Original Article

Development of a predictive heat stress index for the Mi-25/35 helicopter

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The Mi-25/35 helicopter is one of the fastest helicopters in the world, flying at a mzximum speed of 335 kmph. Heat stress in the Mi-35 helicopter was studied with a view to determining the effects of low level high speed flying on cabin temperatures. The cabin temperatures were measured during 10 sorties using a RSS-211-D portable heat stress monitor. A correlation was established between the cabin and environmental temperatures with a Pearson's coefficient of 0.88. An index was developed using a regression equation and was found to have a high predictive value in subsequent sorties. This was found to be easy to use, reliable and fit to give a clear Go-No Go indication for the sortie. This index is being presented.

Keywords: Heat stress, indices, thermal load.

Heat stress results from an imbalance in metabolic heat production of the pilot and the net result of its exchange with the environment (1). This is an important problem while flying in India. It is compounded by low altitude high speed flying (2). The Mi-25/35 helicopter is an attack helicopter in use in the Indian Air Force (IAF). It is one of the fastest helicopters in the world, flying at a maximum speed of 335 kmph (3). It is employed for close air support and anti-tank missions which involve nap of the earth flying. While the helicopter is air-conditioned, it has been designed for Russian conditions, which are not as severe as the Indian summer. This study was done with the intention of assessing the heat load inside the aircraft while flying at low and medium levels (50m to 300m) during summer months in northern India.

Material and methods

The heat stress was measured using a Wibget RSS-211-D portable heat stress monitor (Mfd Reuter-Stokes Inc, Canada). This is a thermistor based solid state thermometer with an LCD digital readout. It has a trident probe for measuring dry bulb, wet bulb and globe temperatures. The globe temperatures are measured using a miniature 50 mm globe and are corrected automatically to the standard globe thermometer temperatures. It also automatically calculates the WBGT index. This was used directly in all cases (4).

The accuracy of the said apparatus was checked periodically against standard mercury thermometers

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and was found adequate. The temperatures were measured outside the aircraft on ground, inside the aircraft cabin on ground, and in flight. The in flight measurements were taken throughout the sortie at 5 min intervals. Though the two cockpits and the cabin are interconnected, temperatures were measured in all three compartments to establish that the temperatures in all three compartments were the same. As the cabin conditioning vents are along the roof of the cabin, temperature differences were studied between head level and foot level temperatures in the cabin. Ambient temperatures were recorded with the help of the airfield meteorological department. This was done at half hourly intervals using a sling psychrometer. Efforts were made to conduct the experiment under similar ambient temperature conditions (±2.5°C) to preserve constancy in the experiments. All recordings were made during sorties done on sunny days only.

Ten sorties including nap of the earth flying, 1 vs 2 combat and missile firing sorties were studied. No significant difference were found in the cabin temperatures amongst these various sorties, probably as all of these were at low levels. Correlation between the ambient and cabin temperatures was studied and was high enough for a predictive index to be established, which is being presented as an equation.

Results

Subjectively, heat load was not considered a problem by the pilots. The results of objective assessment are presented in tables 1-4.

As is evident from the tables, the air-conditioning system of the Mi-35 aircraft is extremely effective and maintained the average WBGT index within the comfort zone in almost all ten sorties. The difference between the ambient WBGT index and that inside the aircraft was highly significant (t test significant at <0.5).

Table 1. Dry bulb temperatures

Sortie No.	Ambient (Avg)	Cabin (max)	Cabin (Avg)
1	36.8	39.8	32.9
2	41.3	41.2	35.9
3	36.8	35.7	31.4
4	37.6	38.3	31.6
5	34.6	35.0	27.3
6	35.6	35.9	27.2
7	35.0	37.1	27.1
8	39.2	39.3	30.9
9	37.4	37.6	30.6
10	32.5	32.8	26.1
Mean	36.7	37.3	30.1
SD	2.34	2.38	2.96

