

A Unique Situation of Cyclic Saturation in a Helicopter during an Aerobatic Display : Human Factors Perspective

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ABSTRACT

Cyclic saturation is a condition in which the helicopter does not respond to a cyclic input, the lateral control for roll manoeuvre runs out of limit. The No. 2 of 4 aircraft formation display piloted by one of the most experienced pilot of helicopter aerobatics display team while carrying out a positioning turn to left for 'synchro cross' went into a left spiral and crashed into the ground. A very high degree of bank to the left combined with high rate of roll, excessive collective input while in turn, increased G loading of the helicopter led to a situation of cyclic saturation to the right so that the aircraft did not recover from the left spiral. Because of the high impact crash of the helicopter in a nose down attitude with left bank, the co-pilot who was on the left side of the cockpit, sustained fatal injuries and the pilot occupying the right side seat of the aircraft sustained serious injuries. Human factors analysis revealed a perceptual error on the part of the copilot who was in control of the aircraft with respect to the other aircraft of the formation, which compelled him to give excessive control inputs. The degradation of flying skills under adverse situation of ground approaching rapidly and its consequent effect on recovery actions has been discussed. An inadequate resource management was identified as an organizational failure. Design issues of significant human factors concerns have been highlighted. Remedial measures from the aeromedical view point have been suggested.

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Key words: Aircraft formation display, Synchro cross, Perceptual error and Organizational failure.

Cyclic saturation is a condition in which the helicopter does not respond to a cyclic input, the lateral control for roll manoeuvre runs out of limit either at left or right. This has been reported in many instances in helicopters with rigid rotors [1,2]. Such a condition arises on combination of control inputs such as high collective, high bank, excessive rate of bank, high pitch input and increased G-loading. This typically occurs to right in helicopter in which the rotors turn clock-wise direction [3]. As the helicopter banks, the blade at the nose of the helicopter experiences an airflow (the helicopter is also moving ahead) which may be from 'above' the disc or even 'below' the disc. In case, it is 'above' the disc it may result in reduction in the angle of attack due to increased 'induced flow'. For a clockwise turning rotor (when seen from above) mounted on a helicopter banking left, this may cause the disc to flap down to the retreating side (or to the right). However, if this airflow is from below -

which is the case during high 'g' banked turns, this results in an increase of angle of attack resulting in the disc to flap 'up' as it retreats on the right side. If the helicopter is in a left banked turn this may cause it to roll further left. However, if the pilot intends to maintain the original bank angle he/she will be required to move the cyclic further 'right' (outside the turn; against the resultant flapping). Ultimately, during a sustained high 'g' turn this may result in the pilot running out of the possible lateral cyclic mechanical movement to the right and the situation is referred to as cyclic saturation to right. The recovery from this situation can be achieved by lowering the collective while maintaining the cyclic to the right [4]. The case described below is one of the few where cyclic saturation to right occurred in a helicopter during an aerobatic display.

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As the aerobatic display is usually executed at a low altitude, this situation becomes unique in terms of entering into a cyclic saturation and recovery actions.

Case details

A left hand seat qualified fully Ops pilot and a supervisor was authorized to fly a 4 helicopter formation display as No. 2 along with his co-pilot. The sortie involved practice of 4 aircraft formation display as per the helicopter display profile. The sortie was uneventful till cross over break was executed. Subsequent manoeuvres involved a turn through 180° to the left by No. 2 & 4 to roll out on a heading of 090 along the runway for the next manoeuvre 'synchro cross'. Both No.2 (ill-fated helicopter) and No. 4 commenced the turn on call from the leader. Instead of rolling out on a heading of 090, the No.2 helicopter was seen to go into a left spiral with excessive bank and nose down attitude. The helicopter did not recover from the spiral and crashed to the North of 09 dumbell. The co-pilot, who was on left seat received fatal injuries and the pilot occupying the right seat received serious injuries.

The accident occurred due to the aircraft entering into a situation of right cyclic saturation in left turn. This situation primarily resulted due to high collective input even before initiating a turn to the left with a step input of left cyclic. In the next second the cyclic has continued to move to right as expected. However, the aircraft has shown no signs of recovery and the bank has kept increasing. The situation probably was aggravated by the fact that the co-pilot who was on the control of the aircraft had continuously come up on collective. Since the left bank resulted in nose dropping, he has given backward pressure on cyclic to keep the nose level, resulting in increased G-loading and further compounding the situation. The pilot having realized that the bank was becoming excessive in

five seconds after the initial input, took over the controls and attempted to recover. He has lowered collective by 5% with the cyclic fully to the right. This recovery action could not have the desired effects.

