Symposium Paper

AEROMEDICAL PROBLEMS OF HIGH SPEED LOW ALTITUDE FLYING

Problems of High Speed Low Level Flying— A Pilot's Point of View

Gp Capt PM Ramachandran, AVSM, VM*

Introduction

IN the evolution of tactics employed for air warfare, the attacker and the defender have matched their wits and tried to gain whatever advantage that was possible under the circumstances. In the current scenario in our subcontinent, penetration of enemy territory at a very low level at high speed is the best method to minimise radar detection range if not totally avoid being detected. This in turn lessens the time available for activation of enemy defences and therefore increases the chances of survival reducing the attrition rate. In areas covered by wide chains of low looking radars and quick reaction low level anti-aircraft missiles, the pilot is forced to maintain such fast speeds at such very low levels that many other problems are introduced in the process. In the final analysis, the chances of survival would again get degraded by self inflicted accidents and thus the attrition rate would again show a reverse trend. The object of this paper is to highlight some of the problems of a pilot flying at high speeds at very low levels and to indicate the current approach to a few solutions.

Types of Missions and Tasks

The types of missions which are flown at low level would include the deep penetration strike (DPS), interdiction and close support missions. The distances covered over enemy territory could be upto 300 nm in the DPS role and about 200 nm in the interdiction profile. The close support missions are generally flown close to the bomb line where the tactical ground fighting takes place. These distances would naturally depend on the location of the targets as well as the radius of action of the attacking aircraft. The normal cruise speeds could be around 13 to 15 km per minute and for short periods during the dash to the target or the get away from the target, the speed could be as high as 20 km per minute. In air defence missions, the pilot may be required to intercept or chase an enemy formation approaching or getting away at low level. In this task, the interceptor has to fly at speeds even greater than Mach 1.0 but he could maintain a slightly higher altitude right upto the terminal phase.

In trying to appreciate the problems, the task that the pilot has to do is to be borne in mind. Briefly it is as follows :

(i) Flying of the aircraft.

(ii) Management of aircraft systems (engine operation, fuel/hydraulic/electric/pneumatic/other systems).

(iii) Radio communication.

(iv) Navigation.

(v) Formation flying or position keeping with respect to other members of the formation.

(vi) Look out for enemy fighter aircraft (spotting and reporting).

(vii) Tactical manoeuvres, including evasive action against enemy defences, both ground to air and airborne interceptors.

(viii) Avoidance of high terrain features, high tension cables and balloon barrages.

(ix) Avoiding birds.

(x) Avoiding highly defended areas by tactical routing.

* Chief Test Pilot, Aircraft and Systems Testing Establishment, Bangalore-560017

(xi) Identification of target, positioning for attack and accurate weapon delivery.

(xii) Regrouping of formation and recovery to base.

Thus a formidable list of tasks has to be carried out by the pilot of a single seater aircraft when flying under conditions of emotional stress, especially when committed to high risk operations over enemy territory. In the performance of above tasks at low level and at high speeds, certain problems need highlighting and their solutions, partial if not full, as available today would also be mentioned.

Problems of Low Altitude High Speed Flying

Flying at Low Level: Flying at low level is by itself an advanced phase in a pilot's training. Even if one member of a formation stays slightly high, the approach would be detected at a much farther range and tactical surprise would be lost. As an approximate guide, an aircraft at 50 mtrs height would be detected only at 30 kms as compared to 50 kms for another flying at 150 mtrs. The proximity of the ground allows very little tolerance for piloting errors especially with respect to maintaining the correct height. In this aspect, the visibility conditions are quite important. On a hazy day, when the horizon is not clearly visible, the pilot finds it difficult to maintain a level flight path. The task of executing a level turn at a turning point becomes critical and is greatly aggravated if the terrain below is either a desert or water. The undulations of sand dunes is not clearly discernible and a gradual descent in a shallow spiral of even 1° would result in a loss of height of 50 mtrs in about 10 secs. In modern aircraft, the automatic flight control system or autopilot has been introduced to relieve the pilot of the workload and concentration required in the task of pure flying. The height lock enables the aircraft to maintain a preset barometric height. In addition, it has several other modes one of which is the "pull up from dangerous altitude" mode. When this switch is kept on, the autopilot initiates a pull up to a safe altitude whenever a preset critical altitude is reached as measured by the radar altimeter. The radar altimeter coupling is not an ideal solution as it measures the height directly below the aircraft and not sufficiently ahead to enable an effective evasive pull up. Terrain avoidance radars are being used to meet such requirements in long range low level strike aircraft such as the F-111. However, for a pilot to use the autopilot even at 100 mtrs, the confidence level has to be high. At 50 mtrs. very few pilots would place their trust on an autopilot. In order to ensure a high level of reliability, duplicated or triplicated systems are required.

