在以后的许多会上，陆续提出了需要进一步研究的问题。此后，专家们一直致力于各种型号及用途的飞机强度标准的研究与制订。

本领域的发展一直与 TsAGI 所做的工作密切相关。譬如，第一部苏联飞机强度规范于 1926 年由 TsAGI 出版。以后每隔 2～4 年，重版一次，总结归纳用户使用经验、分析和试验研究的结论，不断完善标准，扩大其适用范围。可以认为，从第一部标准起，所有标准通常都包含了军机和民机的结构强度要求。直到 50 年代末期大力发展民用航空时，才决定分开编制两种标准，1961 年出版发行了原苏联的第一部运输机强度规范，1967 年初版及后来（1974 年，1985 年）出版的《苏联民用航空适航性条例（NLGS)》中的第 4 章“结构强度要求”即以这些标准作为基础。比较出版的时间可以看到，后来各版本的间隔比早期的长得多，这是因为颁布新的修订本需对规范要求做必要的修改。第二、三版的民机适航性条例中，对强度方面就进行了三次综合修订。这些修订是 TsAGI 和原苏联国家航空登记局专家，航空工业部和民用航空部各研究院所，以及原“经互会”成员国飞机结构设计局之间密切合作的结果。

在演变过程中，苏联强度规范也经历了所有标准所经历的典型方法阶段，从百分之百地使用所谓的“假设载荷”方法（即所有许用值都是由经验关系确定的）开始，到以一定的数学关系式将许用值与飞机运动状态及其特征性能的少量参数联系起来。目前是结合“设计准则”来使用这一方法的。规定的原始数据是飞机的运动参数和/或外加作用载荷，这些参数应认真考虑所有特征及有关系统，加上特定的分析来确定。

当然，从事完善苏联飞机强度规范的工程技术人员 将规范中的条款也同其它国家的类似标准进行了比较，以保证其安全性及适航性水平与欧洲共同体处于同一水平上。可是，在很多公式及强度标准结构上，仍存有明显的不同点，目前正继续进行研究，以尽量地接近于美国（FAR）及欧洲共同体（JAR）的标准。下面将解决此问题所进行的主要工作结果报告如下：

- 飞机结构强度规范主要依赖于载荷系数极限，尤其是对于每一次机动情况。最近，对于重量小于 27500 公斤的飞机，苏联民航飞机适航性条例规定的加速度比 FAR（或 JAR）的大（见图 1)。通过对安-24、雅克-40 和拉-410 等飞机重心处载荷系数统计数据的分析，决定采用 FAR 中规定的函数值。

图 2 中给出了结构分析中必须考虑的机动的 n-v 图。图中标出的 Ⅰ 、Ⅱ 、Ⅲ 点是 NLGS 的补充条款，在 FAR 或 JAR 中则没有。

图 2 中点 I 描述了最大负载荷系数和飞机速度的关系，FAR 中规定在速度 V_D 时的载荷系数为零。

点Ⅱ表示起飞或着陆状态时过载为1.5g的加速度，速度$\overline{V_F}$和副翼完全偏转的特性；FAR中设有考虑这种情况。

点Ⅲ是起飞或着陆状态下零载荷系数和速度V_F的关系，并规定了前缘缝翼上的负载荷。FAR中设有这种考虑。

过去的经验表明，作为规范的这些标准并没引起载荷条件的明显增加，然而如果在新的民用航空适航性条例中保留这几条要求的话，就会提高某些飞机的飞行安全性。

• FAR中确定垂直面内检查机动载荷的设计准则似乎太绝对了，因为它没有考虑飞机运动的动态特征，这包括装有自动控制系统的机种。但在苏联民航适航性条例中关于飞行员完成这种机动的动作规定是十分复杂的。类似的情况在JAR中也能看到。

• 水平面机动的设计准则的主要特征是，FAR（或JAR）中规定方向舵侧滑一个稳定的角度值后回复到中性位置，而NLGS中则认为动态效应使方向舵达到最大滚转角度，后者引起垂直安定面载荷有所增加，飞行高度越高，载荷越大（见图3）。但是，装一简单的偏转角运动阻尼器后，可减少偏转角的动态效应，进而降低载荷。因而决定保留NLGS中的有关标准。

• 关于发动机发生故障时的非对称载荷，FAR和JAR中考虑了仅一台发动机发生故障的情况。而苏联民机适航性条例中假设飞机装有四台发动机，飞机对称平面一侧两台发动机同时或相继发生故障的情况（取决于发生这种故障的概率），这与FAR中“B”飞行部分中写的要求一致。这种情况下，FAR和JAR都假设当飞机的偏航达到最大比值时飞行员开始平衡已有的偏航，而NLGS则假定，只有当偏航的角度达到最大值后才发挥飞行员的作用。这样，NLGS中的标准似乎是更大范围地包括了使用中可能出现的情况。因此，决定在新的民机适航性条例中保留这些标准。另外，NLGS中把一侧发动机破坏后作用于飞机上的载荷视为不会引起破坏的极限载荷，而FAR和JAR中则假设为最大的载荷。所有的标准以及一些特殊的规定都是为了降低由于不定位置的发动机碎片导致机体结构损伤带来的灾难性结果的概率。以这种观点来看，飞机处于侧滑设计角度时，机体破坏的假定是不合理的。而认为安全系数必须大于1.0（当发动机产生故障时，可能产生最大载荷），一旦发生紧急情况，这一安全系数将相对低于平常值，有时甚至降至1.2。

