Original Article

# Aircrew Sitting Geometry in Fighter Aircraft Cockpit

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***Sitting posture of a pilot is influenced by the back tangent angle of the crewseat which in turn effects the slouch and head orientation required to keep the line of sight horizontal. MIL STD-1333A defines the crew seating geometry based on anthropometric data of USAF pilot population. This paper describes the methods used to adopt MIL STD-1333A to suit IAF pilot anthropometric data for establishing seat geometry in a fighter aircraft cockpit.***

***Key words: Eye design point, seat reference point, seat back angle, seat pan angle.***

The Eye Design Point (EDP) is a reference point based on eye location that permits vision envelope required for an aircraft. It allows for postural slouch and forms the datum point from which aircrew station geometry is constructed. The Seat Reference Point (SRP) is the intersection of the back tangent line and the bottom tangent line. The Neutral Seat Reference Point (NSRP) is the SRP with the seat in the nominal mid position of the seat adjustment range. This seat position will place the 50th percentile (sitting height) man with his eye at the EDP[1]. This fundamental geometry is depicted in Fig.1.

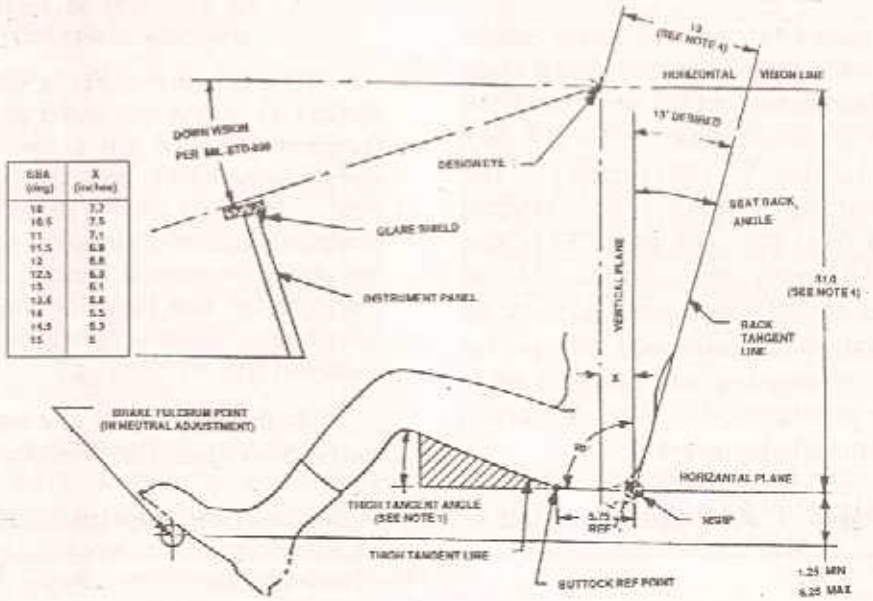


*Fig 1. Air Crew Seating Geometry*

Notes:

1. Thigh Tangent Angle shall be a minimum of 5° and a maximum of 20°. For helicopters, the minimum of 10° shall apply.
2. The seat adjustment shown are for the 5th through 95th percentile pilot population.
3. The vertical dimension range from NSRP to break fulcrum point does not include vertical seat adjustment dimensions.
4. Dimensions based on 13° seat back angle.
5. "X" is the distance from Design Eye Point to vertical plane of NSRP for various SBA's (Refer Inset Table)

Courtesy: MIL STD-1333A

Since these points form the datum from where design aspects of other cockpit features are located, it is imperative that these points are determined to suit the anthropometric requirements of the user population. The anthropometric data of the IAF pilot population[2] is compared subsequently with the USAF pilot population on which the MIL-STD 1333A[3] is based. The correlation factors for relevant parameters are derived and the tentative figures for the IAF pilot population evolved using those correlation factors.

**Anthropometric Data**

The relevant anthropometric data of the IAF and the USAF pilot populations is shown in Table I. From this table the following are evident:

a. For all percentiles, the Sitting Height(SH) of the IAF pilot population is about 1.5% less than their American counterparts.

b. The figures for the Eye Level Height (ELH) for the IAF pilot population has been deducted by subtracting 111.0 mm. from the SH. (The anthropometric data for the IAF pilot population is lacking in this regard). The figure was derived after a random sample survey (n = 47). The mean ELH was found to be 111.0 mm less than the SH and the mean ELH to SH ratio was found to be 0.87. These figures compare well with similar data available in literature[4]. A ratio of 0.86 is being used as a multiplicative ratio by certain Western aircraft manufacturers.

Factors influencing sitting height

The factors influencing SH are as follows :

a. The seat back angle (SBA) .

b. The seat pan angle (SPA)

c. Contours of the seat surfaces.

d. Clothing and harness.

These factors influence the "normal" sitting posture of a person on any given seat. It averages about 25 to 50 mm less than the erect SH, an effect called the "slump" or "slouch"[5]. The slump is the net effect of factors like:

a. The curvature of the spine with the head balanced over the shoulders.

b. The pelvic tilt / fixation.

c. The SBA which necessitates re-orientation of the head to keep the line of sight horizontal as depicted in the Fig. 2.

The slouch / slump, a spinal motion, has a vertical (z) component and a small fore and aft (x) component. There are a few figures stated by certain authorities to quantify the z component: 44 mm[1] ; 25 - 50 mm[6]. The x component is a complex function of statistical variables related to the above mentioned factors. It is not surprising therefore, to find data for the fore and aft (x) component, virtually nonexistent and frequently validated only on mock-up[5].

