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SUBJECTIVE ASPECTS OF VIBRATION IN HELICOPTERS

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ABSTRACT

In modern helicopters the crew have to perform an increasingly difficult role in a machine whose fundamental mechanics make it subject to vibration. Data is presented comparing the vibration to which the helicopter crew are exposed with the recently published International Standards Organisation (ISO) criteria. From this it would appear crew vibration in helicopters is not excessive, but further work is necessary to investigate the influence of the helicopter environment on the highly specialised crew tasks. Whilst the long term solution to the aircrew vibration problem is to reduce airframe vibration, more effort should be made to isolate the crew member by means of the seat in the short term.

1. INTRODUCTION

With the increased complexity and duration of operational flights in current and projected helicopters, various human factor problems to which aircrew are exposed require greater attention if the overall efficiency of the vehicle is to be improved. A particular area which justifies closer examination is the crew vibration environment. Various investigations have been recommended by the AERDC working party on helicopter human factors to study this (Ref.1).

The subjective problems associated with helicopter vibration lie in three main areas

(a) the effects of whole body vibration on fatigue, physiological damage, comfort and certain performance criteria

(b) the combined effects of whole body vibration and vibration of displays on visual tasks

(c) the effects of localised vibration of the aircrew extremities (head, hands and feet) upon certain performance criteria.

Although considerable engineering benefits would be achieved by a reduction in helicopter vibration levels, the effects of helicopter vibration on aircrew have not been fully quanitifed. A considerable quantity of structural vibration data is collected during the development programme of new helicopter types. At WHL, cockpit vibration levels are also recorded, during a range of flight conditions, on each helicopter manufactured as a production clearance procedure (Ref.2). Some research workers have attempted to interpret subjectively results based on structural measurements (Refs.3, 4 and 5). Relatively few studies have attempted to define the input vibration characteristics to aircrew (Refs.6, 7, 8 and 9).

It was decided to monitor the vibration input to the pilot on a range of Sea King helicopters (Figure 1) during their production clearance flights. (Ref.10). A subsequent investigation was carried out in conjunction with the RAE and the IAM at RNAS Culdrose on in-service Sea King ASW aircraft, the vibration input to the body being monitored at the 4 crew positions (Ref.11).

This report gives a summary of this work showing typical vibration levels recorded. These levels are compared with the human vibration tolerance criteria and with vibration monitored on other helicopter types.

2. PILOT VIBRATION RECORDED DURING PRODUCTION CLEARANCE

Vibration data was recorded during thirteen production clearance flights on a total of eight Sea King helicopters for a range of flight conditions. The helicopters included the ASW, SAR and Commando variants. Three positions in the cockpit were monitored. The crew positions on the ASW variant are shown in figure 2.

a) the pilot buttock/seat interface

b) the interseat console

c) the pilot's seat back.

At each position three axes vibration was monitored.

For all recorded flights amplitude/frequency analysis has been conducted using a 500 line, hybrid real time analyser. The analysis, in terms of peak velocity, covered the frequency range 0 to 100 Hz (Figure 3).

As expected, the most significant vibration order in terms of velocity was 5R (main rotor blade passing frequency). This was the case for all positions, directions, flights and flight conditions. After each flight pilots confirmed 5R to be the most disturbing frequency,

Figure 4 shows the variation of vibration level measured at the pilot buttock/seat interface for the various relevant flight conditions. With the exception of the transition to hover, which is a particularly severe vibration condition on the Sea King, the vibration at the seat bar rarely exceeds .15 'g'. A build up in vibration level occurs during the transition to hover, the maximum level of this build up is quoted, which normally occurs at about 25 knots. Thus, although this particular condition is severe, the total duration of that level during any flight will be very short.

Although vibration levels at the 10R and 15R orders were noticeable high tape recorder noise at these frequencies precluded detailed study. First rotor order vibration was apparent particularly during high power conditions. In the lateral direction a discrete between 6Hz and 7Hz was present on all conditions (corresponding to a mode of the airframe) and tail rotor induced vibration (1T and 2T) was significant. High levels of random low frequency vibration (below 2Hz) was present on all recorded conditions.