• 特定标准中考虑了更复杂的情况，例如飞行中突风对飞机的影响。图4中描述了作为突风梯度间隔（以机翼弦长为测量单位）函数的载荷系数（伊尔-62型运输机重心处的系数）。针对特定的飞行模式，使用不同的标准，计算了这些数据。可以看到，尽管突风的状态、突风的梯度间隔不同，但FAR和NLGS规范却得到相似的值，而JAR（尤其是NPA 25C-205中提出的标准）得到的载荷系数则明显减小。

• 对于使用总寿命超过130万飞行小时的原苏联运输机（图5），其载荷系数重复频率的使用数据统计分析表明：对一架飞机（确定使用载荷水平时，一般假定概率为2×10^{-5}）在5万飞行小时内，希望其载荷系数的平均值为0.61，这是NLGS中规定的设计值，而不是安全系数为1.5时的0.67。这样，考虑10%的突风强度水平的影响，就有了一个降低载荷系数极限值12%～16%的可能，结果是与JAR的标准又接近了一步，然而，这一减少量与FAR的不一致。我们相信这种情况与FAR的专家们商议是会取得一致的。

• 对于地面操作载荷的要求，苏联民机适航性条例与FAR（JAR-25）在很多方面一致。但是有两点重要区别。首先是着陆时垂直速度的标准值。FAR与JAR-25中规定为3.05 m/s，它与飞机和机场的参数无关。按照NLGS要求，减震设计中要用到这个速度，该速度是由两种速度构成的，其一是飞机着陆时与机场相触瞬间产生的垂直分速度，其二是起落架机轮因跑道粗糙不平受撞压而产生的附加垂直速度。前者取决于飞机的使用情况，而后者取决于机场内跑道的粗糙程度以及飞机着陆时的速度水平。按照NLGS给出的简化关系式，参考距离为10～20 m，铺砌跑道的局部颠簸载荷等于0.025，这样垂直下沉速度的设计水平就可能覆盖2.8～3.5 m/s的范围。运用各种飞机的飞行试验结果，发展了一套用于描述跑道颠簸载荷谱的概率分析模型。图6提供了用这一模型对伊尔-96、A 310飞机在二种

颠簸谱下的计算分析结果。参数概括了苏联民航机场真实特征情况的范围。所考虑的这些数据是以 2×10^{-5}的概率作为第一次近似值来确定垂直下沉速度的设计值，表示出颠簸特征的一个大值。

图 7 说明了同样的机种，在相同的粗糙度下依赖于垂直速度的参数研究结果。使用的载荷谱为：

$$S=\frac{C}{\Omega^2}[\frac{M^2}{rad/m}]$$

计算分析时很简便，同时能很好地模拟跑道情况。这些研究结果为专门分析苏联民航机场载荷谱特征打下基础。从载荷分析的观点来看，这些结论对发展考虑粗糙度在内的标准能提供帮助。注意到民航适航性条例中，所有的机场跑道按目前的情况分为二类：

——人工铺筑跑道

——土跑道

· 与FAR 相比，民航适航性条例的第二个特征是列入标准中的地面操作载荷概念，它是关于起飞地面滑跑的起落架载荷。FAR 25.491 中仅包含通用的条款。NLGS 中包含了确定在人工铺砌跑道上起飞滑跑产生的载荷的关系式。这些公式与 JAR-25 附加标准 CC10-1 中的公式相似，而且 NLGS 还包括了确定在土跑道上起飞滑跑时起落架载荷的有关公式，这些载荷与土层的强度在有关。另外，飞行手册中还规定了飞机起飞和着陆所允许的土层强度的最小值。这些载荷可根据滑跑时标准撞击情况的详细分析来确定。分析中还考虑了方位变化对垂直和水平载荷的影响。

· NLGS 比较多地考虑了紊流中飞行的飞机所受的动载荷情况，与 FAR 不同，NLGS 考虑了离散阵流和连续的大气紊流。对于后一种情况，可以用包线给出。以上两种情况的载荷应参考飞机重心处的基准载荷系数。即弹性飞机受突风的影响可以假定为弹性飞机重心处承受规定的载荷系数。这种处理方法对刚性和弹性机体结构都是综合规定标准的。另外，还可以更精确地描述使用载荷系数出现率的统计分布。

· 对于特殊的载荷情况，如紧急着陆条件，NLGS 和 FAR 存在一定的差异。对有效载荷与座椅我们仍没有引入使用载荷规范。1988 年对后者的使用动载荷进行了标准化规定。美国标准似乎赞同苏联规范的分析结论。

