Analysis of combat acceleration profile of two air superiority fighter aircraft

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The combat acceleration profile of two air superiority fighter (ASF) aircraft of Indian Air Force (IAF) was studied to determine the extent of in-flight acceleration stress. The flight data recorder (FDR) based data was analysed towards this aim. The mean peak +Gz found was 6.35 G for the Eastern ASF and 6.69 G for the Western ASF. The mean duration of aerial combat manoeuvre (ACM) was 147.78 s for the Eastern ASF and 65.47 s for the Western ASF. The mean rate of onset during ACM was 1.14 and 1.17 G/s respectively, for the two aircraft studied. The total duration of ACM above +6Gz was 2.92 s for the Eastern ASF in 75.5% of situations, and 7.32 s for the Western ASF in 68.18% of situations. The findings suggested that acceleration stress during aerial combat manoeuvres is determined by the performance capabilities of the aircraft and the tactics employed as per the weapon delivery system.

Keywords: Aerial combat manoeuvres, acceleration stress, high-sustained G, tactics, flight data recorder.

The prime air superiority fighter (ASF) aircraft of the Indian Air Force (IAF) are rated amongst the most advanced in the world today. For ease of reference, the ASF are referred as Eastern and Western air superiority fighters in this paper. The Eastern ASF has an extremely potent airborne interception radar and air-to-air missiles combination. The Western fly-by-wire ASF has sophisticated sensors and avionics, with multi-role mission capability. Together, these fighter aircraft give the IAF a beyond-visual-range (BVR) capability with their advanced medium range air-to-air missiles [1].

The aerial combat manoeuvre (ACM) includes transient manoeuvring and ability to perform tight turns [2]. These manoeuvres are the most spectacular phase of combat. This study had been undertaken to understand the acceleration environment during ACM in two air superiority fighter aircraft with high, sustained performance capability.

Materials and methods

A retrospective analysis of 103 combat sorties flown by 16 fully operational pilots was done. The pilots had about 2040 h (± 633 h) of flying of which 414 h (± 217 h) were on the current aircraft type. A total of 218 situations were analysed.

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The data relevant to this study was obtained from the graphs and/or digital print outs of the flight data recorder (FDR), mounted on the aircraft [3,4]. The parameters derived from the flight data recorder were duration of ACM in s, flight altitude in m or ft, indicated air speed in kmph or knots, magnitude of +Gz in G, duration of +Gz at difference of 0.99 Gz each, rate of onset in G/s, and rate of offset in G/s.

Results

Table 1 presents the ACM of Eastern ASF per situation.

The mean peak +Gz during ACM in Eastern ASF aircraft was 6.35 G. The mean rate of onset and offset was 1.14 G/s and 0.59 G/s. The mean duration of ACM was 148 s.

Table 2 presents the ACMs of Western ASF per situation.

Analysis of acceleration profiles of Western ASF during ACM revealed mean peak +Gz level of 6.69 G. The mean rate of onset of acceleration was 1.17 G/s. The mean rate of offset was 0.73 G/s. The mean duration of ACM was 66 s.

Table 3 presents the difference in ACMs of Eastern ASF and Western ASF per situation.

Analysis of the ACM between the two ASF revealed significantly high peak G and rate of offset for the Western ASF. The total duration of ACM per situation was significantly less for the Western ASF.

Table 4 presents the mean duration at various G levels per flight.

The detailed analysis of duration at each +Gz level per sortie is discussed subsequently.

Discussion

An analysis of combat acceleration profiles of Eastern and Western ASF aircraft was done to study the

Table 1. ACM of Eastern ASF

Aircraft	Peak G (G)	Minimum G (G)	Total Duration (s)	Rate Onset (G/s)	Rate Offset (G/s)
Mean	6.35	0.94	147.78	1.14	0.59
SD	0.84	0.22	86.14	0.57	0.36
Minimum	4.2	0.11	20.0	0.07	0.11
Maximum	9.1	1.62	380.0	3.03	1.83

Table 2. ACM of Western ASF

Aircraft	Peak G (G)	Minimum G (G)	Total Duration (s)	Rate Onset (G/s)	Rate Offset (G/s)
Mean	6.69	0.7	65.47	1.17	0.73
SD	1.3	0.47	30.01	0.62	0.52
Minimum	4.1	-1.49	26.0	0.19	0.13
Maximum	9.09	1.88	167.0	3.25	2.72

Table 3. ACM per situation - Eastern ASF vs Western ASF

Aircraft	Peak G (G)	Minimum G (G)	Total Duration (s)	Rate Onset (G/s)	Rate Offset (G/s)
Eastern ASF					
Mean	6.35	0.94	147.78	1.14	0.59
SD	0.84	0.22	86.14	0.57	0.36
Western ASF					
Mean	6.69	0.7	65.47	1.17	0.73
SD	1.3	0.47	30.01	0.62	0.52
't' value	2.263		9.401	0.368	2.281
probability	< 0.05		< 0.001	NS	< 0.05