3. VIBRATION SURVEY ON IN-SERVICE SEA KINGS

A subsequent investigation was carried out by a joint RAE, IAM, WHL team to monitor various environmental criteria on in-service Sea Kings. Vibration data was recorded during a total of five flights on two aircraft. Positions monitored included the buttock/seat interface at each crew position and instrument panel vibration. Fig.5 shows the 5R vibration levels at each crew position for the hover, 100kts, and transition to hover conditions.

From this data it is apparent that vibration in the vertical direction is higher for the crew sat at the front of the aircraft than those sat at the rear. In the lateral direction however the port observer clearly experiences the higher vibration.

Vibrations monitored at the pilot's position for the hover and 100kts condition were considerably in excess of the 50%ile levels previously monitored during production clearance flights.

4. SUBJECTIVE ACCEPTABILITY OF HELICOPTER VIBRATION

The effect of vibration on the human body has for some time been an area of interest to research workers. Guinard (Ref.12) in 1970 reviewed over 600 relevant papers, and the International Standards Organisation (ISO) have produced a document for the evaluation of human exposure to whole-body vibration (Ref.13). The ISO document proposes limits of amplitudes of vibration as a function of frequency, direction of input and duration to meet the following criteria

a) Comfort (Reduced Comfort Boundary)

b) Working Efficiency (Fatigue Decreased Proficiency Boundary)

c) Safety and Health (Exposure Limit).

Figs. 6 and 7 show the ISO criteria for working efficiency in the vertical and horizontal directions respectively.

Also shown on these figures are vibration data at crew interface points on the following helicopter types:-

1) Sea King (this report)

2) SH3A (ref.6)

3) CH47C (ref.6)

4) CH46A (ref.7)

In the case of the Sea King the levels are presented for:-

a) the average of the levels recorded during the 100kts cruise condition at the pilot's station

b) the 'worst' transient condition.

It can be seen that in the case of the Sea King, vibration during the cruise condition lies substantially below the 8hr F.D.P. boundary. Furthermore, by reference to Fig.4, it can be expected that for 20% of 'new' aircraft 5R vibration levels in both the vertical and horizontal directions can be expected to lie below the 8 hr. F.D.P. boundary for the pilot's position at 100kts. It is noticeable that at other orders on the Sea King, vibration for the most severe conditions lie below the 8 hr. F.D.P. criteria.

In terms of the guide lines laid down by the ISO criteria, vibrations in modern helicopters are therefore not excessive. The influence of vibration on crew performance however is highly task dependant. Much of the research on which the ISO is based consisted of measuring the influence of vibration on simple tasks such as tracking, writing, reaction time etc.

5. CONCLUSIONS

Controlled laboratory tests are required to establish the influence of the helicopter environment on working efficiency. For these tests it will be necessary to give the pilot and crew representative tasks and to introduce various levels of helicopter vibration.

In terms of visual acuity and vibration of the extremetries it will be necessary to also vibrate the aircrews immediate environment. These tests will prove to be substantially more difficult as, in the case of visual acuity for example, phase characteristics between the head and the viewing object are critical. It is suspected that, in helicopters, vibration induced impairment of vision is caused more by the subject vibrating than by the object.

When considering overall working efficiency it would be a mistake to expose subjects only to vibration. The contribution of other environmental effects such as noise and temperature, and other ergonomic criteria such as seating, information presentation and work space layout must be considered.

A questionnaire was issued to WHL and Boscombe Down test pilots recently to establish what they considered to be the main areas of helicopter/pilot incompatability. Using the A & AEE subjective assessment scale (Fig.8) they were asked to rate vibration, noise, cockpit layout etc. on the various helicopter types of which they had experience. The results of the questionnaire are shown in Fig.9. It is evident that the main area of pilot complaint on most helicopters is uncomfortable seating. It would appear that a significant contribution to improving helicopter human factors could be made by improving the crew seat. In the short term improved seat design also would enable aircrew isolation from vibration. Postural support improvements, as well as making the crew more comfortable, will also increase their tolerance to dynamic stresses i.e. vibration and impact (Ref.14). Some seat design considerations are shown in Fig.10. WHL have proposed a programme aimed at designing an ergonomically optimised seat (Ref.15).

