Original Article

Aircraft-aircrew Anthropometric Compatibility Assessment

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Aircrew-aircraft cockpit compatibility is an important consideration in the design of aircraft cockpit and selection of pilots for flying duties. This paper gives on overview of the various techniques of evaluation of aircraft compatibility and outlines a protocol for assessment for the marginal sized pilots. Recommendations are made to salvage pilots with borderline anthropometric parameters.

Keywords : Cockpit geometry, eye datum position, anthropometric standards, pilot selection.

The cockpits of modern fighter aircraft are intricate in design and highly complex in nature. From the man-machine interface point of view, one area of concern is the physical compatibility of the man and the machine. It is essential that while interacting with the aircraft, the pilot should not only be comfortable and efficient during all the stages of flight but also safe during emergency situations like ejection and crash landing[1,2,3]. The aircraft designers are well aware of the requirements and make use of the relevant anthropometric data of the user population for the design and workspace layout of the cockpit[3]. Mil-standards[3,4,5] and Mil-specifications are also available for ready reference by the aircraft designers to achieve optimum aircrew-aircraft compatibility. Inspite of this, problems of visual interference, physical interference and inadequecies of reach occasionally crop up. In the Indian Air Force (IAF), with its heterogeneous nature of aircraft sources, the incidences of such aircrew-aircraft incompatibilities are more because these cockpits are not specifically made to user's anthropometric data. Compounding the problem are various modifications to personel survival packs (PSPs), gunsights, or even the basic seat structure that are sometimes incorporated without proper evaluations of the cockpit anthropometric implications.

Anthropometric limitations for various fighter and trainer aircrafts of the IAF have been laid down after conducting necessary cockpit trials. As per the present policy, the marginal cases are to be subjected to cockpit trials prior to flying on a given aircraft. However, a protocol for such cockpit trials has not been specified. To be useful, the protocol must be available to assess the aircrew-aircraft compatibility from the conceptual stages of aircraft design upto the squadron level assessment.

The aim of this paper is to give an overview of the various techniques of evaluation for aircrew-cockpit geometry and state a protocol for such compatibility assessment in cases like marginal sized pilots and modified cockpits at the squadron level.

Present Techniques to Evaluate Cockpit Geometry

The present techniques consist of the following :

a. Drawing reviews
b. Mathematical models
c. Subject trials at the following stages of aircraft development :

   i. Wooden mockup
   ii. Flight Simulator
   iii. Prototype test flights
   iv. Squadron level assessment

While these methods have been refined over the years and produced useful data, they have inherent limitations.

Limitations of Present Evaluation Techniques

The validity of the above mentioned methods depends on the following factors:

a. Skill and experience of the evaluator
b. Adequacy of criteria
c. Reliable anthropometric data and correct selection of subjects
d. Limitations inherent in the techniques
e. Control of the test conditions
f. Availability of test equipment.

Specific Requirements

The specific aircrew-aircraft anthropometric compatibility problems in the IAF are related to one of the two basic situations :

a. For newly developing indigenous aircraft, major cockpit modifications to existing aircraft or the procurement of new aircraft types.

b. For the "marginal sized" aircrew, newly posted/detected either at training establishments or squadron level.

While there are certain common features in the requirements for both the situations, there are also fundamental differences in the approach to each situation.

In the case of a newly developing indigenous aircraft,the user defines and specifies his anthropometric requirements of the pilot population that have to be accommodated. He also provides the relevant anthropometric data. The aircraft designer uses this data to make various drawings to finalise the basic cockpit design[3,4], the range of the seat adjustability vis-a-vis eye design position and rudder pedal adjustability range to meet the user requirements. Once the drawings are finalised, the actual simulation of these drawings is done on the wooden mock-up and actual subject trials are conducted with suitable subjects to confirm that the wooden mock-up meets the user requirements as far as the physical conditions are concerned. A number of subjects covering all the vital parameters of the required anthropometric data are normally conclusive till the user representatives are satisfied that the proposed cockpit design will accommodate the subjects with the minimum and maximum specified anthropometric data[6].

