Aeromedical Assessment of a Helicopter Crew Seat: the Flight Engineer Workspace

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Abstract

Background: Certain deficiencies regarding Flight Eng seat of Mi-17 ac series has been reported by user population and concern has been raised. Pursuit to Air HQ task, aeromedical evaluation for Flight Eng(FE) seat of Mi-17 V5 was conducted, issues identified and few recommendations made.

Aim and Task: To carry out aeromedical assessment of Flight Engineer's seat of Mi-17V5 ac in terms of ergonomics of reaches/clearances and comfort of the Flight Engineer workspace along with evaluation of the harness system.

Methodology: Proposed evaluation was carried out on ground in the cockpit of parked Mi-17V5 helicopter by studying cockpit design, physical measurements, assessment of seat characteristics and cockpit trials with appropriate subjects in terms of reaches/ clearances, overall operational maneuverability, comfort/mobility.

Results: Results revealed that present restraint system is incapable of providing full range of required longitudinal mobility and forward movement, especially for aircrew with anthropometric parameters closer to minimum percentile values. Limitations of Lap belt assembly were identified in terms of anchoring mechanism and absence of inertial reel.

Conclusion: Flight Engineer seat and workspace geometry per se has got no limitations in terms of comfort levels, clearances and performance of FE. Restraint system in its present configuration appears to be the limiting factor affecting mobility and maneuverability of aircrew. Certain modifications recommended, to make it a high mobility restraint system, may go long way in increasing safety aspects and attaining operational optimization for Flight Engineers.

IJASM 2015;59(1):7-14

Key words: Flight Engineer, Aircrew, Ergonomics, Workspace, Helicopter, Restraint system.

Background:

Aircrew require mobility, fatigue reduction, and safety associated with their life support systems and workstation. Flight crew seat along with available work space and restraint system has an important bearing on aircrew performance, wellbeing, fatigue and safety. Restraint system in particular is designed to restrain aircrew during aircraft manoeuvres and more importantly during a crash situation. The restraint system must also provide for quick and easy ingress and egress from the cockpit and allow sufficient mobility to permit access to flying controls and be compatible with all flight equipment. Mi-17 ac is equipped with Flight Engineer seat with modifications depending on the ac variant. Certain deficiencies regarding Flight Engineer seat harness system has been reported by user population. To address the issue aeromedical evaluation for Flight Engineer seat of Mi-17 V5 was conducted, issues identified and few recommendations made.

The purpose of the study was to carry out aeromedical assessment of Flight Engineer's seat of Mi-17V5 in terms of ergonomics of reaches/clearances and comfort of the Flight Engineer workspace along with evaluation of the harness system. The aim was to identify and understand the biodynamic interactions of current in-service restraint system in order to identify any issues that need addressing in future restraint system modification / design.

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Methodology

Proposed evaluation was carried out on ground in the cockpit of parked Mi-17 V5 helicopter. The following aspects were studied:

(a) **Design Considerations.** The cockpit drawings of ac were studied for the relevant dimensions & parameters. All such relevant seat & cockpit parameters were measured on ground and other characteristics including harness system evaluated in terms of aeromedical issues.

(b) **Selection of Subjects.** The trial subjects comprised of trained aircrew (Pilots and Flight Engineers) of Mi-17 V5 ac. The relevant anthropometric measurements were obtained from medical documents (Form-1) of subjects along with recording of current height and weight. Based on anthropometric data, subjects were divided into two categories of short and tall subjects. Anthropometric parameters of subjects are presented in Table -1.

(c) **Cockpit trials.** The subjects donned suitably sized flying clothing and strapped up in the flight engineer's seat. The following criteria were used for assessing aircrew cockpit compatibility:-

(i) The ac manuals and drawings did not reveal any information regarding Design Eye Point (DEP). However, the failure to ascertain the DEP was not the limitation for the study, as the flight engineer's seat is fixed and there is no scope for adjustments.

(ii) Overhead clearance, clearances from the central console & MRB breaks including space provided in front of the knees for foot and toe.

(iii) Ability to reach all the control switches in the central console (MFDs, autopilot), front top and top corner side panels. Based on importance, frequency, criticality, requirement during different phases of flight and emergencies, the controls were divided into three priorities as shown in the Table - 2.

(iv) Ability to reach controls was studied in three settings: firstly subjects fully restrained (shoulder harness locked and lap belt tightened), secondly with shoulder harness fully extended and lastly with extended shoulder harness and lap belt loosened. Different settings were taken into consideration to evaluate functional reach with use of pelvic shift, arm & shoulder extension and upper torso stretch.