ACKNOWLEDGEMENTS

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FIG. 1

SCHEMATIC LAYOUT OF CREW POSITIONS IN A.S.W. VARIANT

FIG. 2

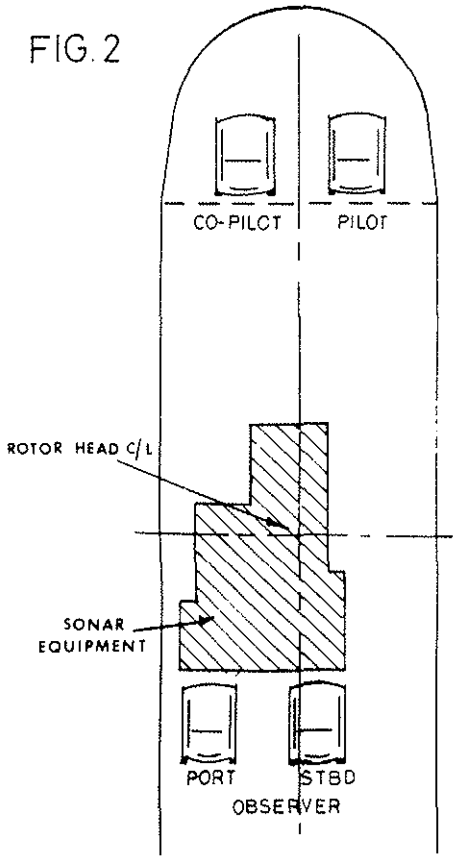


FIG 3. TYPICAL VIBRATION SPECTRUM

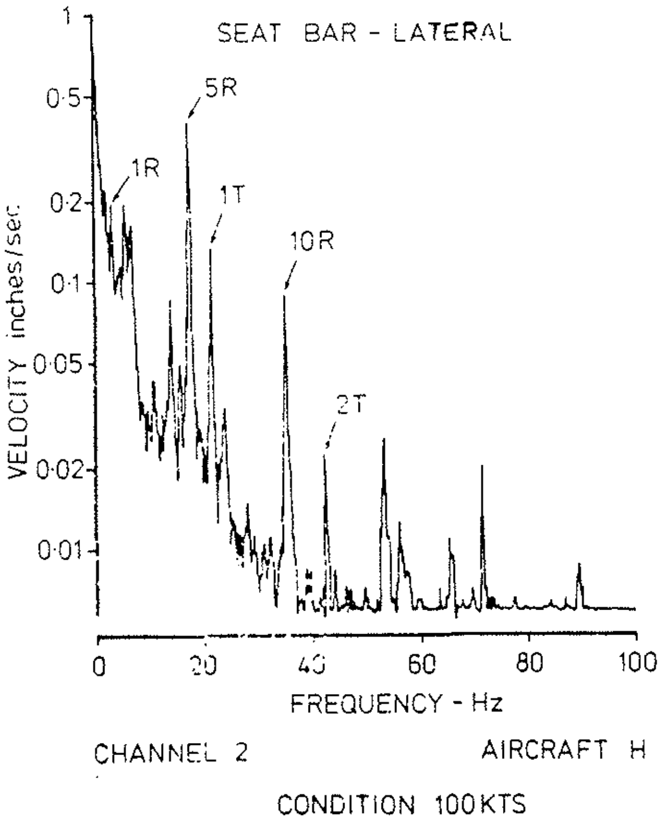


FIG 4. 5R VIBRATION LEVELS AT SEAT BAR vs. FLIGHT CONDITION IN TERMS OF PERCENTILES.