Management of Aircraft Systems: The modern day high performance fighter aircraft is an example of the most advanced and sophisticated technology and is a highly complex machine. The numerous subsystems in the aircraft would take a great deal of the pilot's time and attention if sufficient automation is not provided in the system. Some examples are automatic fuel feed sequencing, engine air intake geometry control and the automatic flight control system. It is of course necessary that all automatic systems have a high degree of reliability and only in the case of a malfunction, which should be occasional, should the pilot be required to intervene manually. In this context, the warning systems in the aircraft assume importance. These are designed to draw the attention of the pilot whenever the automatic systems fail or when some other failures take place. Earlier practice of having numerous warning lights distributed all over the cockpit has given place to centralised warning panels with a large master blinker located prominently in the field of view of the pilot. This is also connected to an audio warning in the pilot's earphones. Audio signals are also used to indicate dangerously low altitudes, passage over marker beacons, illumination by enemy fighter radars, missile lock on etc. Different tones for different functions have been used but the best solution has been the voice warning system. Later versions which require computer interfaces also tell the pilot what best action he could take to deal with the problems. In some of these, the relevant check lists and emergency procedures can be called up on a screen as a projected display to serve as an 'aide memoire' to the pilot. These measures enable the pilot to devote his attention to the mission on hand and to deal effectively with any failures that arise.

Navigation: One of the primary responsibilities of the pilot is to reach the target as per a preplanned tactical route which would avoid heavily defended areas and achieve surprise. He may also be required to arrive over the target at a precise time to enable coordinated attacks in conjunction with other formations or ECM missions. When the navigation is done at very low levels, the extent to which the pilot can pick up an identifiable land mark becomes very limited, especially in conditions of poor visibility or haze. The duration available for such identification is of the order of a few seconds at the present day speeds. In the initial days of a war, the pilot will be flying over totally unfamiliar territory and hence identification of land marks would not be an easy task. A single pass over the target is all that would be possible. Navigational aids which are available during peace time such as radio beacons would not be available during war times and assistance from own radars is not possible for low flying aircraft. Similarly, voice communication range is also limited to line of sight range in the VHF and UHF bands and therefore DPS aircraft have been fitted with HF radio sets for long range communication from low levels when on deep strike missions. A self contained on board navigation system is thus an absolute necessity and its accuracy should be such as to enable a successful first pass attack. When approaching the target area, the speed is increased to 'dash' speed for making the task of the anti-aircraft defences more difficult. It has been established that under such circumstances, if the target is more than 1 km to either side when spotted at a distance of about 4 kms, it would not be possible for the pilot to manoeuvre the aircraft for aligning himself with the target in time for proper weapon delivery. A Head Up Display driven by an inertial navigation system through associated digital computers is the present day solution to this problem. Even with these systems, the workload on the pilot in terms of the number of switch selections for operating the Nav. attack system and weapon control system is still heavy and a positive effort to reduce the workload by better ergonomics and engineering is necessary.

Formation Flying and Look-out: While flying operational missions, generally two types of tactical formations are used. In a " broad frontage " formation No 1 (leader) and No 3 (deputy leader) are abreast with about 1 km between them, and their wing men are staggered on the outside. The second type is similar to the positioning of the four fingers of a hand with the leader ahead of the others. The main assignment for the wingmen is to keep a good lookout especially towards the rear for spotting enemy attackers well in time and report the same to the leader on the R/T. In this respect the ' broad frontage ' gives more rear coverage than the ' finger four ' but the latter permits easier manoeuvring of the formation and is generally used for low level missions. It is thus obvious that the wingmen are required to fly mostly looking backwards. Frequent quick glances at the instruments and the terrain ahead is all that is possible. Aircraft with bubble type canopies with no bulkhead immediately aft of the cockpit are ideal under such situations. Rear view mirrors can be useful only for a limited range and field of coverage. Craning of the neck with the shoulder straps unlocked cannot be avoided. If at any time during the mission the formation is intercepted by enemy fighters, hard evasive manoeuvres or combat manoeuvres would have to be carried out. At this time the aircraft and the pilot would be subjected to high 'g' forces of around 6 g and the pilot would be required to keep track of the position of the enemy aircraft following behind as well as the other members of the formation with whom he is carrying out coordinated manoeuvres. A very high degree of flying skill as well as physical tolerance would be required in addition to mental alertness for coping up with the situation. Good handling characteristics and performance of the aircraft would contribute greatly to the success or failure at this stage.

Spotting: In an aerial combat, the pilot who spots his enemy earlier gains a great tactical advantage as he can immediately start turning his aircraft to get behind his adversary. The range at which the enemy aircraft can be spotted depends on its size, the 'aspect' which it presents to the observer, its relative movement, its colour and contrast against its background and whether it leaves an engine exhaust (smoke) trail or vapour trail. In practice, some individuals seem to have a 'Hawk eye' and manage to spot aircraft out of seemingly empty sky. Practice in systematic scanning of the sky in elevation, azimuth and range (which implies focussing of the eye at different ranges) is essential for successful spotting. Generally, the pilot of a low flying aircraft would pick up another aircraft flying higher against the sky background (especially if the sky is whitish due to haze or sheet type of clouds). On the other hand, the task of an air defence pilot trying to spot a formation approaching/getting away at 'deck' level is very difficult especially if the aircraft are camouflaged to suit the terrain below. On many occasions, even after spotting once, the pilot would lose contact again unless he keeps his eye on the target all the time, while he is closing in for the attack. Smoke free jet exhaust is important in this context. It would be tactically prudent to switch the after burner off under such conditions as soon as a sufficiently high speed is attained and 'dry' power is used thereafter.