In the absence of any available data of our own in this regard, mathematical estimations were

***Table - I Anthropometric data of the IAF and the USAF Pilot populations***

| Height (mm) | Pilot Percentile Population | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | USAF | | | | | IAF | | | | |
| | 1% | 2% | 50% | 97% | 98% | 1% | 2% | 50% | 97% | 98% |
| Sitting | 835.7 | 843.3 | 914.4 | 972.8 | 980.4 | 823.0 | 827.0 | 889.0 | 950.0 | 956.0 |
| Eye Level | 723.9 | 731.5 | 800.1 | 858.5 | 866.1 | 712.0 | 716.0 | 778.0 | 839.0 | 845.0 |

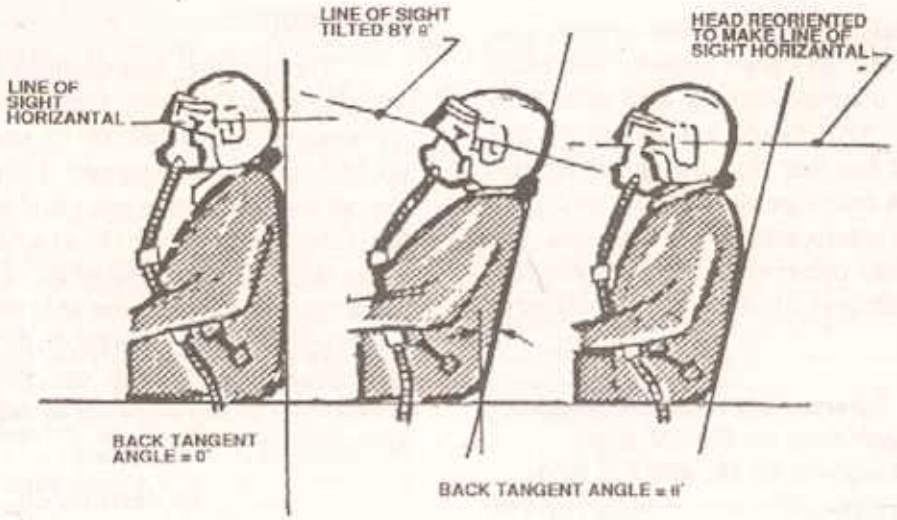


***Fig 2. Head re-orientation with different seat back angles***

resorted to. Two assumptions were made for the mathematical estimations at this stage :

a. The amount of slouch is greater for higher percentiles and less for smaller percentiles, and the correlation is linear. In other words a constant (multiplicative factor) could be used to express slouch as a function of ELH.

b. Slouch is maximum in an erect posture (SBA = 0°) and nil when horizontal (SBA = 90°). It therefore conforms to a Cosine relationship.

Logical as it may seem, the factor of reorientation of head for keeping the line of sight horizontal has not been considered. Therefore, such assumptions could possibly be applicable for limited seat back angles only. MIL-STD 1333A specifies for a range of 10° to 15° of SBA only.

Since the MIL-STD 1333A defines ELH after taking slouch into account, the "multiplicative factor" for the amount of slouch catered for in the MIL-STD was calculated. The findings were, that for a SBA of 13° as shown in the MIL-STD drawing, the vertical (z) component was 31 mm for the 50th percentile USAF aircrew. This works out to a multiplicative factor of 0.03395 or 3.395% of the ELH.

If the same multiplicative factor is transposed for the IAF pilot population, the slouch for the 1st, 50th and 98th percentiles works out to 27.9, 30.2 and 32.9mm respectively for the vertical (z) component. As regards the x component, we took a standard figure of 330mm (as given in the MIL-STD drawing) as the perpendicular distance between the EDP and the back tangent line. The calculated offset between the NSRP and the EDP was found to be very close to what is given in the MIL-STD. The figures are given at Table II.

***Table- II Comparison of calculated vs MIL-STD figures of offset for SBA of 10 to 15.***

| SBA ( deg ) | Calculated (mm) | MIL-STD 1333A (mm) |
|---|---|---|
| 10 | 197.8 | 195.5 |
| 11 | 184.4 | 180.3 |
| 12 | 170.6 | 167.6 |
| 13 | 156.9 | 154.9 |
| 14 | 143.2 | 139.7 |
| 15 | 129.2 | 127.0 |

In the absence of any values greater than the SBA of 15° in any quoted reference, extrapolation of our methodology was done for a SBA of upto 21°. Such extrapolation was necessitated by the fact that current generation aircraft use SBA much greater than 15°for criteria like comfort and enhancement of G tolerance. The values of various parameters for the IAF pilot population for 18° and 21° SBA are annotated in Table III.

***Table - III*** ***50 th percentile values of various parameters for the IAF pilot population for 18° and 21° SBA***

| | SBA ( 18° ) | SBA ( 21° ) |
|---|---|---|
| DM | 759.4 mm | 763.6 mm |
| MR | 100.5 mm | 60.6 mm |
| θ | 7.54° | 4.54° |

DM is the eye level height, MR is the distance between NSRP and the perpendicular projection from the EDP to the horizontal line through NSRP and θ is Back Tangent Angle

These figures were validated on an actual wooden mock-up of a fighter cockpit and it was found that the EDP could be reached from the designed SRP even by extreme percentile subjects with no discomfort.

## Conclusions

Though the end justifies the means of "reverse engineering" to derive a working model, we realised the handicap of non-availability of specific data in this regard. Current generation aircraft like the F-16 (Eagle) and the Mirage 2000 use SBAs much greater than what is catered for in the MIL-STD. With the factor of reorientation of head required to keep the line of sight horizontal with higher SBAs, extrapolations may not be appropriate. Specific data needs to be generated to take care of the influence of the various factors on the sitting posture.

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