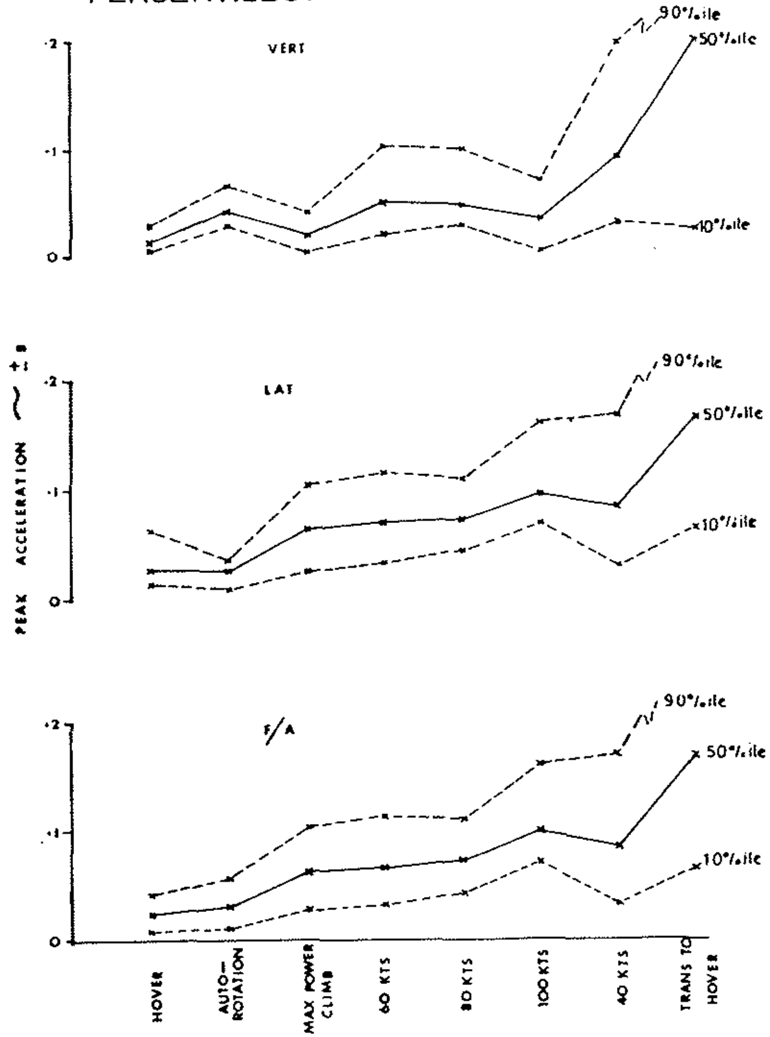
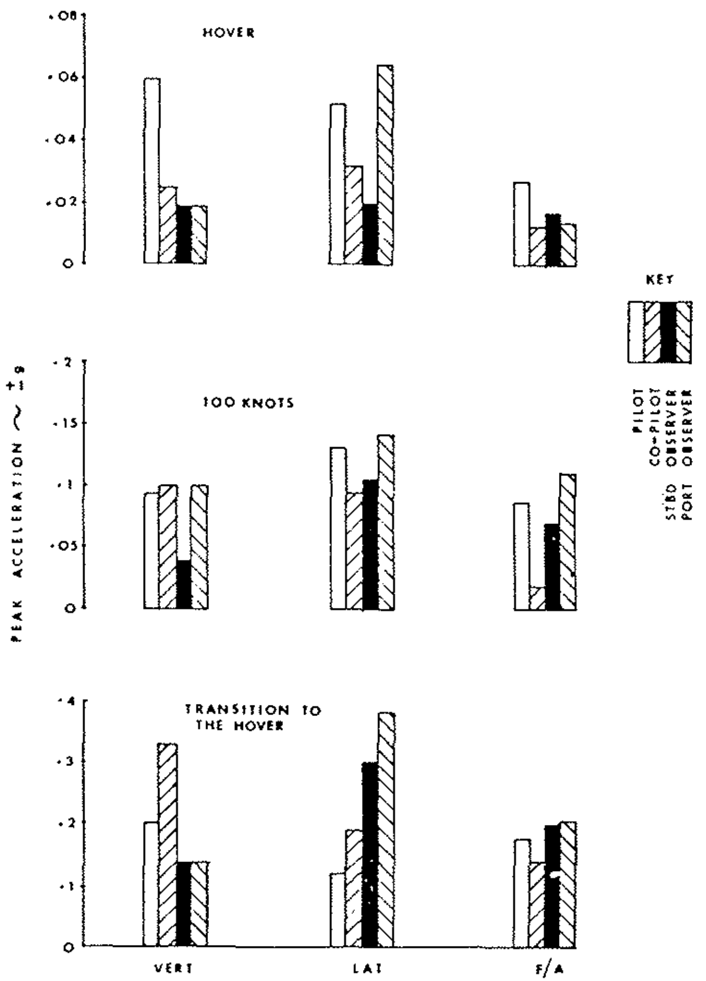


