Symposium : Design of a Modern High Performance Aircraft

HUMAN ENGINEERING ASPECTS : WORK SPACE LAYOUT

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Today's high performance fighter aircraft by definition encompasses light weight advanced fighter concept. This basically provides a baseline system with emphasis on air superiority performance.

From the pilot's point of view the most striking feature is likely to be the ability of the new designs to sustain high load factors in manoeuvres over a large part of the flight envelope. The consequence of this manoeuvring capability is that the outcome of future flights may be determined by the ability of the pilot to operate effectively under conditions of high G. The outcome of today's 'dog-fights' is, therefore, highly dependent on human factor aspects which are related to high normal accelerations - visual acuity, use of limbs and mental activity. This has posed a new challenge to the designer of a new high performance aircraft as well as to the human engineering specialist in formulating a work space which is fully compatible in this role. The focal point of this activity is thus the 'high G' cockpit.

Geometrical Factors

One of the primary goals in cockpit design should be to determine compatibility of high G cockpit concepts with minimum cockpit size, providing for both integration of a reclined or articulating seat and pilot's full functional capability within the cockpit.

As an initial step, an overall envelope for crew station should be defined which is compatible with a high performance light weight fighter concept. The following important points of departure from the standard conventional cockpit design are apparent:-

Cockpit dimensions are reduced all round.

The heel restline is raised by 11.4 cm to reduce blood pooling in the lower legs, maintain rudder pedal access in the reclined position and to reduce aircraft cross-sectional area.

Seat back angle is increased to 20 deg based on ejection angle considerations and pilot comfort.

Over the nose vision is enhanced from a minimum value of 11 to 15 deg improving the air to air combat role.

The central stick is replaced by a side stick to permit integration of the high G seat.

Anthropometric Considerations

Pilots come in all shapes and sizes. The likely variations regarding Indian pilot population are available to local designers from the Institute of Aviation Medicine. An obvious design requirement is that sufficient room and adjustment to seat and controls exist, so that all pilots within, e.g., 3 - 99 percentile of the anthropometric range shall be able to fly the aircraft, to reach all controls, and to see all displays. The need for easy entry to and exit from the cockpit is also self-evident. These basic requirements apply to any aircraft. The design of a fighter cockpit must respect additional needs. The first of these is concerned with escape, should the pilot need to abandon the aircraft in flight. Relevant military specifications lay down design criteria regarding safe ejection, canopy jettisoning, use of leg restraints and knee clearance of stick, panels and coaming.

Visual Requirements

An all important requirement of a high performance fighter is that the pilot must have adequate vision both inside as well as outside the cockpi Field of view is of prime importance combat. The fuselage line and the abse nce of canopy and windscreen suppor structure are vital factors. In addi tion, if the pilot will accept a redu ction in panel space, a lower sill lir can be used. The compromise betwee external view and panel space become even more apparent in the design of cockpit with a reclined seat. In thi regard, the accurate location of th pilot's eye position forms an importan factor. The over-the-nose view of th aircraft must be maintained at about 1 deg. The lower limb geometry determine the bottom edge of instrument panel It has been proved by various worker that a 45 deg seat inclination drasti cally reduces the panel space. Anothe important aspect is that the pilot must have a suitable sighting system for weapon delivery. The gun-sight of older fighters and the head up display (HUD) of modern fighters fulfill this role. From the human engineering point of view, successful use of HUD depends on accurate location of the pilot's eye position. Thus it is important that the seat inclination must be made relative to this eye design datum. Further, as the seat inclines, the distance of the pilot's eye from the panel also increases.

Reach Envelope Considerations

A difficulty associated with the reclining seat is the reach consideration for various cockpit controls. As the seat tilts, the need to relocate the stick, the controls and the selectors increases so that they are retained within easy reach of the pilots.

Such changes in relocation of stick, throttle, controls and selectors are possible in the context of current technology.

It is interesting to note that based on the same assumptions of the range of pilots to be accommodated, and the field of view to be catered for, there is a remarkable similarity in cockpit geometry among different design organisations and countries though the aerodynamic features of their aircraft are quite different.