Discussion

In the present case, the co-pilot anticipating a turn into head winds and perceiving that he might be lagging behind had increased power by raising collective combined with giving rapid cyclic input to put-on bank. This combination resulted in a situation of cyclic saturation to right. The pilot having realised the situation took over the controls in five seconds and gave input as advised in the flight manual. The heights at which this helicopter display team operates would have given the pilot time for only one attempt at recovery. The flight manual is vague on how much of collective is to be lowered. He lowered collective by 5% which proved to be insufficient and with the ground rapidly approaching he had instinctively come up on collective subsequent to initial lowering.

Detailed investigation of available evidences and HFACS (Human Factor Analysis and Classification Systems) analysis as per the laid down procedures [5, 6], revealed some of the significant human factors issues in this mishap. These are discussed below: -

Unsafe Acts: The co-pilot who was in control of the aircraft seemed to have wrongly perceived his position with respect to No. 1 & 3 and might have applied high bank at excessive rate. Anticipating that he was going to lag behind after the turn for synchro cross he seemed to have come up on collective even before the turn. Even though the pilots have not violated the laid down parameters with respect to degree of bank, roll rate and collective input as specified in the flight manual,

the combination has led to a situation of cyclic saturation to the right. These acts by the co-pilot which resulted in the situation of cyclic saturation to right were recognized as perceptual errors. To recover from such a situation, it is essential to lower the collective while maintaining the collective to the right. The pilot having realized the problem had taken over the controls from the co-pilot and had given the necessary control inputs as per the flight manual and SOP. However the control inputs seemed to be inadequate which led to the accident. Subsequent to initial lowering of collective (input for recovery) the collective had been raised continuously, which had compounded the situation further and this action by the pilot was recognized as unsafe act during attempted recovery.

Unsafe Condition: The corrective action of lowering collective was given 5 seconds before impact. At this time the helicopter was in a step bank of 70 degrees and a pitch down attitude of almost 40 degrees. The height of the helicopter at the time of initiation of the manoeuvre was only 80 m AGL. When the recovery actions by the pilot were initiated, the altitude dropped to 60 m AGL with the ground approaching rapidly. Emotional arousal under such an adverse situation is a natural human reaction which can lead into panic and stress, as happened in this case as revealed by CVR. Complex cognitive and motor skills tend to be degraded under psychological stress and there is a tendency to revert to more primitive behavior and reflex action [7]. This could probably explain the action of the pilot of coming up on collective few seconds before impact.

Organizational failure: The problem of cyclic saturation to right has been observed as long as 10 years back by the test pilots when the helicopter did not respond to right cyclic input while in a step turn to left. One year later similar problem was experienced once again by the test pilots. Both the

incidences had been projected and the Manufacturer has been asked to document the condition and correct the problem. However, this problem has not been addressed adequately by the Manufacturer. Documentation pertaining to saturation of right cyclic in a left turn is grossly inadequate in Flight Manual in spite of repeated reported incidences. There has been no quantification in terms of entry or recovery parameters during such a situation. Also it was observed that the flight manual has not been certified by the concerned certifying agencies and there is a failure in the part of IAF to monitor adequately the progress on the subject matter. All these were observed as inadequate resource management and a failure at organizational level.

Design Considerations: In the present case, the aircraft has gone into a situation which leads to an accident without giving any audio visual warning to the pilots. Also the recovery action as specified in the flight manual of 'slight lowering of collective' is highly subjective and the pilot could not have appreciated the amount of collective that he lowered due to lack of direct indication of collective movement. It was considered that this could have contributed directly to the recovery actions and hence to the accident itself.

Recommendations

The following are few suggested remedial measures from the aeromedical point of view:-

- (a) Documentation pertaining to saturation of right cyclic in a left turn needs appropriate and specific quantification.
- (b) Suitable audiovisual warning needs to be incorporated to caution crew of impending control saturation.
- (c) The lowering of collective to recover from

such a situation needs to be quantified and the appreciation of collective movement needs to be displayed by incorporation of collective torque indicator.

- (d) Necessary instructions be issued to include demonstration and recovery techniques for control saturation at a safer altitude in the conversion syllabus.

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