Magnitude and Incidence of + Gz in a Modern Fighter Aircraft in its Different Combat Roles

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Abstract

The incidence and magnitude of + Gz profiles, in a modern fighter aircraft, in its different combat roles, have been recorded and analysed. The + Gz encountered in fighter aircraft has been found to be radically different from the acceleration profiles in use on the Human Centrifuge. Suggestions to have realistic simulation of + Gz on the Human Centrifuge have been made.

Introduction

Significance of acceleration stress in aviation was first highlighted by Bauer[2] in 1926. In 1927-29, the Schneider Trophy races, pilots reported dimming of vision and confusion during turns at high speed. Following this, considerable work was done to study the physiological effects of acceleration. Diringshofen[4] subjected animals to acceleration in 1932; while the first studies[5, 6] on human subjects were conducted in 1935 in Germany on a Human Centrifuge specially constructed for the purpose. In early 40s, a number of human centrifuges[6] were established in various countries and since then the centrifuge is being used very extensively the world over for different physiological studies on human subjects.

In the modern high speed, high performance aircraft, the acceleration stress continues to cause fatigue and affect pilot performance. The future fighter aircrafts like YF-16, YF-17 and MRCA are capable of performance at very high 'G' loads. The advances in protective measures against + Gz have relatively lagged behind. Recently many acceleration laboratories have diverted their attention to this problem, and research in this field is on the increase. On reviewing literature on + Gz stress available at IAM it was realised that data on + Gz profiles of fighter aircraft was not available. This lacuna does not appear to be due to lack of inflight recording facilities but certain other considerations, like security seem to have weighed against wide publication of the data.

To study the effects of + Gz in the human centrifuge, predetermined G time profiles are normally used, for various categories of test subjects. The representative G time profiles in use at IAM Bangalore are given in Table I, Figures 1 and 2 below :—

TABLE I

Category of subjects	Rate of onset	Rate of decay	Peak 'G'	Duration at peak
Helicopter, Transport Pilots and non-aircrew	Slow onset 0.5G/sec	0.1G/ sec	As required, normally upto 5G.	15-20 sec.
Fighter pilots	Rapid onset rate 1.0G/sec	0.1 to 0.2G/ sec	As required, normally upto 6-7G	15-20 sec.

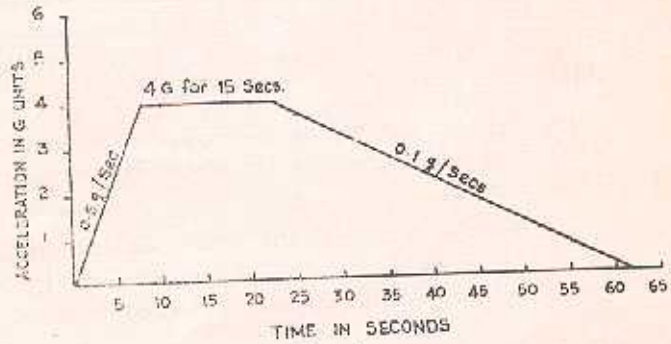

Fig. 1
Acceleration Profile for Helicopter and Transport aircrew and non-aircrew subjects

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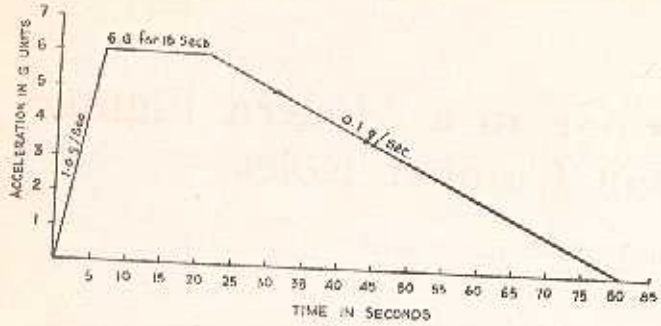