NS: Not Significant

Table 4. Mean Duration at various G levels per flight

Aircraft	Mean Duration (s)							
G levels	2-2.99	3-3.99	4-4.99	5-5.99	6-6.99	7-7.99	8-8.99	9-9.99
Eastern ASF								
Mean	45.13	15.53	12.45	14.59	3.86	2.07	1.67	1.0
SD	33.72	13.0	8.14	8.22	3.14	2.07	1.7	(n=1)
Western ASF								
Mean	30.12	20.17	14.9	9.92	7.6	4.56	2.9	3.0
SD	19.85	15.11	11.06	8.38	6.72	4.19	3.01	(n=1)

in-flight acceleration stress. The determinants of acceleration stress were peak G-magnitude and duration, rates of onset and offset and duration of ACM [5].

For both the ASF the mean peak G levels were found to be less than 7 G. The mean rate of onset were less than 1.2 G/s. The mean rate of offset were less than 0.8 G/s. (Table 1, 2). The results reported in this study can be explained on the basis of present day tactics. The tactical considerations do not demand high rate of onset of acceleration except as a last ditch manoeuvre. The tatics demand that the escort/combat air patrol mission designated to the aircraft, is not attaining a 'kill' of the enemy aircraft, but ensuring the success of the designated mission. This change in concept has led to shorter duration of ACM. With the early detection by radars and ease of locking on the target by BVR air to air missiles (AAM) [1], the distance between engaged aircraft has increased. Moreover improved self defence by electronic countermeasures, plays a crucial role in combat. Hence speed is not an essential factor of combat in aircraft with similar capabilities of combat.

A comparison of Eastern ASF with Western ASF revealed that mean peak G was significantly higher for the latter. There was no difference in rates of onset. Significantly higher rate of offset were found in case of Western ASF. The difference in duration of ACM was significantly shorter for Western ASF. (Table 3).

While employing similar combat tactics, the significant differences between the two competitively manoeuvrable ASFs was probably due to electronic flight control (fly by wire) of Western ASF [6]. The electronic-flight control system makes Western ASF highly agile, thus allowing better manoeuvrability. Therefore higher peak +Gz and offset rates were found in the aircraft. The shorter duration of combat of the Western ASF was because of the range of the radar and the missiles, which along with agile performance capability, allowed ease of positioning for or evading the attack.

It must be added here that commenting upon better performance capability of Western ASF vis-a-vis Eastern ASF is not justified since none of the combat sorties included in this study were Eastern versus Western ASF. A real evaluation of performance is possible only after analysis of combat sorties between the two ASFs.

In the present day scenario of high sustained G (HSG), duration of stress at various G levels is an ideal indicator of magnitude of stress. The duration at +Gz levels of more than 6 G was analysed for each sortie included in this study. It was found that Eastern ASF pilot spent a mean duration 2.92 s in 75.47% situations (n=80) of ACM situations above 6 G, whereas it was 7.31 s in 68.18% situations (n=75) for Western ASF.

From the analysis of duration at various +Gz levels it was evident that Western ASF pilots spend longer duration at higher G levels. Eastern ASF, with matching performance capabilities as Western ASF, employing similar tactics spent lesser time at various G levels. This could be explained on the basis of simulation of missile envelope carried by each aircraft. The Eastern ASF simulate carriage of missiles with a similar launch envelope. Hence sustaining manoeuvring at one go does not achieve a launch condition. In comparison Western A due to an expanded launch envelope of its missi can achieve the launch conditions invariably by sustained manoeuvre at high a levels.

Conclusion

The Eastern and the Western ASF aircraft h capability to sustain high G. This study reve that the latest tactics have shortened the dura of ACM. But the requirement of sustaining hig G remains an essential feature of aerial combat is evident from this study. Therefore the pilots these high performance aircraft are susceptible +Gz induced symptoms including G induced l of consciousness. In view of G levels found in study it was felt that high G training is essential the ASF pilots who are exposed to high G for va ing durations.

References

1. Touching the sky: The IAF Today, 1991.
2. Spick M. Figher Pilot tactics. The techniques of light air combat. Cambridge: Patrick Stephens 1983.
3. Aircraft MiG-29 B, Flight Manual No P-K 580, *3433 (07)*.
4. Flight data recorder P/N PE-6011-1, -2, Manual 313603-2, *Avions Marcel dassault breguet a tion*, 1989.
5. Leverett SDJr, Whinnery JE. Biodynamics: s tained acceleration. In: DeHart RL, Whinnery eds. *Fundamentals of Aerospace Medicine*. Ph delphia: Lea & Febiger, 1985; 202-49.
6. Operating Manual : Mirage 2000 H-TH. M200H-i-1. *Aions Marcel desbut-Breguet Avia* 1989.