Original Article

Inflight measurement of vibration levels at seat and floor of Chetak and Pratap Helicopters

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A study was carried out to determine the inflight vibration levels at the seat and floor of Chetak and Pratap helicopters. Vibration levels were recorded using a sound level meter which was coupled with a human vibration unit and a tri-axial accelerometer. A weighting network complying with ISO 2631/1 for frequencies between 1-80 Hz was used and four sorties were flown in each helicopter. The intensity of vibration was found to be predominantly due to the vibrations in the vertical axis (Z). The fore and aft (X-axis) vibrations were very small compared to that of Z and Y axes. During straight and level flight, the average acceleration values at the seat and floor levels of Chetak were 0.3 m/sec² and 0.826 m/sec² respectively while for Pratap the corresponding values were 0.520 m/sec² and 0.895 m/sec². On a subjective scale, vibration levels were found to be acceptable to the aircrew.

Key words : Low frequency vibration, Weighted acceleration, Average acceleration (a_{eq}), Maximum Peak (MAXP), Maximum rms (MAXL)

In military aviation, helicopters have come to play a significant role due to their extreme manoeuverability. In the Indian Air Force too, helicopters have an important role in fulfilling a variety of operational tasks. The pilots of these helicopters are exposed to a wide range of vibrations with variable amplitudes [1], which reach the aircrew through the peripheral supporting surfaces like the seat and floor. Such vibrations can disturb the aircrew in several ways depending on the nature, route of entry and intensity. Long duration exposure to low frequency vibrations cause fatigue and other physiological disturbances, which may affect aircrew performance ability.

Low frequency vibrations are of great concern, as major resonances of different parts of the human body occur below 25Hz, pilots are not easily protected in these frequencies by mechanical damping systems [2].

The present study was therefore undertaken at the Institute of Aerospace Medicine (IAM) and Aircraft and Systems Testing Establishment (ASTE), Bangalore to determine the vibration profiles of Chetak and Pratap helicopters to assess the vibration levels reaching the aircrew.

Material and Method

A modular precision sound level meter (B&K Type 2231) was coupled with a human vibration unit (B&K type 2522) and a tri-axial accelerometer (B&K Type 4322)for the measurement of vibration in the frequency range 1-80 Hz. An application module (Human vibration module - B&K Type BZ 7105) loaded in the memory of the sound level meter samples the signals from each input channel at the rate of 32 samples per sec and stores the data in RAM.

16 KB RAM allows storage of a total of 99 records at a time with the option of presetting the measurement period of each record to any convenient duration. Real time clock setting is used for proper documentation of the stored record. Each record consists of Record number, Start time, Stop time, Duration, Measurement mode, Detector time constant, Measurement unit and the calculated data such as Maximum peak (MAXP), Maximum rms (MAXL) and a_{eq} values.

Here, a_{eq} is the acceleration level averaged over the measurement period. It is equivalent to the continuous steady state acceleration level which would have the same total energy as the real fluctuating vibrations over the same time period and calculated as :—

$$a_{eq} = \frac{1}{T}\int_0^T a(t)^2\,dt$$

where, a(t) is the time varying acceleration and T is the time interval over which it is measured.

For whole body measurements, a_{eq} is calculated after computing the sum of the overall weighted acceleration value using the formula :

$$a = [(1.4a_x)^2 + (1.4a_y)^2 + (a_z)]$$

where, a_i is the weighted acceleration values in the i-direction and i = x, y, z

Four settings viz, X, Y, Z and SUM are available with the human vibration unit for display of measurements. The SUM setting is available only when the displayed parameter is a_{eq}

A total of four sorties were carried out in Chetak and Pratap helicopters. All sorties were performed in fine weather under calm wind conditions. Duration of sorties varied between 30 to 60 mins.

Vibration levels were measured at the pilot's seat and at the cockpit floor. The tri-axial accelerometer was firmly placed in close contact with the underlying surface by using straps and adhesive tape. Whole body triaxial mode with frequency weighting (1-80 H_z) complying with ISO 2631 was used [3]. Selecting mm/sec² as the measurement unit, data was recorded automatically for various phases of flight. Record numbers were noted from the display screen during each sortie so as to correlate it with the various events of flights. On the ground the recorded data was retrieved manually and analyzed.

Subjective Feedback : A questionnaire was given to helicopter pilots (instructors and students) and flight engineers of ASTE and a field Helicopter unit for their comments regarding vibration levels. Subsequently, the data on subjective feedback was analysed.

Results

a_{eq} values for the three orthogonal axes X, Y & Z and the SUM channel for all the sorties were tabulated and analysed. The average values of a_{eq} for various phases of flight for the two helicopters are given in Figures 1 to 4. Tables I and II give the average of maximum MAXP and MAXL values obtained for the two helicopters during various phases of flight under different sorties.