Fig. 2

Acceleration Profile for Fighter Pilots

These G profiles have been standardised after repeated trials on a large number of subjects in various countries including India. However, it will be incorrect to presume that the profiles being used by the acceleration physiologists/laboratories all over the world are exactly similar to those existing in actual flight environment in a fighter aircraft. It is a common knowledge that though the magnitude of + Gz as experienced by a fighter pilot is very variable, depending on the type of aircraft, type of sortie, and type of manoeuvre, it generally tends to be of a higher magnitude than that routinely utilized in the centrifuge. It is, therefore, obvious that there is an apparent discrepancy between the acceleration profiles encountered by the fighter pilot in the air and those employed on the ground in the human centrifuge. The present study was initiated in an attempt to investigate this discrepancy and to define a more realistic acceleration profile for simulation of + Gz on the ground.

Aim of the Study: The aim of the study was to determine frequency, magnitude, duration and rate of onset of + Gz as encountered in a fighter aircraft by use of inflight airborne recorder. It was envisaged that such a study will

(a) help to an extent in realistic reproduction and simulation of + Gz stress in the human centrifuge.

(b) Provide material for better understanding of the + Gz stress as experienced by a fighter pilot during actual combat flying.

Materials and Methods

Flight data recorder: An automatic in-flight airborne recorder[1,7] fitted in a high performance fighter aircraft was used to record various parameters of + Gz. This recorder, apart from recording many other flight parameters like aircraft [illegible] height, position of control surfaces etc. also [illegible] all variation of + Gz and + Gx as a function [illegible] on a 35 mm film.

This instrument essentially consists of an acc[illegible] meter placed behind the cockpit, the signals [illegible] which are carried as electrical impulses and [illegible] ed on a film cassette located in the fin of the air[illegible] After the sortie, the film is available for the [illegible] of various parameters recorded on it.

In this study + Gz data was recorded [illegible] high performance aircraft during different type[illegible] combat sorties. The types of sorties included [illegible]

(a) 2 Vs 1

(b) Close and tactical formation

(c) Ground attack

(d) Low level strike

(e) Low level cap

(f) General handling

(g) Instrument flying

Since all variations of + Gz were record[illegible] continuously from take-off to landing for all [illegible] sorties, the data obtained was quite voluminou[illegible] The sorties covered have been grouped under [illegible] heads considering the pattern of their G-profile[illegible] These groups are :-

1. Air combat sorties
2. Ground attack sorties
3. Handling sorties.

Results

The results have been tabulated in Table-I, II and III. Table-I shows the frequency with which different levels of + Gz were reached. Table-II shows the frequency of different levels of rate of onset of + Gz. Table-III shows the duration at peak G. It will be noticed that the data pertinent to each group/type has been pooled.

TABLE I

Peak G levels—Their frequency of occurrence

Sortie Type	Frequency of occurrence of G Levels						Maximum G level experienced
	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9	7–7.9	
1. AIR COMBAT	35	13	9	5	1	–	6.2
2. GROUND ATTACK	20	13	5	5	4	2	7.2
3. HANDLING	2	9	–	–	–	–	3.8

TABLE II

Rates of Onset

Sortie Type	Range and average G/sec		Frequency of occurrence in G/sec					
	Range G/sec	Ave G/sec	1–1.9	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9
1. AIR COMBAT	0.04 1.35	0.53	4	—	—	—	—	—
2. GROUND ATTACK								
a) Turns	Less than 1	—	—	—	—	—	—	—
b) Pullouts	1.47 6.45	3.39	1	6	5	1	2	1
3. HANDLING	0.05 0.81	0.31	—	—	—	—	—	—

TABLE III

Duration of peak 'G'

Sortie Type	Durations at Peak
1. AIR COMBAT	Usually less than 15 seconds
2. GROUND ATTACK	
a) Turns	10 – 15 seconds
b) Pull-outs	0.3 – 1.9 seconds (average 1.1 sec)
3. HANDLING	10 – 15 seconds

Conclusions

At present various profiles of + Gz being utilized in the human centrifuge have largely been determined by repeated trials. They are not based on and are not similar to the G – profiles existing in actual flight conditions.