FIG 5. 5R VIBRATION LEVELS AT SEAT BAR FOR THE 4 CREW POSITIONS.



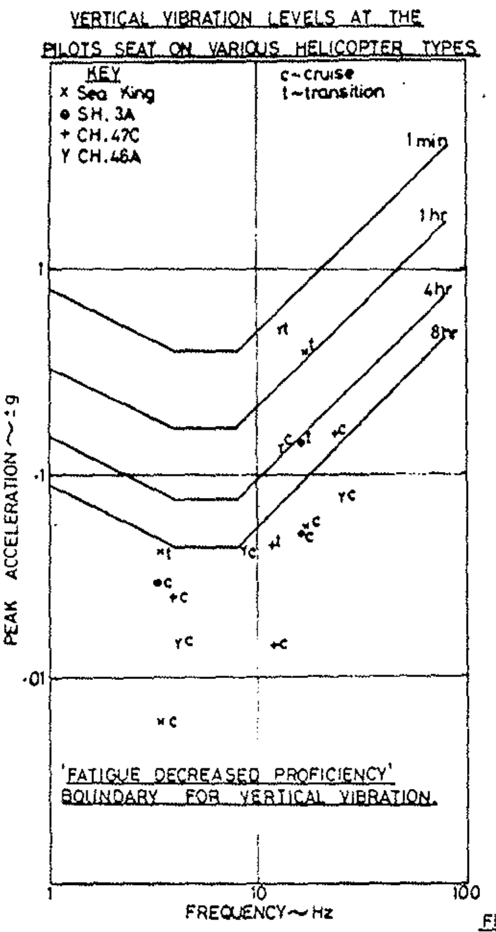


FIG. 6

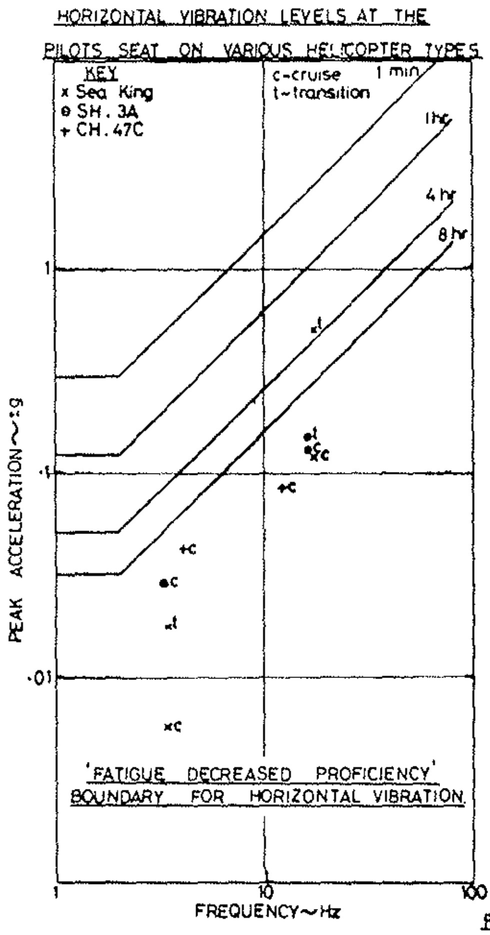


FIG. 7

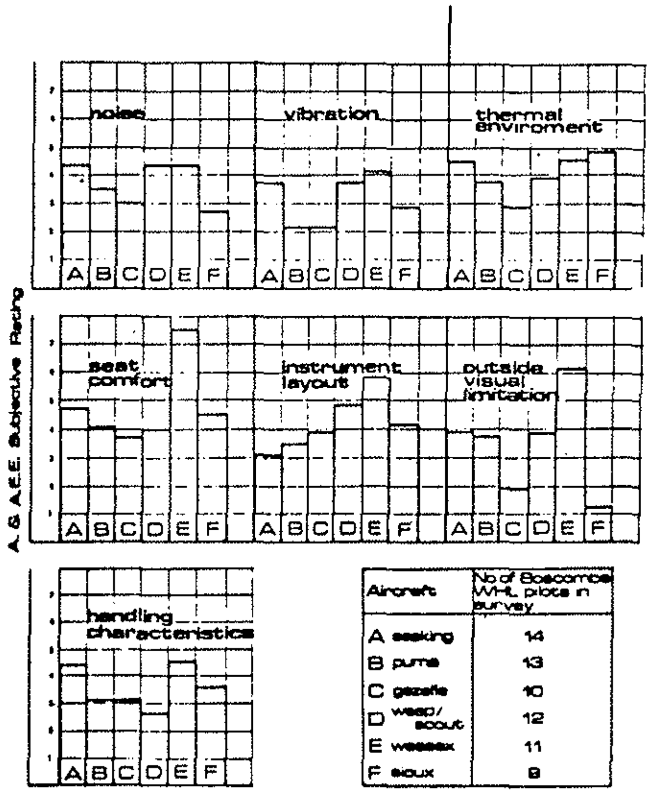
A & A E E RATING SCALE

0		No Vibration
1) 2) 3)	Slight	(Not apparent to experienced aircrew fully (occupied by their tasks, but noticeable if (their attention is directed to it or not otherwise occupied.
4) 5) 6)	Moderate	(Experienced aircrew are aware of the vibration, (but it does not intrude so that their work is (affected, at least over a short period.