(v) Overall operational maneuverability, comfort and mobility.

Results

(a) Flight Engineer Seat : The flight engineer seat (Fig-1) is a foldable platform type which is fixed to the right side of the entrance of cockpit by tension spring attachments. It is a non adjustable seat having a seat pan equipped with removable cushion. The Seat back angle is 90 degrees formed by closed cabin door having a cushioned back rest with no recline adjustment. The seat is not equipped with arm rests, head rest and any energy absorbing system to limit the crash loads. The exterior surface and edges of seat did not reveal any untoward projections, sharp edges, capable of obstructing smooth operation of FE or having any injury potential.

(b) Restraint system : The seat is equipped with a harness restraint system consisting of two shoulder straps provided with their inertial reel, two waist straps without inertial reel and a fastener (Fig-1). There is no central touch down or crotch strap. The characteristics are as follows:

(i) Shoulder straps : The straps are not provided with any buckles to adjust the length as it is spring loaded which makes length auto adjustable depending on downward pull by the occupant. The straps are stretchable upto 37" and are 1.9" wide. Visual inspection and physical examination in terms of quality, thickness and stitching reveals satisfactory assembly.

(ii) Lap belts : The waist straps are provided with buckles which makes it possible to change the strap length for individual selection. Each strap is 22" long and 1.9" wide. Visual inspection and physical examination in terms of quality, thickness and stitching reveals satisfactory assembly. A pouch is attached at the lower side of compartment door for stowage of lap belt assembly when not in use.

(iii) Anchorage : Shoulder harness has anchoring mechanism on seat back i.e. on the cockpit door on the compartment side. Lap belt straps are anchored on cockpit door (seat back), 1.5" above seat pan (cockpit door closed). Older anchorage/ latching hooks/ slots for lap belts of Mi-series ac are retained on either side of entrance which has got no role in present restraint system of Mi-17 V5.

(iv) Release mechanism : Restraint system is equipped with single point attachment mechanism i.e. safety harness fastener which is essentially a cylindrical body with a cap knob. The body has slots over its circumference, where the metal tips of the straps are inserted. The cap knob is used to unlock the strap restrainers in the fastener by raising it and rotating through an angle of 60 degrees. The mechanism appears to provide firm connection for the left and right hand shoulder strap and lap belt fittings. When the release mechanism is actuated, it simultaneously releases all four fittings. It is designed to be easily opened with either hand and minimizes the possibility of inadvertent release. It has no protrusions, sharp edges, or features which would tend to entangle or catchon clothing.The single-point mechanism is equipped with a pad attached to its underside to provide a soft interface and to permit distribution of loads to the torso.

(v) Inertial Reel : Both shoulder straps are served by a single inertial reel mounted on the compartment door. It is engaged / disengaged by means of control knob located on left side of seat on the door. When the control knob is set to the left, the inertial reel is engaged for operation, and when the control knob is set to the right, the inertial reel is disengaged thereby ensuring stiff restraint of the straps. Any sudden jerk/ stroke on straps automatically locks the inertial reel, making it an additional safety feature.

(c) Cockpit Trial for Short Subjects : The results of the cockpit trials revealed that in general none of the subjects were found incompatible on account of external/ internal vision and inability to read relevant instruments. Evaluation was done for all three settings. Values presented in Table-3 are in approx. figures for shortest subject.

It was evident from the trial of short subjects that none of them were able to reach any controls/ switches in all the three settings, in spite of shoulder harness fully extended and lap belt loosened (Fig-2). All the subjects could reach overhead 'HP cocks' even when fully restrained. No awkward neck, back and lower extremity posture was identified while attempting to reach controls.

(d) Cockpit Trial for Tall Subjects : The assessment of taller subjects revealed the following:

(i) No issues were identified during ingress, egress. Adequate over head clearance space is available for movement of upper body and head for taller aircrew. Adequate space (> 10cm as per Mil Std 1472-F) was identified in front of knees for foot and toe clearance, eliminating any issues of leg room constraint. Seat pan and back rest dimensions including cushions were found appropriate in terms of comfort levels. Shoulder straps passes over the shoulders in a plane perpendicular to the back tangent line not exceeding 30 degrees. A shoulder harness pull-off point 22" above buttock reference line revealed that the straps don't apply an excessive downward load on the spine of taller occupant. Shoulder harness anchorage appeared not to permit > 0.5" lateral movement to ensure that the occupant is properly restrained laterally (US Mil Std - 8236-F).

