Original Article

+Gz ENVIRONMENT IN A MODERN COMBAT AIRCRAFT

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Acceleration (+Gz) profiles in a modern combat aircraft in Indian Air Force (IAF), capable of pulling high sustained +Gz during various combat sorties (2 vs 1, 2 vs 2, 1 vs 1 and aerobatic sortie) were analysed. Five parameters viz time, +Gz levels, flight altitude, angle of attack and speed, in digital form were extracted from the flight data recorder fitted in the combat aircraft. Eight situations, during various combat sorties, showing positive G levels of 6G for more than 10 seconds, were analysed. Peak G levels obtained were 9± 0.5 G in most of the combat sorties. Duration at high G levels (above 6G) varied from 10 to 37 seconds at a time during any one situation. These accelerations were seen to be repetitive with high variations. The data obtained in the present study is being utilised in simulating representative profiles on the human centrifuge at Institute of Aerospace Medicine (IAM) to the extent possible.

Keywords : Centrifuge simulation, Flight Data Recorder, High Sustained +Gz.

Introduction

The inflight environment in a combat aircraft is an unique multi-stress environment. The summation of physical and psychological stresses can be awesome. Continual monitoring of the inflight environment is necessary to ensure aircrew safety. This may also help in to continually improve the protective devices and procedures for assisting the aviator in higher stress situations.

The introduction of the modern high performance combat aircrafts in IAF has imposed tremendous demands on the aircrew. With the incorporation of Electronic flight control system (fly-by-wire) and better thrust to weight ratio in the modern combat aircraft, high sustained positive 'G' forces have become a major aeromedical problem facing aircrew today. A higher thrust to weight ratio implies that under high 'G' conditions, the engine has sufficient power to prevent the speed from decaying thus resulting in high sustained +Gz capability. In addition, electronic flight controls allow high +Gz to build up so rapidly that aircrew may lapse into unconsciousness without passing through stages of greyout or blackout.

In the present study, acceleration profiles in a modern combat aircraft in IAF, capable of pulling high sustained +Gz, during various combat sorties were analysed. The study was undertaken with the aim of obtaining +Gz profiles for simulating inflight acceleration environment of combat flying in the human centrifuge. Moreover, the study could give insight into tolerance levels of the positive 'G' as experienced by fighter aircrew during actual combat flying.

Materials and Methods

An automatic flight data recorder (FDR) fitted in the combat aircraft was used to record various parameters required for the study. The FDR has a magnetic tape recorder for continuous recording of flight parameters. The magnetic tape has a recording capacity of eight hours. The recording of the earlier flight is wiped off by the recording of the flight in progress. The system is energised as soon as the pilot presses the engine starter. The data recorded includes aircraft parameters, engine parameters, flight number and time elapsed since system start up, expressed in seconds. There are about 35 parameters continuously recorded every second in FDR.

For the present study, only five parameters in digital form were extracted from the flight data recorder. These were time, +Gz levels, flight altitude, angle of attack and speed. Only those sorties were analysed in which the pilot reported back after landing that he pulled considerable high 'G' associated with or without any symptoms like greyout or black out. However, aircrew flying the aircraft tolerated these positive 'G' forces and completed their mission successfully. The sorties analysed in this study were of the following types:-

(a) 2 Vs 1 (b) 2 Vs 2
(c) 1 Vs 1 (d) Aerobatic sortie

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Results

A total of twenty situations during various combat sorties were studied. However, only eight were analysed and tabulated as other situations did not reveal high sustained positive 'G' profiles. All the profiles in which the time spent above 6G was 10 seconds or more were tabulated. These high levels and duration of +Gz require that the aircrew perform a coordinated straining manoeuvre in combination with an anti 'G' suit in order to maintain vision. All the high 'G' sorties analysed were done at medium levels i.e. 9000 ft - 12000 ft and thus amount and duration of 'G' sustained was lesser. Only one high 'G' sortie at serial number 1 (Table I), an aerobatic display, was at low altitude of 610 ft AGL. As seen from the table I, peak 'G' levels obtained were 9 ± 0.5G in most of the combat sorties. However, duration at peak 'G' varied depending upon the type of sortie. Maximum rate of onset/decay (Jolt) were seen to be varying between 2.1 to 5.9G/sec.