A total of 6 instructor pilots, 6 student pilots and 6 flight engineers responded to the questionnaire survey. An account of their flying experience and subjective ratings of vibration in the two helicopters are given in tables 3(a) and 3(b) respectively.

Discussion

As the vibration levels reaching the aircrew is of great aeromedical concern, vibration levels at the pilot's seat and the floor of the cockpit of the two helicopters were recorded. A total of four routine operational sorties were flown, keeping the sorties as identical as possible. However, there were multiple take-offs and landings in any one sortie. Similarly, hovering could not be carried out in Pratap helicopter. Owing to variation in the duration of sorties, the present time could not be kept at a constant value.

Table I

Average of Maximum MAXP and MAXL acceleration values (mm/sec^2) : Chetak Helicopter

Event	Axes					
	Z		X		Y	
	MAXP	MAXL	MAXP	MAXL	MAXP	MAXL
On the Seat						
Taxying	1315	668	238	187	601	391
Take off	864	456	102	84	439	265
Straight and level	934	380	61	44	546	328
Hover at altitude	1450	832	17	11	776	660
Landing	1315	604	41	28	560	381
On the Floor						
Taxying	2300	912	89	34	425	165
Take off	2735	1210	80	52	415	161
Straight and level	2930	1170	90	40	618	225
Hover at altitude	2580	920	123	54	460	169
Landing	2045	975	84	26	745	427

Table II

Average of Maximum MAXP and MAXL acceleration values (mm/sec²) : Pratap Helicopter

Event	Axes					
	Z		X		Y	
	MAXP	MAXL	MAXP	MAXL	MAXP	MAXL
On the Seat						
Taxying	1961	1068	72	54	798	532
Take off	1730	1031	48	37	822	547
Straight and level	1875	980	31	23	916	682
Hover at altitude	N/A	N/A	N/A	N/A	N/A	N/A
Landing	4675	2550	40	28	2440	1550
On the Floor						
Taxying	2760	1069	419	34	609	340
Take off	1830	774	120	82	501	225
Straight and level	3290	1375	57	28	808	417
Hover at altitude	N/A	N/A	N/A	N/A	N/A	N/A
Landing	3950	2350	499	444	1825	1275

Table III (a)

Flying Experience (hrs)

Category	Mean ± SD
Instructors	1494 ± 888.7
Student Pilots	62 ± 8.2
Flight Engineers	1992 ± 599.0

Table III (b)

Subjective rating of vibration

(n = 6 each)

	Instructors		Student Pilots		Flt Engrs		Percentage	
	Chetak	Pratap	Chetak	Pratap	Chetak	Pratap	Chetak	Pratap
Not uncomfortable	1	1	3	3	2	N/A	33	33
A little uncomfortable	2	3	2	3	2	N/A	33	50
Fairly uncomfortable	2	1	1		2	N/A	28	8
Uncomfortable	1	-	-	-	-	N/A	6	8
Very uncomfortable	-	1	-	-	-	N/A	-	-
Extremely uncomfortable	-	-	-	-	N/A	N/A	-	-