7) 8) 9)	Severe	(Vibration is immediately apparent to (experienced aircrew even when fully occupied. (Performance of primary task is affected, or tasks can only be done with difficulty.
10	Intolerable	Sole preoccupation of aircrew is to reduce vibration.

FIG 8

HISTOGRAMS of PILOT/HELICOPTER INCOMPATABILITY

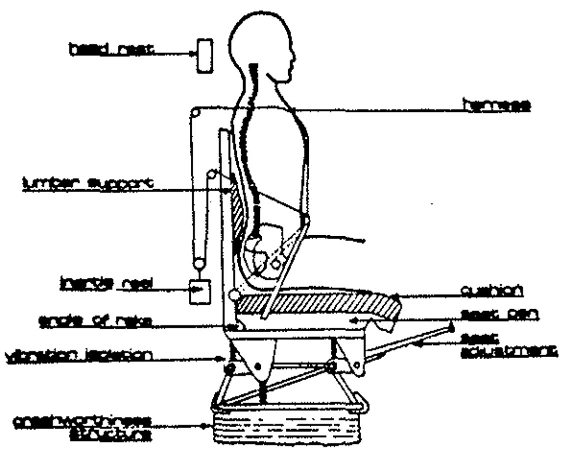
(average ratings of Boscombe + WHL pilots)



Aircraft	No of Boscombe WHL pilots in survey
A seaking	14
B puma	13
C gazelle	10
D wasp/scout	12
E wessex	11
F sioux	9

FIG.9

SEAT DESIGN CONSIDERATIONS



NB integrated with A.E.A's

FIG.10