The data obtained in the present study brings out certain peculiar features of + Gz stress as actually experienced by a fighter pilot which apparently have not been taken into consideration for making use of the human centrifuge more realistically.

These features are :–

(a) The rates of onset of + Gz are much higher in actual flight conditions as compared to those employed routinely in the centrifuge. This is especially so in Ground Attack sorties.

(b) Peak 'G' reached is generally higher in the actual flight conditions.

(c) In certain types of sorties high 'G' manoeuvres follow each other in quick succession, whereas in the human centrifuge, the subject is exposed to gradually increasing levels of +Gz, the runs being interposed by a specified period of rest.

(d) During a fighter sortie the peak 'G' during pull-outs increased gradually as the sortie progressed, so that the pull-outs towards the end of the sortie were of considerably higher 'G' value than those in the initial part of the sortie.

The data obtained from this study has been utilised in formulating a representative profile of each of the three types of sorties normally encountered by a pilot. These profiles could be used to programme a centrifuge for realistic simulation of the 'G' forces experienced by a pilot. The profiles are given in Fig 3 for Air Combat, Ground Attack and Handling sorties.

The rates of onset and decay in these profiles have been intentionally rounded off to lower values than actually encountered in flight to values which could be comfortably tolerated by a subject in a centrifuge. Higher rates of onset and decay produce very marked angular accelerations and cause motion sickness in most of the subjects.

The differences between the actual + Gz profiles and the one in use for physiological studies on the human centrifuge are very large. This is partly due to the inherent design weaknesses of a centrifuge and also due to the angular accelerations present during exposure on a short radius centrifuge. The above handicaps are further complicated when the centrifuge is remotely controlled or programmed to produce only one profile at a time.

The situation could be improved to an extent by having the control with the subject himself. Such a modification would provide us with a Dynamic Flight Simulator. This will permit the subject to anticipate the start and the magnitude of the + Gz stress, which is actually under his own control, as the case in an aircraft. Thus, testing on the human centrifuge would be more realistic.

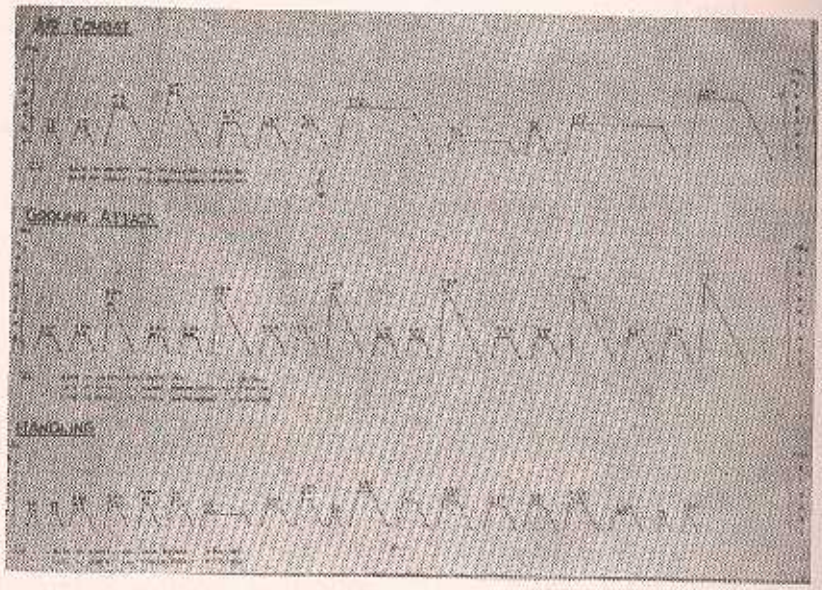

Fig. 3

Representative acceleration Profiles of a high performance aircraft for Air Combat, Ground attack and Handing sorties

Technical advancements in control mechanisms [illegible] to think optimistically of such a modification to the human centrifuge in the near future.

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