· 关于抗气动弹性问题，NLGS 中关于颤振、发散、反效操纵的要求与 FAR 中的相接近。但是前者还考虑了其它一些项目；装有自动控制系统（ACS）飞机气弹稳定性必须验证。已知的难题包括机体结构与操纵面之间互相影响的危险性评估。NLGS 中还要求给出飞机处于“ACS”系统开环状态下频率响应的相位及绝对值两者的界限范围。这一范围必须由理论分析、全尺寸飞机地面试验和可靠条件下的飞行试验来验证。

NLGS 还给出了关于摆振自由度的特定要求，这在 FAR 中没有给出。同时必须通过理论分析、冲击试验及飞行试验检查其安全性。

· 由于大范围地使用复合材料，对 NLGS 第三版进行的第一次修订中包括设计及试验安全系数的特殊规定。图 8 中表示出必须用全尺寸结构及结构元件试验确定的特定安全系数与强度变化系数的关系。

本次会议上发表的几篇报告概括出了机体结构疲劳性能方面的成果，现在简要地说明 NLGS 中是如何开展这些领域内的工作的。与 FAR 一样，NLGS 花了很大的力量研究损伤容限设计结构的必要性。但是，用破损安全准则或安全寿命准则也都可以确定使用寿命极限。与 FAR 不同的是，NLGS 要求做耐久性及损伤容限的全尺寸结构试验。NLGS 很重视全面的可靠性试验，用这些试验数据来确定首翻检修期和修理间隔，然而，NLGS 和 FAR 标准之间的主要差别之一是对结构疲劳强度的检查原则不同。NLGS 规定使用寿命极限是一段一段地确定的。在批量生产使用之前，应确定第一个使用周期。当达到寿命极限后，必须规定一个新的间隔周期。典型的周期间隔为 5000～10000 飞行小时，一个新的使用寿命周期取决于：

——飞行任务和使用条件；

——载荷水平（必要时可由飞行试验确定）；
——载荷系数频率的数据量；
——疲劳和损伤容限补充试验的结论；
——已定论的同类型飞机操作使用的经验。

综上所述，可以看出新的强度标准原则上与 FAR 一致。但是，某些标准将执行苏联民航适航性条例严格规定的要求。另外一些要求，如 JAR-25Y 的 ACJ，则形成附加的基本条款。这样，就可以完全满足 FAR 的要求，而又保持了 NLGS 的适航性水平。

（童明波　吴晓峰　译校）

附　　图
FIGURES

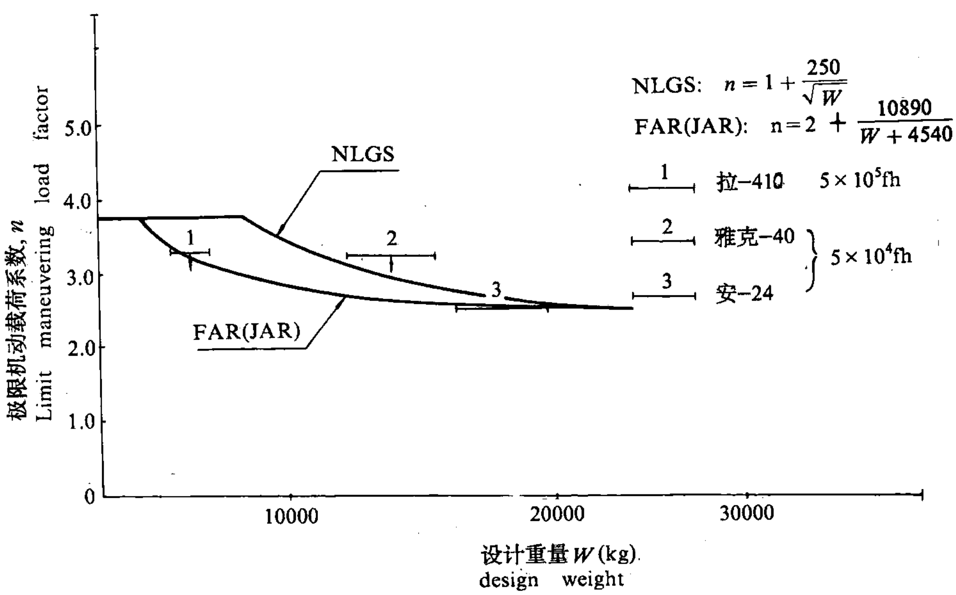

图 1　飞机设计重量与极限机动载荷系数的关系

Fig. 1　Relations between design weight of aircraft and limit maneuvering load factor