Displays and Controls Concepts

Simple electronic displays are already in use in aircraft cockpits as indicators, and as alphanumeric status devices. Extending their use to other display requirements entails a radical rethinking of cockpit design. With increasing confidence in computers, sensors and control technology, comes the opportunity and advantage to relocate, redesign and rearrange the controls and displays.

Displays: Before replacing electro-mechanical instruments by multiple CRTs, careful thought should be given to ensure that no existing facilities are lost. The electronic displays have features which can be exploited to provide options which were previously not possible.

Electronic displays are more acceptable to pilots, and produce better performance, partly due to their greater information content. Multi moding is an effective way of utilising a limited display surface, particularly for navigational purposes and for the monitoring of systems under normal conditions. Pilots require certain classes of information at all times. To make control selections for diagnosing trouble is unacceptable if immediate pilot action is called for. Where possible, both analog (dial or strip) and digital indications should be incorporated into the display.

Integration and evaluation of displays for a high G cockpit is a difficult exercise because of the reduced panel space and associated large geometrical changes. It is no longer just replacing conventional instrumentation by electronic equivalents. A completely new cockpit layout is required. From the human engineering point of view, the starting point of such an exercise is to categorise all controls and displays, and to relate them to function, associated system utilisation and redundancy. A comparison can then be made with controls and displays of a conventional cockpit. The necessary controls and displays must then be allocated to available panel area. Since there is dramatic reduction in front panel area with increased seat back angle, the side panels offer a useful alternative. However, the need for multi-moding of display is evident.

Controls : The conventional control stick invariably obscures the view of the lower central panel. Consequently, the displays and controls which are used only occasionally are located there, e.g., oxygen and engine start. The central area provides most of the display surface at large seat-tilt angles necessitating relocation of the stick.

The pilot can no longer reach the front panel or coaming in the advanced cockpit, and the position of the stick requires a change. It is no longer possible to arrange a fixed location of the stick within comfortable reach of the full range of pilots, when seat adjustment is made for the correct eye position. Electrically signalled controls give the designer much greater freedom in the choice of the primary control stick. An installation on the right hand side panel, the force side stick as used in the F-16 aircraft is one such alternative. There are arguments both for and against force side sticks. Doubts remain as to whether pure force control is as good as a force/deflection feed system, more so at low speed. The loss of side panel space, particularly if some form of arm support is needed, requires to be minimised. A side controller with all the switching functions which at present occupy the conventional stick top is to be provided. Similarly, the throttle is located on the left hand side panel and incorporates fly-by-wire principles. Many other important secondary control functions are incorporated into the throttle. This ensures effective reach as well as operation of the primary as well as secondary controls.

Implications

Performance improvements allow new generation fighter aircraft to sustain high G over a large part of their flight envelope. Success in combat will be influenced by the ability of the pilot to operate under high G. This requirement has direct implications on the design of the cockpit and poses a challenge to human engineering experts. Radical changes in the fighter cockpit design are implied if the pilot's seat is tilted beyond 30 deg. It has been proved that noticeable G protection is not achieved until the seat is tilted beyond 45 deg. Variable geometry seats have been designed, which might provide the pilot with the best of both worlds, but they do not solve the human engineering problems of cockpit design, but only transfer the problems to a new area. Thus, the designer of a new high performance fighter aircraft has a difficult decision to make. Several modern fighters like F-14, F-15, F-18, F-16 and Mirage have high sustained G capability, but do not resort to seat tilt for G alleviation. However, technology to design a high G cockpit is currently available.

Conclusion

The aircraft cockpit designers and human engineering experts face a new challenge in the work space design of a modern high performance aircraft. The aim is to have a new and state-of-the art cockpit which is workload minimising and pilot friendly. Hands On Throttle And Stick provides all operational mode selections and actions. Raised pilot position, increased seat inclination, lowered sills and bubble canopy can give superb combat view all round. Technology allowing the pilot to maximise mission effectiveness and flexibility is available.