Spotting is not confined to locating enemy aircraft only. Birds and obstructions such as high tension cables need to be seen well in advance if any avoidance is to be effective. Knowledge gained during earlier missions in the area and transferred correctly on to a map would help in subsequent missions.

Birds have posed one of the greatest hazards to low flying aircraft. For high speed aircraft, the impact momentum is so great that serious structural damage results even from small birds. However, in most cases of damage to the aircraft structure, the pilot would be able to bring the aircraft back but in the case of a bird hit on the engine air intake, the situation may become quite serious. Some engines are unable to 'digest' the birds and this is aggravated at high speeds when stability of the airflow through the air intake is essential. High speed aircraft have a low lift/drag ratio and hence a high rate of descent with engine off. Therefore, as soon as the engine flames out following a bird hit at low level, the pilot has to go through his drill for relight quickly and correctly and even then the chances of a successful relight before reaching the Minimum Safe Ejection Altitude are not bright due to the mechanical damage to the engine and lack of time. Spotting of birds in time for effective evasive action amidst all the preoccupation with other tasks is thus more a fond hope than practical. In the majority of cases, a pilot realises he has missed hitting a lone bird by a narrow margin as it whizzes past him. However, flocks can be generally spotted in time and the formation leader/deputy leader who are looking ahead can warn through radio the other members who are scanning the rear quarters. Losses of aircraft (and in some cases pilots because of fatal delays in deciding to eject) have been heavy, especially on single engined aircraft. In this regard, twin engined aircraft have a decisive advantage. The confidence level of a pilot on a low level deep strike mission would be greater when he has at his control two engines to cater for such an eventuality. The chances of physical injury to the pilot in cases of bird hit on the front windshield are minimised by employing bullet proof multilayer glass. Shattering of such glass still occurs in some cases and the helmet visor offers some protection against flying glass pieces. It is therefore essential to fly with the visor down all times.

Hot Weather Flying: One of the well know problems of the Indian environment is because the high ambient temperatures of around 40°C 45°C encountered in summer. If the cockpit has perspex canopy with no ventilation like the Canberr then the cockpit temperatures could be as high 60°C at the head level. In aircraft like the Mi and Gnat, once the canopy is closed, the situation very similar. Aircraft with sliding canopy like th Hunter and Marut are better off in such condition When the aircraft is airborne and the airconditioni system is switched on, there is some relief to th pilot. However, the efficiency of airconditionin systems vary greatly from type to type and som of these are designed primarily for operatio in temperate or cold climates. Operating suc aircraft at low level in summer taxes the physi logical endurance of the pilot to a great exten The temperature of the ram air increases conside ably at high speeds due to ram effect and thus th efficiency of the heat exchanger in the airconditio ing system degrades a lot in low altitude high spee flights. The answer to this problem is in the prov sion of a good air conditioning system which operative as soon as the engine is started. A larg mass flow at a low cabin inlet temperature is nece sary and the air distribution ducts should be we located to ensure cooling air entry and exit at th right places. Even though this problem is we known for a long time, the remedial measures hav not progressed sufficiently.

Turbulence and Buffet: An aircraft designe faces a real challenge when designing an aircra specifically for low altitude high speed mission because of the stress factors involved on the aircra structure. The turbulence induces positive/negativ 'g's on the aircraft which affect its fatigue life. It i obvious that a pilot sitting in the aircraft is subjecte to the same stresses. The severity depends on th amount and intensity of the turbulence, the speed o the aircraft and its "gust-riding" qualities. The las factor is dependent on wing design and hence a inherent characteristic of a particular type of aircraft The amount and intensity of turbulence is quit high on hot summer days especially during premon soon periods when unstable airmass conditions prevail Under such conditions the pilot has to put u with a very uncomfortable ride if speed cannot be reduced due to operational requirements. Accurate weapon aiming also becomes difficult.

Light Level: Operational missions are flown under varying conditions of light level from glaring daylight to darklight. Many missions are mounted at dawn or dusk when the pilot goes through the transition period also. On a bright day, a high degree of accommodation is required for registering the reading of an instrument tucked away in a dark corner under the instrument panel coaming while glancing into the cockpit briefly. A visor of uniform tint is unsuitable for this purpose. A visor with gradually decreasing tint towards the bottom would be more desirable. For catering for the various outside light conditions, two over lapping visors, one clear and one tinted, would be needed. Helmets with such refinements are yet to be introduced in the IAF.

Conclusion

An attempt has been made to highlight some of the problems of a pilot while at high speeds at very low altitudes. These could be alleviated to a certain extent by the efforts of designers and doctors leading to better design and ergonomics. The fact that a human being is highly adaptable and therefore allows a great deal of tolerance in his operating environment should not be taken for granted as sometimes it may be a crucial contributory factor to serious accident.