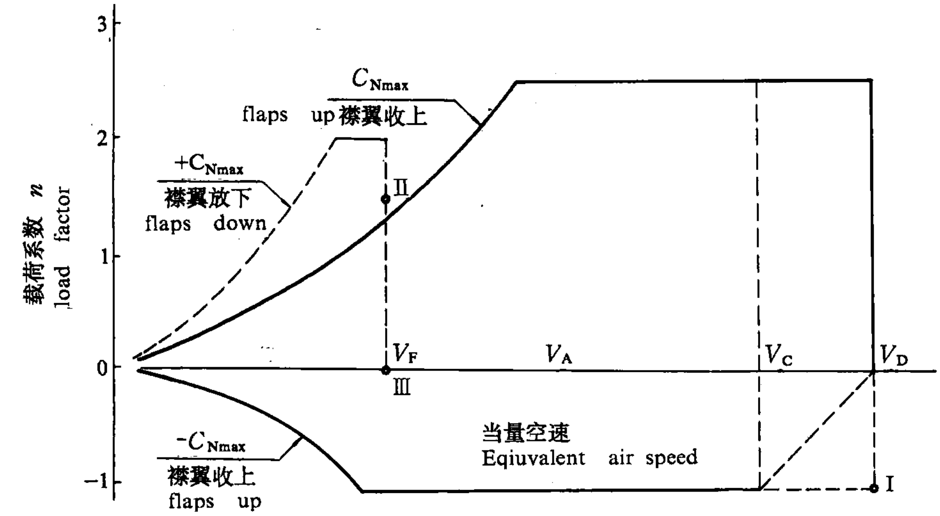

图 2 结构分析的机动的 n-v 图

Fig. 2 n-v diagram for maneuvers of structural analysis

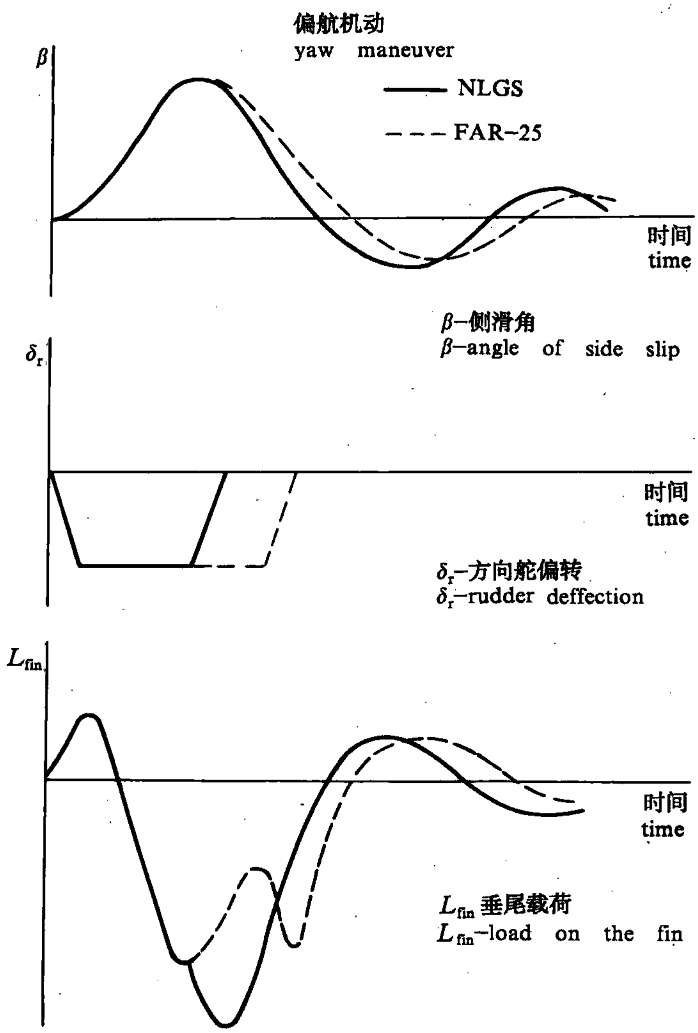

图 3 动态效益对方向舵载荷的影响

Fig. 3 Influence of dynamic effects on vertical stabilizer loads

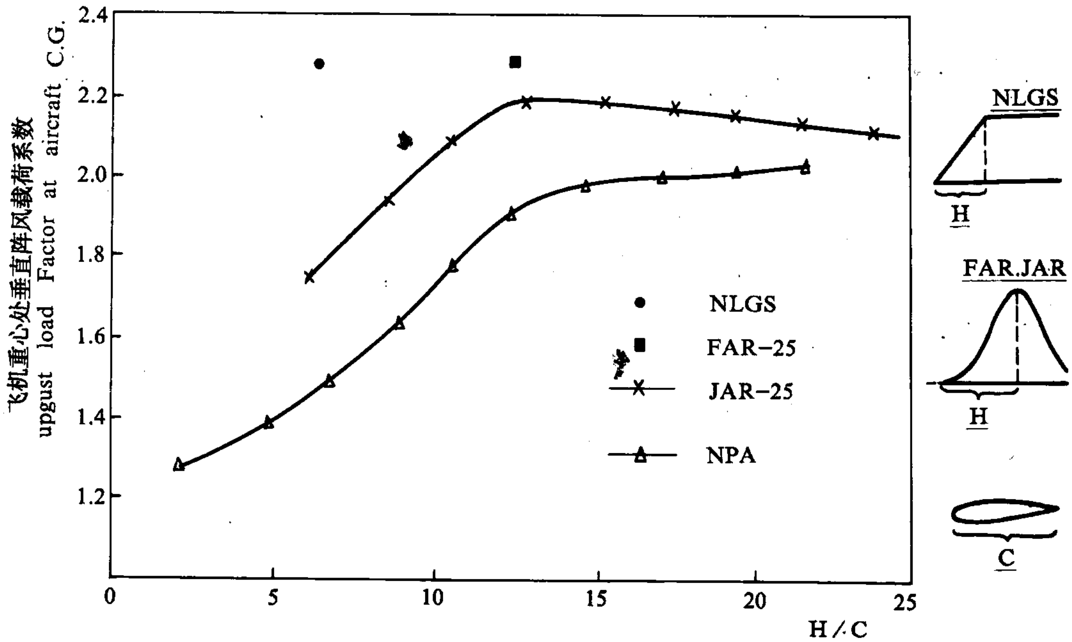

图 4 突风梯度间隔函数的载荷系数

Fig. 4 Load factor as a fuction of gust gradient distance

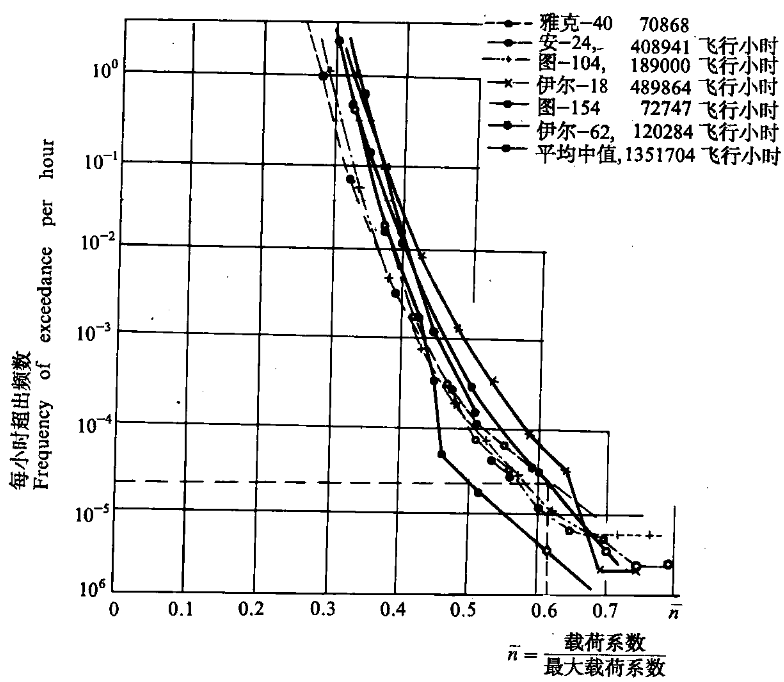