In case of a major modification to an existing aircraft cockpit or the procurement of a new aircraft type, the range of seat and rudder adjustability as well as the eye design position are already fixed and no changes are contemplated in these areas. The aim of the cockpit trials here is to find out the percentile user population who can safely be accommodated in this cockpit without compromising his comfort, efficiency or safety. This is more of "reverse human engineering" i.e. fitting the man to the machine. However, the end result is that the minimum and maximum anthropometric limitations for such aircraft are specified for future use.

Protocol for assessment of Aircrew - Aircraft Anthropometric Compatibility

The basic purpose of the assessment is to verify that the user population can perform safely and efficiently during all the stages of flight including emergency. Essential steps to be followed in such assessments are :

a. Experienced aircrew involvement : It is always prudent to involve an experienced aircrew on type. Not only would practical advice be forthcoming, but he will also be able to draw a line between the theoretical and practical view points.

b. Aircraft details : Role of the aircraft, details of escape mechanism, display system, ranges of adjustment of seat and rudder pedals and other relevant cockpit features need to be documented. The tasks of the pilot must be divided into the visual and the motor.

c. Use of correct subjects : The subjects (preferably aircrew) with minimum and maximum anthropometric parameters should be used for the trials. Since one subject is unlikely to have all the required parameters, a number of subjects may be required for the trials.

d. Subject preparation : The subject must be fully fitted out in the proper Aircrew Equipment Assemblies (AEAs) for the given aircraft. He must be strapped comfortably, with the normal flying laxity of the harness, except in the cases where the arm reach is being assessed, when he should be tightly strapped in order to assess whether he can reach the primary flight controls or not.

e. Determination of the Eye Datum Position (EDP) : This can be done by study of the pilot's notes. Sometime the sitting height limitations are specified per se, or an Eye Datum line is marked on the head rest of the seat. It may be necessary at times to specify the EDP. This can be done with the help of experienced aircrew on type, whereupon a consensus is drawn from amongst

them on the optimum over-the-nose-vision, over-the-side vision, inside the cockpit vision and specific visual requirements for the Head Up Display (HUD) and other electro-optical devices. An appropriate mark can then be made for this "Consensus EDP" on the seat or adjacent cockpit structures.

Cockpit Trials

For minimal percentile subjects : The seat must be kept in the highest position and rudders adjusted fully aft. The properly kitted subject is strapped up in the seat and the following points are ensured :

i. The subject's eye must coincide with the EDP while the subject is seated in normal flying posture.

ii. He should be able to apply full rudder and toe brakes without any pelvic shift.

iii. Arm reach factors for primary inflight controls with the harness fully tight and inertia reel mechanism locked should also be assessed.

For 'maximum' percentile subjects : The seat must be kept in the lowermost position and rudders adjusted fully forward. The properly kitted subject is strapped up in the seat and the following aspects are ensured :

i. The subject's eye should coincide with the EDP with the subject in normal flying posture. In case his eyes are above the EDP, ensure that there are no visual "cut-off" areas both inside and outside the cockpit.

ii. There should be adequate clearance between the top of the helmet and the undersurface of the canopy when the fully strapped subject is seated erect as in ejection posture. A minimum of 2 to 3 cms overhead clearance is considered adequate for seats without overhead ejection firing handle[3]. A minimum overhead clearance of 7 to 8 cms is required with overhead ejection firing handle[3,5].

iii. He should be able to apply full rudders and toe brakes without any difficulty. When rudders are in neutral position, a minimum clearance of 4 to 5 cms from the subject's shin and lower edge of the main instrument panel (MIP) must be ensured[3,5]. There should be no fouling of the lower limbs with any cockpit structure or MIP with his feet placed on the rudders in full operation with toe brake application. A minimum of 2 cms lateral clearance of lower limbs from other cockpit structure should be available[3]. This is important from the ejection consideration. In doubtful cases, seat pullout trials with the subjects may be required to ensure that no fouling will take place during actual ejection[3].

iv. Arm reach inadequacies for cockpit controls and fouling with other cockpit structures/controls should also be looked into. This is important because there are cases on record where pilots with maximum arm reach have fouled with some important cockpit controls or structures while operating some other controls. Similarly, cases are also on record where pilots with maximum arm reaches have received upper limb injuries as a result of fouling during ejection.