(ii) Work Posture : Evaluation of work posture did not reveal any constraints in terms of abnormal neck flexion, knee flexion or bending of spine. In general, evaluation of cockpit geometry and seat dimensions reveals that the maximum sitting height, mid-shoulder width, hip width, thigh length and leg length are not critical in aspects of seating comfort for the FE.

(iii) Reaches : Though reaches are critically evaluated for shorter subjects, it was done for taller subjects too, to dwell upon the limitations of harness system and to identify any fouling of any body part / clothing with cockpit structure/ instruments. The data for reaches is presented in Table-4 for tallest subject.

(iv) It is evident from results that taller subjects were also unable to reach any controls/ switches in fully restrained position and could reach all controls only when shoulder straps were fully extended and lap belt loosened.

(v) It is also evident that height, sitting height and functional arm reach may play an important role in terms of reaches as subjects with higher values of anthropometric parameters had better reaching ability.

(e) Lap Belt anchorage evaluation for all subjects. Lap belt when donned appears to form shallow angle (<45°) between the lap belt centre line & the buttock reference line for all subjects (Ideally bet 45-55° as per Mil Std 58095-A). Anchorage point on cockpit door appears to be located a bit higher creating the shallow angle as described. Lap belts appear to rest a bit higher over iliac crests, closer to abdomen (Fig - 3).

(f) Emergency Escape : The flight engineer can use the overhead hatch or the left or right side bubble canopy for escape. The harness or the seat shall not restrict the movement during emergency or ditching. There is quick release mechanism on the seat harness, which will prevent delay while escaping, from awkward positions like roll or inverted.

Discussion

The goal of this evaluation was to identify specific human engineering and work factors that could contribute to increased discomfort in this population, that can be a safety hazard, and to suggest corrective actions required for remedy.

The study revealed no ergonomic and human factors issues in terms of dimensions and design of seat, which will affect comfortable seating of FE. Absence of arm rests, head rest, seat adjustment and reclining mechanism shall not critically affect seating comfort and performance of FE. Absence of energy absorbing mechanism during crash does potentiates chances of injury, but looking at the space constraint, design and location of FE seat, the possibility of installing any seat with E/A mechanism appears austere.

Though seat is equipped with shoulder harness along with inertial reel and lap belt (without reel), the reach to critical controls appear grossly limited for all subjects when fully restrained and marginally short for shorter subjects even with shoulder straps fully extended and lap belt loosened. *This proves that present restraint system is incapable of providing full range of required longitudinal mobility and forward movement, especially for aircrew with anthropometric parameters closer to minimum percentile values. The length of extended shoulder strap appears insufficient for smaller subjects.*

The anchoring mechanism on compartment door forms shallow angle as described in results above, making lap belts rest higher over iliac crests. Width of webbing is less as compared to standard requirement of. In an accident with high combined vertical & longitudinal impact forces the restrained body tends to sink down into the seat & is simultaneously forced down - if the lap belt angle is too small and width of strap is less, the belt can slip over the iliac crests of pelvis & allow the pelvis to rotate - the inertial load of hips & thighs tend to **pull/ submarine** the lower torso under the belt. Lower torso restraint is then accomplished through lap belt loading on soft abdominal portions of the body, possibly causing visceral injury in addition to spinal injury. *Absence of inertial reel in lap belt assembly is another limitation further restricting the forward mobility.*

It is evident that operation of controls require frequent opening of fastener making it unsafe for FE. *During start-ups, take offs and any emergency, without effective restraint, FE run the risk of falling on cockpit critical instrument / controls like cyclic, further aggravating or precipitating the crisis and jeopardizing personal and flight safety.*

Recommendations

Certain modifications which are required to make it user friendly without compromising the safety features are recommended below:

(a) Lap belt assembly needs to be provided with inertial reel. Preferably it should be integrated with existing inertial reel, control knob and control cable, of shoulder harness so that engagement/ disengagement of lap belt assembly and shoulder harness is controlled by a single knob, making it more user friendly.

(b) Width of lap belts to be increased to recommended standards i.e. 2 - 2.25" for comfort and increased safety.

(c) Anchorage mechanism is to be looked into to explore the possibility of creating the angle of 45-55 degrees between centre line of lap belt and buttock reference line. Option of shifting anchorage point bit lower down on compartment door (without obstructing closure of the door) should be explored for creating the required angle.