Table 2. Wet bulb temperatures

Sortie No.	Ambient (Avg)	Cabin (max)	Cabin (Avg)
1	23.2	26.6	22.1
2	27.7	24.8	23.0
3	24.5	24.6	20.7
4	24.7	22.5	20.8
5	24.0	26.0	18.7
6	25.3	27.0	20.2
7	28.0	30.3	20.0
8	30.3	33.0	25.3
9	29.3	30.1	22.3
10	29.2	29.5	19.3
Mean	26.6	27.4	21.2
SD	2.43	3.05	1.86

Pearson's coefficient of correlation was calculated to determine the relationship between the ambient temperature and cabin temperatures. This was found to be 0.81 and was considered to be high enough for a regression equation to be devised to predict temperatures in air from the ground ambient temperatures. The equation is:- $WBGT_{(cabin)} = 0.7084\ T_{wb} + 0.3036\ T_{db} - 8.08$.

Table 3. Black globe temperatures

Sortie No.	Ambient (Avg)	Cabin (max)	Cabin (Avg)
1	46.7	40.5	33.5
2	49.7	41.5	38.0
3	41.7	36.3	32.4
4	46.1	37.6	33.0
5	44.0	35.1	28.0
6	38.2	37.3	28.1
7	42.0	37.2	28.2
8	47.8	46.2	33.0
9	39.5	39.2	31.9
10	33.3	33.2	27.1
Mean	42.9	38.4	31.3
SD	4.73	3.48	3.25

The validity of this equation was checked. The standard error of regression was calculated and was found to be ±1.092°C.

Table 4. WBGT index

Sortie No.	Ambient (Avg)	Cabin (max)	Cabin (Avg)
1	29.3	30.8	25.5
2	33.5	29.9	27.3
3	29.2	28.2	24.1
4	30.3	27.1	24.3
5	29.1	28.8	21.4
6	28.9	30.2	22.5
7	31.5	32.1	22.4
8	34.7	35.9	27.4
9	32.2	32.7	25.1
10	30.4	30.6	21.5
Mean	30.91	30.6	24.15
SD	2.02	2.38	2.20

Discussion

The pilots did not consider heat load to be a stress factor. Only 22.5% considered it to be adding to workload at all (5). The average increase in workload was assessed to be negligible (2.5% of total).

The helicopter remained comfortable during low level and ultra low level or NOE sorties substantiating the manufacturers claim of comfort between +37°C and -50°C ambient temperatures.

The new heat stress index has been described. The standard error of regression is ±1.092°C which means that 66.66% of temperature values predicted by the equation will fall within ±1.092°C of the actual values. This index can be used to determine the magnitude of heat stress on the aircrew. It is suggested that the same guidelines be used for caution and danger zones as have been described by Nunnely and Stribley in their work on FITS (6).

The above mentioned index has the four prerequisites of a practical index for use in the aviation environment (6) i.e.:-

(a) Readily available input data

(b) Easily read index

(c) Single page presentation

(d) Clear indication of operational go/no go situations.

It however has a few limitations. The nature of data used restrict its application to the Mi-35 helicopter on missions involving significant periods below 300m above MSL.

Heat strain indices were not measured due to two reasons. One was the difficulty of instrumenting the pilots in flight. The other, more pressing reason was the lack of any subjective complaints by the pilots.

References

1. Allan JR. The thermal environment and human heat exchange. In: Aviation Medicine, ed. Ernsting J and King P. London. Butterworths. 2nd edition. 1988. 219-34

2. deTreville RTP. Occupational medical support to aviation industry. In: Fundamentals of Aerospace Medicine. ed. Dehart RL. Philadelphia. Lea & Febiger, 1985; 929-31.
3. Jane's all the worlds aircarft. London. Jane's Publishing Company, 1991.
4. Manufacturers specifications: RSS-211-D heat stress monitor. Reuter Stokes Inc. Canada.
5. Agarwal A. Assessment of heat load and workload in the Mi 25/35 helicopter. Field Project for 32 Advance Course in Aerospace Medicine, Bangalore. 1993.
6. Nunnely SA, Stribley RF. Fighter index for thermal stress (FITS): Guidance for hot weather aircraft operations. *Aviat Space Environ Med*. 1979; 50: 639-42.