Table I

Type of Exercise	Role of Aircrew	Peak 'G'	Time > 6 G (Secs)	Time > 2 G (Secs)	Jolt G/s
Solo	Aerobatic	9.50	13	23	5.57
2 v 1	Attacker	9.17	16	97	2.10
2 v 1	Attacker	9.33	25	111	4.64
2 v 2	Defender	8.65	37	63	4.05
2 v 2	Defender	8.16	10	54	5.90
2 v 1	Defender	8.90	13	29	3.30
2 v 1	Defender	7.78	14	56	4.47
2 v 1	Defender	8.00	16	100	2.70

Table II shows the total duration at various 'G' levels in a situation. However, during the whole duration studied, 'G' values did not come below 2G. It was seen that most of the combat sorties involved 2-3 situations with interval of 3-5 minutes between them. Only one aircrew was seen to have any objective manifestation after the sorties from the various profiles studied. He had undergone situations numbered two and three within a gap of five minutes during the sortie. He developed painless, multiple petechial haemorrhages on the dorsum of his left hand and dorsal surface of lower third of left forearm. This persisted for about 24 hours and disappeared by itself without any treatment. This aircew spent a total of 41 seconds above 6G besides more time at lower 'G' levels within about nine minutes. The petechial haemorrhages have been reported earlier also in our aircrew flying modern generation aircraft[1].

Table II Time spent In secs at different 'G' values

Sl. No.	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	> 8
1.	3	3	1	3	1	4	12
2.	24	24	19	14	6	5	5
3.	22	17	27	20	9	5	11
4.	2	2	7	15	18	14	5
5.	10	24	5	5	4	4	2
6.	5	3	3	4	5	4	4
7.	4	16	13	9	7	7	0
8.	21	28	24	11	7	8	1

The data generated during the study was analysed by a computer and G-time profiles obtained in the graphical forms. Two of the representative profiles are shown in fig 1 and 2. Fig 1 shows time Vs + Gz profile in the aerobatic

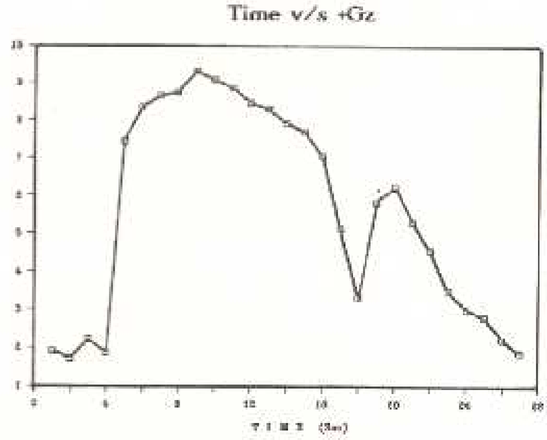

Fig 1

display. It was observed that the aircraft sustained average of 8.4G continuously for 12 seconds during back stop turn. Fig 2 shows that the high accelerations pulled by the aircrew were repetitive with large variations.

Fig 3 shows the relationship between aircraft speed and amount of positive 'G' pulled. It is seen here that even though the aircraft had

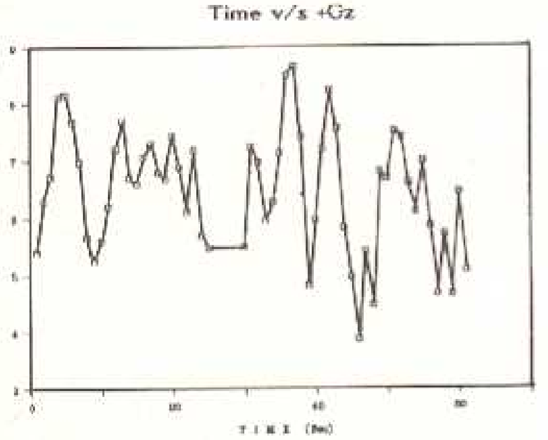

Fig 2

pulled high 'G' upto 9G, there is slight decay or wash out of speed.

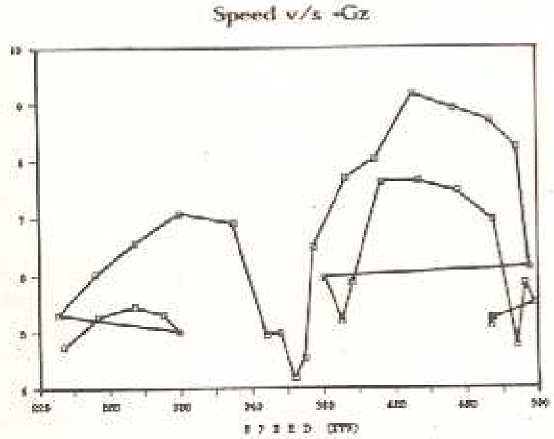

Fig 3

Fig 4 shows the relationship between angle of attack and amount of positive 'G' pulled in the aerobatic sortie studied. The angle of attack of the aircraft varied from eight to sixteen degress during the high +Gz of 8-9G. The importance of this finding is that this angle of attack should be added to the seat back angle of 25°-30° in the modern generation aircraft to theoretically determine the increase in 'G' tolerance provided by these seats. It has been proved by various studies that minimum of 45° tilt back consisting of seat back tilt plus angle of attack is required to provide significant increase in 'G' tolerance[2,3].