(d) Stretchable length of shoulder straps to be increased, so that shorter aircrew could reach controls. Similarly stretchable lap belt length to commensurate with length of shoulder straps.

Conclusion

Flight Engineer seat and workspace geometry per se has got no limitations in terms of comfort levels, clearances and performance of FE. Restraint system in its present configuration appears to be the limiting factor affecting mobility and maneuverability of aircrew. Certain modifications recommended, to make it a **high mobility restraint system**, may go long way in increasing safety aspects and attaining operational optimization for Flight Engineers.

TABLES

Table - 1: Anthropometric data of subjects

Subjects	Branch	Height (cm)	Weight (Kg)	Sitting height (cm)	Leg length (cm)	Thigh length (cm)
1	F(P)	163.5	62	86	99	54.5
2	F(P)	164.1	64	83.6	99.1	54.8
3	FE	162	65	-	-	-
4	F(P)	164	63	83.5	99	54.6
5	F(P)	166	68	89.5	101.5	56.5
6	F (P)	185.1	74.5	95.7	118.5	63.8
7	F (P)	181.5	73	93.9	115.2	60.8
8	F(P)	184	75	95.5	118.3	63.6

Table - 2: Type of controls

S.No.	**Priority I** (most important)	**PriorityII** important)	**Priority III** (less important, occasional use)
1	Hydraulic panel	Central console multifunction Displays 2 & 3	Right hand side electrical control panel
2	Fuel system panel	Auto -pilot control panels	LH side triangular control panel
3	Fire fighting panel	Radio set control panels	-
4	Engine starting panel	-	-
5	Overhead ‘HP cocks’	-	-

Table - 3: Cockpit trial for short subjects

Settings	Priority I controls	Priority II controls	Priority III controls
1	Considerably short by 25 cm	Considerably short by 35 cm	Only able to reach overhead HP cocks, considerably short for other controls by 38 cm
2	Short by 11 cm	Short by 13 cm	Short by 18 cm
3	Barely able to reach, short by 4 cm	Short by 7 cm	Short by 12 cm

Table - 4: Cockpit trial for tall subjects

Settings	Priority I controls	Priority II controls	Priority III controls
1	Considerably short by 18 cm	Considerably short 28 cm	Only able to reach overhead HP cocks, considerably short for other controls by 30 cm
2	Able to reach	Able to reach	Short by 03 cm
3	Able to reach	Able to reach	Able to reach

FIGURES

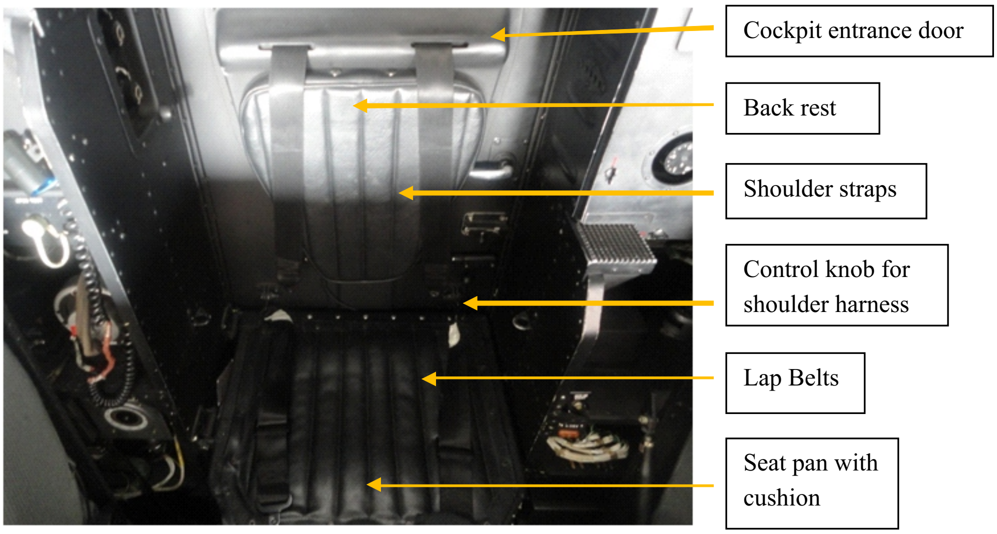

Fig - 1: Flight Engineer Seat

Fig - 2: Cockpit trial for short subject

Fig - 3: Anchorage mechanism for lap belts

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