图 5 总寿命 130 万飞行小时以上的原苏联运输机载荷系数重复频率的统计分析

Fig. 5 Statistical analysis of repetition rate of load factors on former Soviet transport airplanes performed over the total amount of over 1.3 million flight hours

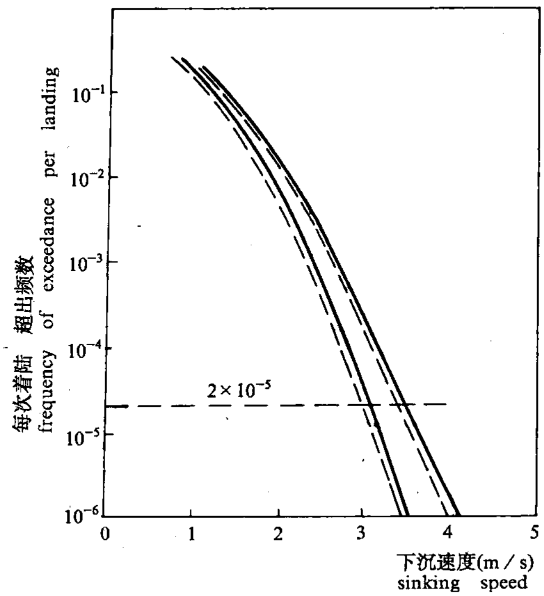

图 6 伊尔-96、A310 飞机在两种颠簸载荷谱下的计算分析结果

Fig. 6 Results of computational analysis for the IL-96 and A310 Airplanes at two spectra of bumps

