Thermal Stress in High Speed Low Level Flying

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THE problem of thermal stress in aviation is more or less confined to flying at low altitudes, obviously because of higher ambient temperatures at these levels. The problem gets multiplied many folds if an aircraft has to fly at low level at high speeds so much so that in the present day in ground attack fighter aircraft flying at tree top levels at near sonic speeds, the problem of thermal stress has become one of the major factors jeopardising aircrew comfort. In low level high speed flying, apart from the high ambient temperatures, the other and more important factor which contributes to high cockpit temperatures is the aero-dynamic friction. The magnitude of heat-load because of aero-dynamic friction rises sharply with increase in speed.

The emphasis today is on low level high speed strike aircraft, an important feature of which is the very high cockpit work-load. Even very experienced pilots feel that the operation of various on-board systems for navigation and weapon aiming are extremely demanding on the pilot's work capacity in the cockpit. All this only emphasises the over riding need of looking into and solving the problem of thermal stress in aviation and making the environment in pilot's work space more genial.

A field study was carried out on supersonic flying at a fighter base in North-West India. It involved serial recordings of cockpit air temperatures before taxying out and just prior to take-off in winters and in summers. Along with this, temperature-humidity index was determined for the full year to identify high thermal stress periods. It was revealed that in the months of May and June, the ambient air temperature fluctuated around 40°C and the temperature-humidity index varied between 80 and 90. A temperature-humidity index above 75 is considered relatively uncomfortable and that above 80 as absolutely uncomfortable.

For determining the cockpit thermal condition and aircrew thermal strain, two parameters were recorded, viz., cockpit air temperature and sweat loss for the duration of the sortie lasting about 35-40 minutes. The result revealed that in winters the cockpit air temperatures at take-off point ranged between 21.1 and 33.3°C with mean value of 28.7°C. In summers the temperature range was from 38.9 to 43.3°C with a mean value of 41.4°C. The rise of temperature during 10 minutes of taxying was 3.2°C in winters and 3.6°C in summers. Nunnely and James in a similar study found cockpit air temperatures rising to as much as 60°C till take-off after a taxy run of 15 minutes when the ambient temperatures were only 35 to 40°C. The pilot's sweat loss in winters varied from a minimum of 50 grams to a maximum of 250 grams with a mean value of 123 grams. In summers the sweat loss was much more, ranging from 450 grams to 1050 grams with a mean of 796 grams.

Exposure of subjects to thermal stress in the laboratory produced a much lesser sweat loss though the temperatures were high. At 59°C with 55% relative humidity a mean sweat loss of only 380 grams was noticed after an exposure of 30 minutes. The comparative analysis of sweat loss values in the laboratory and in the cockpit reflects the severity of thermal stress to which our pilots are exposed in summer season.

Another study was conducted in a twin engine low level strike aircraft in Sardinia recently. Measurement of cockpit temperatures and other relevant parameters was carried out for 22 sorties at medium to low levels at speeds of upto 420 knots. Maximum cockpit temperature of 30°C was recorded when the ambient temperature was only about 24°C. Aircrew thermal strain measurement was also carried out. It was found that although the equilibrium temperature for this aircraft is 10°C lower than other high performance aircraft of the same class, the aircrew were generally above the ideal level of thermal comfort even in the comparatively mild summer of Southern Europe.

Relationships between ambient, cockpit and pilot's body temperatures and between sortie time and cockpit and pilot's body temperatures were studied. The following inferences were drawn :

(a) *Cockpit and ambient temperatures :* Cockpit temperatures did not correlate significantly with the mean ambient temperatures measured on ground immediately before and after each sortie.

(b) *Pilot's MBT and ambient temperatures : No* significant relationship could be established between the pilot's mean body temperature and ambient temperature.

(c) *Pilot's MBT and cockpit temperature :* Pilot's MBT rose linearly with rise in cockpit temperatures. The relationship can be expressed by the equation :

$$\text{MBT} = 36.17 + 0.33\,\text{WBGT}_{\text{cockpit}}$$

In case of failure of cabin airconditioning, the MBT rose more steeply. This relationship can be expressed by the equation :

$$\text{MBT} = 37.2 + 0.11\,(\text{WBGT}_{\text{cockpit}} - 31.0)$$

(d) *Cockpit temperatures and sortie time : With* a functioning cabin airconditioning system, the cockpit temperatures fell between take-off and landing and the relation is defined by the equation :

$$\text{WBGT}_{\text{cockpit}} = 20.57 - 0.044\,t$$

This temperature was reached in about 2 to 7 minutes of switching the airconditioning system "on". However with a failed cabin airconditioning system the cockpit temperature rose exponentially with time. The relation could be expressed by the equation :

$$\text{WBGT}_{\text{cockpit}} = 33.76 - 7.66^{-0.1117\,t}$$

(e) *Pilot's MBT and sortie time :* Pilot's MBT tended to fall between take-off and landing. The relationship was as follows :

$$\text{MBT} = 37.0 - 0.01\,t$$

In case of failure of cabin airconditioning system the MBT tended to rise with sortie time and can be expressed as :

$$\text{MBT} = 37.13 + 0.012\,t$$

Correlating the data, it is possible to predict the pilot's MBT during a sortie at different levels of cockpit temperatures.

The design considerations of fighter aircraft, specially the limitation on weight and space for any on-board equipment comes in the way of installation of a satisfactory cockpit airconditioning system. Since the present day cockpit airconditioning system is based on the velocity and temperature of ram air-flow the cooling capacity is comparatively less at low altitudes where ambient temperatures are higher. In addition, the system is totally ineffective during ground operation, i.e., taxying till take-off point and ground standby. As a matter of fact Nunnely et al demonstrated that maximum cockpit temperatures were recorded just prior to take off after a 15 minute taxy run.

In view of this it seems that the only promising method of achieving a somewhat satisfactory thermal environment is the creation of a micro environment around the pilot. And the best way to do it, in the present state of the art, appears to be by the use of Liquid Cooled Suit. The need for developing and introducing this garment for combating aircrew thermal stress was never greater.

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