: Pratap

	MAXL
	532
	547
	682
	N/A
	1550
	340
	225
	417
	N/A
	1275

entage	
	Pratap
	33
	50
	8
	8
	-
	-

Fig - 1 : Mean a_{eq} values - Chetak seat

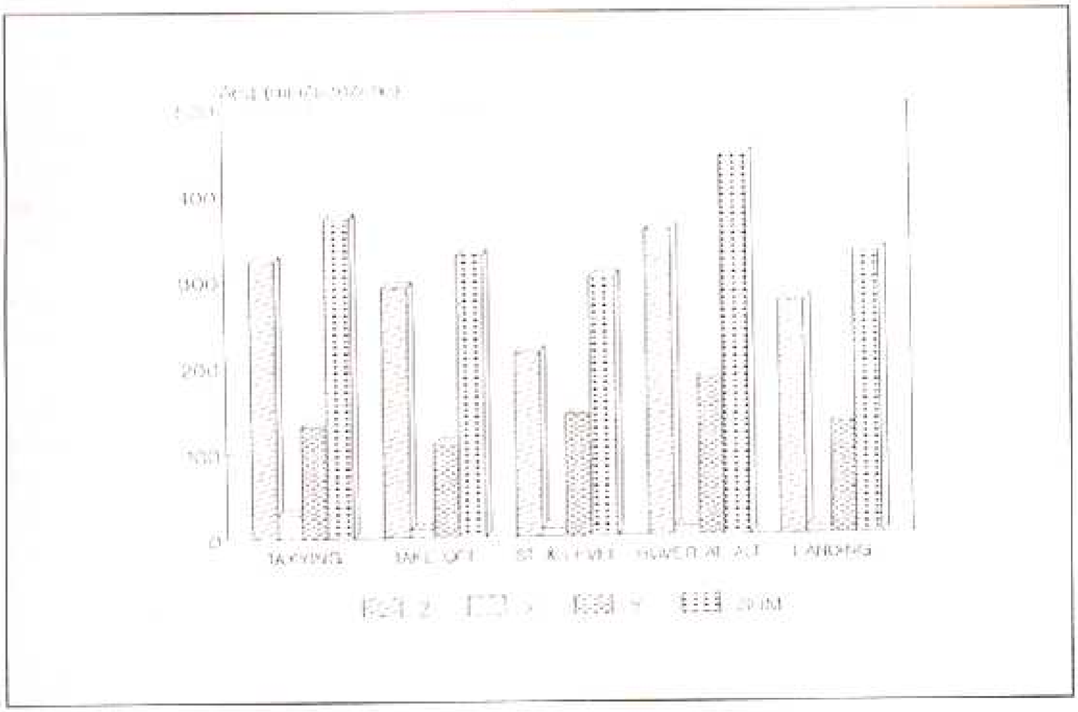


Fig - 2 : Mean a_{eq} values - Chetak floor

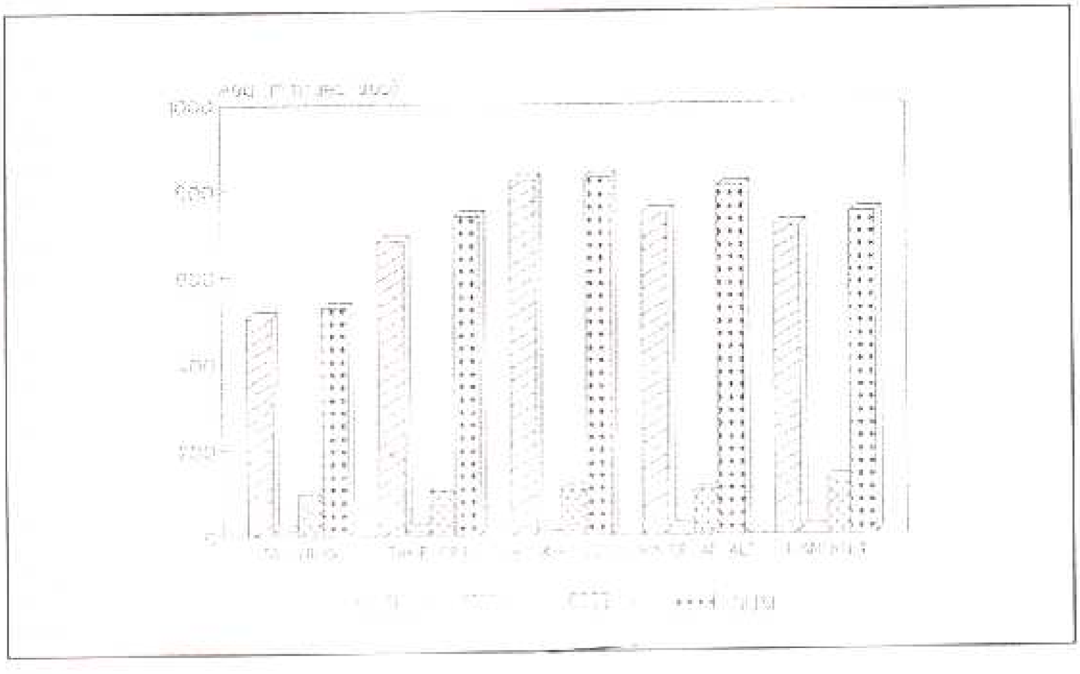


Fig - 3 : Mean a_{eq} values -Pratap seat

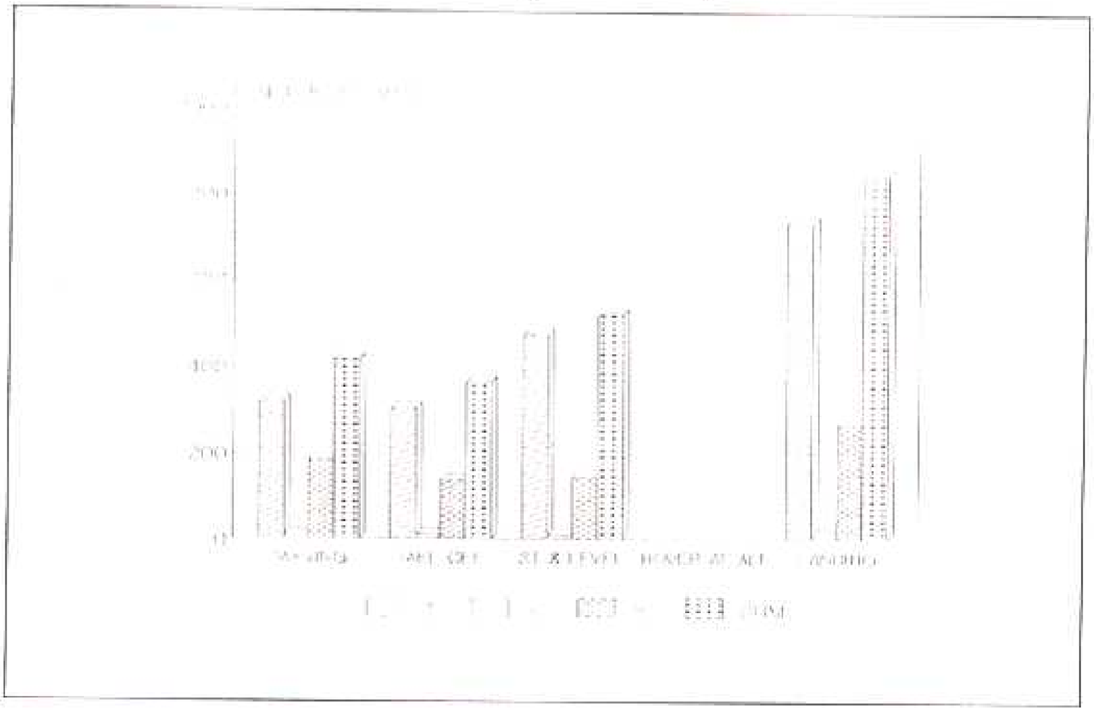
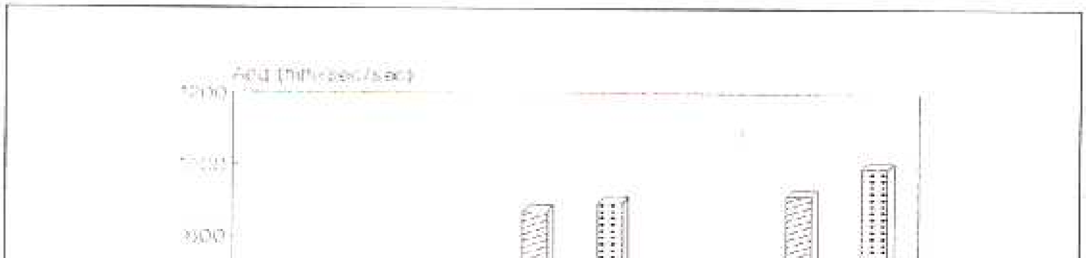


Fig - 4 : Mean a_{eq} values -Pratap floor



Since the vibration levels were recorded simultaneously in the three orthogonal axes, the acceleration levels along X, Y & Z axis could be compared during various phases of flight. It was seen that the intensity of vibration was predominantly in the Z axis in all the sorties. Similar results were obtained by Macnab et al [1].

Also the intensity of vibration at the pilot's seat was found to be lower than that at the floor level during all phases of flight. This is probably due to damping offered by the metal sheet and thick cushion combination provided on the seat and backrest. The aircrew are therefore experiencing vibrations of lesser intensity. However, on the floor, vibration levels were found to be sufficient enough to affect those who were in direct contact. This implies that in helicopters like Pratap, which is used for transportation of troops, fatigue may be caused in passengers who sit on rigid seats in the cargo compartment.