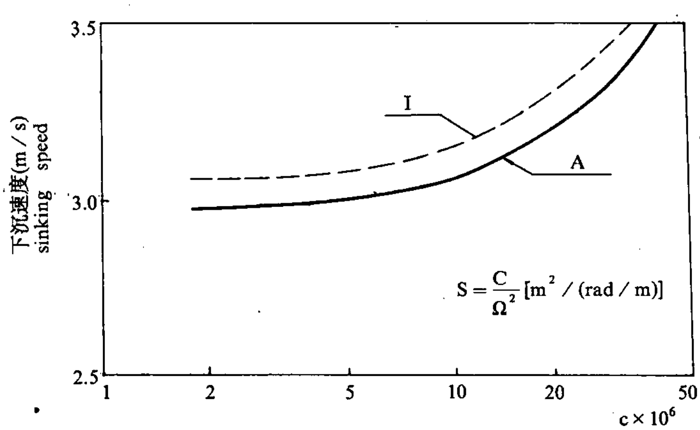

图 7 伊尔-96 和 A310 依赖于垂直速度的参数研究结果

Fig. 7 Paramatric study of dependence of vertical speed for IL-96 and A310

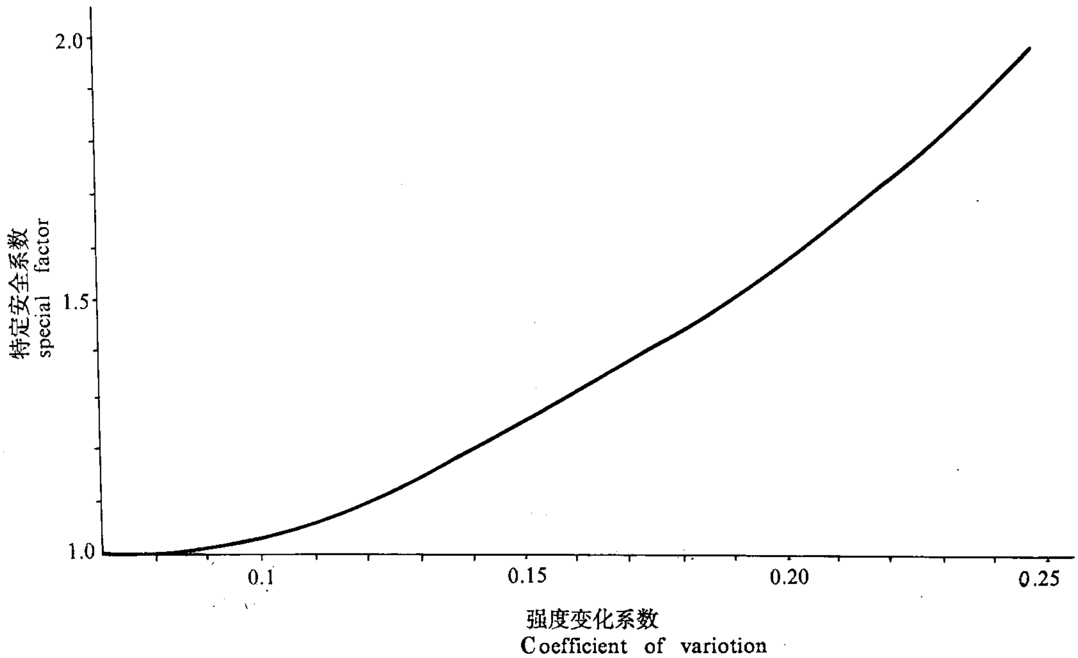

图 8　特定安全 系数与强度变化系数的依赖关系

Fig. 8　Dependence of the special safety factor on the coefficient of variation of strengths

EVOLUTION OF THE CIVIL AIRCRAFT STRUCTURAL STRENGTH REQUIREMENTS IN THE FORMER USSR

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ABSTRACT

In this paper, the development and formation process for the Civil Airworthiness Regulations of the former Soviet Union (NLGS) are reviewed. The NLGS is compared with the Civil Airworthiness Regulations of the U.S. and the European Economic Community (FAR and JAR). The diffrence of the relative specifieations between NLGS and FAR are analysed and disscussed.

It was 75 years ago that the committee headed by Prof. N.E. zhukovsky, the future founder of the TsAGI, has outlined a set of the conditions to be met for the airplane strength to be proven. As well, in a few sittings the questions requiring further investigations were revealed. Since these sittings, the history of our science on the strength standards for aircraft of all types and purposes is counted.

The subsequent development of this science is inseparably linked with TsAGI. In particular, the first Soviet airplane strength standards have been published in proceedings of TsAGI in 1926. Later on, these norms were being republished in 2-to 4-year intervals. An operational experience and results of both analytical and experimental investigations were summarized and generalized to improve the standards and to extend coverage in the problem area. It shall be mentioned that, starting from the first edition, the Norms always contained strength requirements for structures of both the military and civil airplanes. Only at the end of the 1950′s, when vigorous development of the civil aircraft began, the decision has been adopted to divide the Norms, and in 1961 the first strength standards for the transport-type airplanes have been issued in the USSR. These Norms were used as a basis for Chapter 4, "Structural strength requirements", of the USSR Civil Aircraft Airworthiness Requirements (the NLGS) of the first (1967) and subsequent (1974, 1985) editions. Comparing the dates, it follows that the intervals between editions have become much greater than those at the first stage. However, the necessary updating of the requirements is now performed by issuing the amendments. So, three complexes of corrections on aspects of the strength are developed in between the second and the third editions of the Civil Aircraft Airworthiness Requirements; they are a result of close collaboration of the TsAGI and the Gosaviaregistr, the Scientific research Institutes of the Ministry of Aviation Industry and the Ministry of civil aviation airframe design offices of both the USSR and the member countries of the former Council for Mutual Economical Aid.