For 'mixed' percentile cases : Most subjects have a differing segmental measure. In such cases, there may be one parameter at one extreme, whereas other important parameters are in intermediate percentile distribution. Here we must view the case as a function of his extreme parameter, and treat the body as if the rest of it is also of extreme dimensions. This would imply that in a case with minimum percentile sitting height, the seat must be in the topmost position and rudder pedal adjustment will then be according to his leg length. Similarly, a case with maximum leg length will have rudder pedals in fully forward position but his seat position will have to be adjusted to get his eyes at the EDP or optimal visibility and overhead clearance. A permutation combination of the seat and rudder pedal adjustments will have to be done in case no subjects of extreme dimensions are available.

Waivers : Practical considerations

The importance of proper aircrew aircraft compatibility cannot be but overemphasized. There are laid down minimum and maximum anthropometric parameters for aircrew duties in the IAF. Important anthropometric parameters of candidates for flying duties are recorded at their

entry stage before they are cleared for flying[6]. In certain cases, waivers are permitted for the National Defence Academy (NDA) candidates for standing height, sitting height and leg length as per laid down rules, provided the medical board considers that the individual is likely to grow during his training period and achieve the required minimum standards[6]. Cases are on record where individuals given such waivers, achieved the sitting height and leg length requirements but fell short of the minimum standing height specified for aircrew duties. In our experience, standing height of the individual is not a critical parameter for F(P) duties. If the standing height of a pilot is important for administrative reasons (parade etc), then the waiver given to low statured ethnic groups (e.g. Gorkhas, Kumaonis, Garwals etc) needs to be rationalised. If the standing height is to be considered as a function of correlations with other body dimensions or some flying clothing requirements, then this needs to be clarified. In our opinion, if an individual is meeting the minimum sitting height and leg length requirements but is marginally short in standing height requirements, he may be considered fit for F(P) duties.

At the other end of the spectrum, a National Defence Academy candidate having maximum acceptable values for F(P) duties in parameters like standing height, sitting height, leg length, may grow during his training period and overshoot in some of these parameters and thus may become a flight safety hazard. Presently, the policy is to reassess these cases by an Aviation Medicine Specialist before they are cleared for flying training. However, the main problematic area is that two advanced fighter trainers, Ajeet and Type 66/77, which are being used for the fighter training of two streams viz. Hunter Operational Flying Training Unit (HOFTU) and Mig Operational Flying Training Unit (MOFTU), can only accommodate pilots with shorter anthropometric data. Ajeet aircraft can accommodate a leg length of 114.0 cms and thigh length of 62.0 cms only, while Type-66 (trainer for Type 77) can only accommodate a max sitting height of 92.5 cms (94.0 cms without PSP). Similarly Iskra trainer can accommodate a max siting height of 94.0 cms only. Because of these anthropometric limitations of these trainer aircraft, any cadet who is found unfit for these aircraft, i.e. Iskra, Ajeet and Type-66/77, is declared unfit for the fighter stream flying and is routed to the Helicopter/Transport flying. We recommend that such pilots who have sitting height more than 94.0 cms and leg length more than 114.0 cms and thigh length of more than 62.0 cms should do their basic flying training on Kiran trainer and subsequently they should fly either Jaguar trainer (for HOFTU) or Mig-23 trainer (for MOFTU). All these cases will then be subsequently fit for all the other fighter aircraft presently available on the IAF inventory.

REFERENCES

1. Rolfe JM : Psychological aspects of equipment design, In : A Textbook of Aviation Physiology. Editor:JA Gillies, London, Pergamon Press, 1965, p. 1031.

2. Woodson WE: Human Factors Design Handbook, New York, Mc Graw Hill Book Company,1981, p. 216.

3. Mil-Standard 1333A : Aircrew Station Geometry for Military Aircraft, Washington DC, US Dept of Defence, 1976.

4. Mil-Standard 850B : Aircrew Station Vision Requirements for Military Aircraft, Washington DC, US Dept of Defence, 1970.

5. Mil-Standard 1472B : Human Engineering Design Criteria for Military Systems, Equipment and Facilities, Washington DC, US Dept of Defence, 1976.

6. Measurement and Physique, IAP : 4304: Manual of Medical Examinations & Medical Boards : 2nd edition, New Delhi, Air HQ, 1987.