The intensity of vibration varied considerably throughout the sorties. However, during straight and level flight, which forms a major part of a routine sortie,vibration was of intermediate intensity. The average acceleration values obtained in the SUM setting during this phase of flight for Chetak and Pratap helicopters were 0.3 m/sec^2 and 0.520 m/sec^2 respectively. These levels correspond to fatigue decreased proficiency (FDP) boundary advocated by ISO 2631/1 for 8 and 4 hours approximately. Thus the work efficiency of Chetak and Pratap helicopter crew may not be affected even if the duration of vibration stress is extended upto 8 and 4 hours respectively.

From the subjective feedback obtained from 18 aircrew, it was seen that the vibration levels in both helicopters were within tolerable limits of aircrew. Majority of them rated the vibration to be within the region of not uncomfortable to fairly uncomfortable.

Conclusion

1. Vibration of varying intensities were present during all phases of helicopter flying.
2. Vibration at floor level was considerably higher than that at aircrew seat level.
3. Average acceleration levels obtained during straight and level flight were found to be comparable with FDP boundaries of ISO 2631/1 for 8 and 4 hour for Chetak and Pratap helicopters respectively. As such, the in-flight vibration levels in both the helicopters were within tolerable limits and not likely to cause any deterioration in aircrew functioning.

References

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