In course of their evolution the soviet strength standards have passed the way being typical of all the Norms. They began from a 100% use of the so-called "assumed loads"method where any authorized value is defined by means of empirical relationships relating this value to a few parameters of motion of the airplane and to its characteristics, with use being made of certain numerical multipliers.

Nowadays, this method is combined with the "design criteria" method; specified as the initial data are the airplane motion parameters and/or the outside actions, whereas authorized values (for example, loads) should be defined on the basis of special analyses with detailed consideration of all characteristics of the airplane and its systems.

Of course, the developers of the Soviet Aircraft Strength Standards compared their provisions with requirements of analogous Norms of other countries in order to keep the level of safety and airworthiness as high as those in the world community. However, significant difference in formulation of many requirements and in the structure of the strength standards themseleves has been maintainad. Today, we consider that our criteria should come much nearer to the requirement of the USA (FAR) and Western Europe (JAR). With this, main results of work conducted to solve this problem are reported below.

The airframe strength criteria are significantly dependent on the positive limit load factor specific for each maneuver. Up to date, for the airplane whose mass is lesser than 27500 kg the Civil Aircraft Airworthiness Requirements of the USSR specified a greater acceleration than the FAR (JAR) (see Fig. 1). After analyzing the statistical data about load factors at the airplane center-of-gravity for An-24, Yak-40 and L-410, we decided to adopt the function specified in the FAR.

Fig. 2 represents schematically the n-v diagram for maneuvers which must be considered at structural ana—lysis. The points Ⅰ, Ⅱ, and Ⅲ here correspond to the complementary provisions of the NLGS not observed in FAR (JAR):

point Ⅰ depicts a combination of the maximum negative load factor and the flight speed V_D; FAR specifies the load factor to be zero at the speed V_D;

point Ⅱ is characterized by a combination of the acceleration of 1.5g, the speed V_F, and a complete deflection of ailerons for takeoff/landing configurations; FAR does not consider this case;

point Ⅲ is for combination of a zero load factor and the speed V_F in takeoff/landing configurations and defines the negative load on a slat; formally, FAR does not require such situation to be considered.

Our experience indicates that these requirements, as a rule, do not cause notable increase in the loading conditions, however, can improve flight safety for certain airplanes. We assume these requirements to be remained in the new Civil Aircraft Airworthiness Requirements.

The criteria envisaged in the FAR for determining the loads at the "checked manoeuvre" in the vertical plane seem to be obsolete because they do not allow features of the airplane motion dynamics to be taken into account, including the airplanes equipped with automatic control systems. However, instructions of our Civil Aircraft Airworthiness Requirements dealing with pilot efforts during such a maneuver are unnecessarily sophisticated. Therefore we decided to adopt the conditions specified in the ICAO Airworthiness Technical Manual; they result in analogous level of loads on the tail. As well, such kind of conditions may be seen in JAR.

Design criteria for a maneuver in horizontal plane. Main feature is in the fact that the FAR (JAR) propose the return of the rudder to the neutral position to be carried out after the angle of sideslip is of steady-state value, whereas the NLGS considers the maximum angle attained due to dynamic effects. The latter causes a certain increase in the vertical stabilizer loads, the increment being greater for high-altitude flights (see Fig. 3). However, mounting a simple damper of the yaw motion can reduce the dynamic effects in the angle of sideslip, thus reducing the loads. We decided to remain the NLGS requirements.

Unsymmetrical loads at engine failure. Both FAR and JAR consider failure of any one engine only. The USSR Civil Aircraft Airworthiness Requirements postulate the four-engined airplane to be considered under conditions of simultaneous or consecutive failures of two engines (depending upon probability of these events)on one side of the plane of symmetry of the airplane; this is in agreement with the requirements written in Section "B""Flight" of the FAR. In this case, both FAR and JAR assume that the pilot begins to compensate the yawing already when the maximum rate of yaw is achieved, whereas the NLGS assumes these efforts to be applied later, only after the maximum angle of sideslip is attained. Thus, the provisions of NLGS seem to wider cover the situations which are likely to occur in operation. Therefore we decide to keep these requirements in the new Civil Aircaft Airworthiness Requirements. In addition, the NLGS assumes that the loads acting on the airplane after a one-sided engine failure are considered to be the limit loads irrespective of causes of the failure. while the FAR and JAR suggest these loads to be ultimate ones. All Norms incorporate special provisions aimed at minimization of a probability of a catastrophic result after a damage to the airframe from nonlocalized fragments of an engine; in this light. the assumption of an airframe failed due to setting the airplane at the design angle of sideslip seems to be illogical. We believe that the factor of safety must be greater than 1.0 (with respect to the maximum loads likely to occur at engine failure) and, once emergency situation takes place, this factor of safety would be reduced in comparison with the usual value, e.g. down to 1.2.