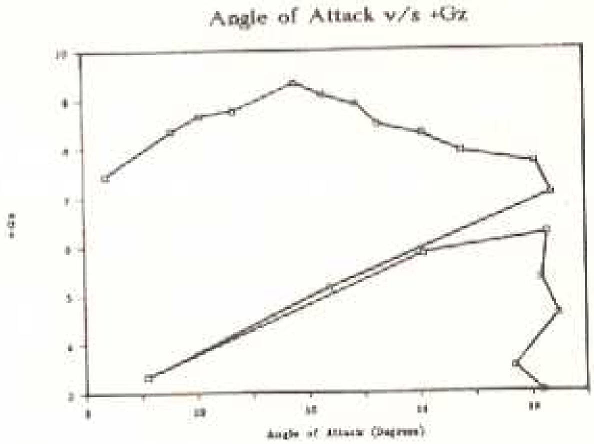

Fig 4

Fig 5 shows the inter-relationship between speed, angle of attack and amount of positive 'G' pulled. It was found that there is significant combined linear relationship between the

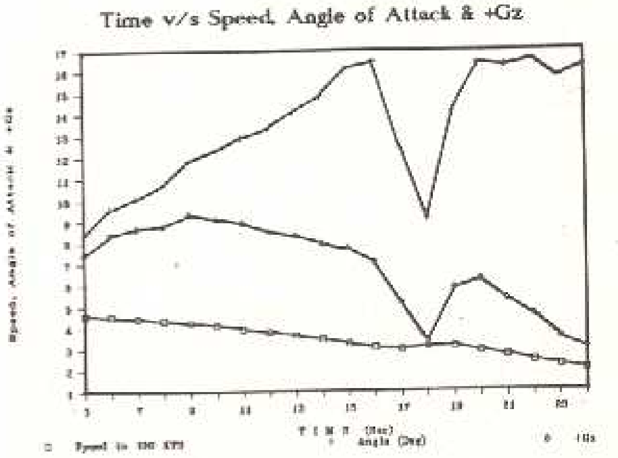

Fig 5

variables of +Gz, speed and angle of attack. The regression equation determined for the aerobatic profile is $+Gz = 72.17 - 0.0472 \times \text{time (Sec)} + 0.03285 \times \text{speed (knot)} + 0.5806 \times \text{angle of attack}$.

Discussion

The peak 'G' levels, duration at high 'G' and rates of onset/offset seen during this study are much higher than those obtained in the previous generation aircraft[4]. The values observed in the present study are comparable to those reported in other modern fighter aircraft like F-16 and F-15[5].

The rates of onset or offset and time spent at high 'G' levels would be higher in actual combat. Combat exercises during peace time are done at medium levels i.e. 9000-12000 ft. whereas air to air combat in Ops conditions would probably be at low levels to avoid radar detection. Due to higher air density at low altitudes, both the engine performance and aircraft manoeuvreability are decidedly better than at medium and high altitudes. This in turn implies that the aircraft can sustain higher values of 'G' for longer periods of time at low levels; whereas at medium altitudes, speed would decay faster and the 'G' value keeps on decreasing automatically.

The data obtained from the study is being utilised to simulate representative profiles of high positive 'G' sorties in the human centrifuge at IAM. These profiles help in imparting realistic training to aircrew especially on the technique of anti - 'G' straining manoeuvres like L-1 or M-1. Such training is considered to be safest and most cost-effective means of preventing losses of aircraft and aircrew due to G-LOC[6,7]. The simulated aerial combat manoeuvres are also being used for evaluating the effects of various means of enhancing positive 'G' tolerance.

The difference between the actual +Gz profiles in a modern combat aircraft and those used for physiological studies on the human centrifuge at IAM is significant especially with regards to rate of build up or decay of positive 'G'. Rate of build up and decay commonly employed in the centrifuge vary from 0.1 to 1G/sec whereas those seen during this study varied from 2.1 to 5.9G/sec. Higher rates of onset/offset, simulated on the centrifuge at IAM, result in high angular accelerations giving rise to unpleasant vestibular effects in the subjects.

Conclusion

Most stressful environment in a modern combat aircraft is due to high sustained +Gz forces encountered during aerial combat. Acceleration profiles are dependent not only on the type of aircraft but also on the type of mission flown.

Peak 'G' observed in the modern generation combat aircraft were of the order of 8-9 G. Maximum rates of onset and offset of positive 'G' forces were of the order of 2.1 to 5.9G/sec. Duration at high 'G' levels i.e. above 6G, seen during the study varied from 10 to 37 secs at a time during any one situation. Moreover, these accelerations were repetitive with large variations. Modern combat aircraft is capable of undergoing upto three such situations with 3-5 minutes interval between them. The data obtained in the present study is being utilised in simulating representative profiles on the human centrifuge at IAM.

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