More complex situation is seen in specifying the requirements with respect to effects of gust on an airplane during flight. Fig. 4 depicts the load factor (for the IL-62 transport airplane center of gravity) as a function of the gust gradient distance (measured in wing chord length units). These data are calculated using different Norms for a particular flight mode. It can be seen that, despite differences in gust shapes and in gust gradient distances, requirements of both the FAR and the NLGS result in similar values, whereas JAR (and, especially, the requirements proposed in NPA25C-205) reduces notably the load factors.

A statistical analysis of the operational data on repetition rate of the load factors on Soviet transport airplanes (Fig. 5) performed over the total amount of over 1.3 million flight hours indicates the following. The ratio of the load factor expected during 50000 flight hours in total for an airplane (the probability of 2×10^{-5}, as is normally assumed for determining the operational values of loads) to the design value required by the NLGS is 0.61 in the mean, rather than 0.67 as the safety factor of 1.5 dictates. Thus, there is a basis for decreasing the limit values of the load factor accounting for the effects of the gust on 10% of gust intensity values respectively by 12%~16%, so, we can come nearer to the requirements of JAR. However, such a decrease will result in noncompliance with requirements of FAR. We believe this circumstance to be agreed in consultation with experts of the FAA.

As for the ground handling load requirements, the USSR Civil Aircraft Airworthiness Requirements and FAR (JAR-25) are agreed in many respects. However, two essential differences should be noted. The first of them is to standardizing the values of the vertical speed at landing. As is known, both the FAR and the JAR-25 specify this value independently of parameters of both the airplane and the aerodrome——3.05m/s. According to the NLGS, this speed which should be used for designing the shock absorbers is considered a sum of, first, the vertical component which the airplane has at instance of touchdown and, second, and additional vertical speed induced by a rolling of airplane landing gear wheels over the uphill of a local bump. In this case, the augend depends on the airplane performance only, whereas the addend depends on both a degree of roughness of the airstrip and the value of the airplane landing speed. According to the simplified relation given in the NLGS, the slope of the local bumps referenced to a 10～20 m length is equal to 0.025. for paved airfields, so, the design value of the vertical sink speed can range from 2.8 to 3.5 m/s. Using the results of flight tests on various types of aircraft, we developed a probabilistic analytical model employing a spectral description of the bumps on an airfield. Fig. 6 offers the results of the computational analysis by this model for the IL-96 and A310 airplanes at two spectra of bumps; the parameters cover the range of actual characteristics of civil airfields of the USSR. These data considered as the first approximation at a probability of 2×10^{-5} confirm the design values of the vertical sink speed and are indicative of great values of the characteristics of bumps.

Illustrated in Fig. 7 is the parametric study of dependence of the vertical speed of the same airplanes on the degree of roughness. The spectrum used is

$$S=\frac{C}{\Omega^2}\left[\frac{M^2}{rad/m}\right]$$

which is convenient for the computational analyses and, at the same time, is capable of approximating well the spectra of actual airfields. Results of this study can be a basis for a special investigation into spectral characteri—stics of all civil aerodromes in the USSR. From the point of view of the loads analysis, these results may help develop requirements taking into account the degree of roughness. Note that the Civil Aircraft Airworthiness Requirements, currently in effect, subdivide all airfields into two groups only:

— paved airstrips;

— unpaved airstrips.

The second feature of the Civil Aircraft Airworthiness Requirements as compared to the FAR in concepts for ground handling loads is in specifying the requirements with respect to landing gear loads for a takeoff ground run. As is known, Section 25.491 of the FAR contains general provisions only. The NLGS comprise relations for determining the loads caused by a takeoff run on a paved airfield; the formulae are close to those of CC10-1, and annex to JAR-25. Moreover, NLGS incorporates relations for determining the landing gear loads at takeoff ground run on an unpaved airstrip, the loads depending on a soil strength; in addition, the Flight Manual specifies the minimum soil strength at which the airplane take-off and landing are permitted. These loads may be refined on the basis of a detailed analysis of crossing the standardized bumps. The analysis takes into account the influence of the California Bearing Ratio on the vertical and horizontal loads.

Much attention is paid by the NLGS to dynamic application of load during bumpy-air flights. Unlike FAR, we consider both the discrete air bumps and the continuous atmospheric turbulence. For the latter case, use is made of the envelope. In the two cases, loads should be referenced to a standardized load factor for the airplane center-of-gravity. Namely, the gustiness for an elastic airplane should be assumed such that the center of gravity of an elastic airplane were subjected to the prescribed load factor. This procedure relates definitely the requirements for rigid and elastic airframes; in addition, the statistics of operational load factor occurence rates may be taken into account more accurately.

As for the special loading cases, differences between NLGS and FAR in the emergency landing conditions exist. We still did not introduce severe loading specifications for a payload and the seats; dynamic loading for the latter is stadardized in the use in 1988. We perform our own analysis, but the