Some Handling Aspects Introduced by Increased Helicopter Requirements

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Increased helicopter operational requirements and the consequent advances in operating techniques are producing problems which need early recognition It is true that an increased requirement usually means an improvement in performance, but invariably each advance in performance introduces new handling problems In this short paper I will discuss two such handling problems as they effect the present military use of helicopters

Already the extension of pure helicopter flight for world-wide operation in any reasonable weathers and up to higher ceilings has provided new handling problems which we encounter regularly in our present work These I will discuss under the general headings of high altitude and instrument flight I am considering the problem of high altitude handling as a manufacturers problem, and instrument flight as a users problem

I wish to acknowledge the permission to deliver this paper, given by the Chief Scientist of the Ministry of Supply, and for the use of much of the material in it I also wish to acknowledge the willing assistance of the pilots and technical staff of our helicopter team at Boscombe Down in the collection of much of the information in it

HIGH ALTITUDE FLIGHT

The helicopter is already required to operate at what we call high altitudes (say 10- 19,000 ft) in certain military and development roles New or improved power-plants, increased speeds and range, world-wide operation and weather flying, all tend to push the effective service ceiling higher As a general example of conditions imposed by today's requirements, consider helicopter flight at Nairobi which is 5,000 ft a m s l The Summer temperature and the relatively lower density makes it equivalent to 8,000 ft I C A N Flight at 5,000 ft in full tropical Summer standard conditions is equivalent to nearly 9,000 ft I C A N Apart from performance considerations the effect on handling characteristics can be significant with this increase of height

In fixed-wing flight the real effects of high altitude on manoeuvre can be considered above say 30,000 ft (Ref 1) The effect of height upon helicopter manoeuvre can be a reckonable factor as low as 8,000 ft I C A N I use the term " manoeuvre " in its original sense, as the ability to change the flight state quickly, accurately, and with safety The limitations to manoeuvre described in this section refer to free flight away from cushion effects in single engined, single-rotor machines

On all types of helicopters now in service, some degree of deterioration in handling characteristics can be observed with increase of height To the pilot this is usually manifest in three ways —in increased airframe vibration, increased sensitivity of the rotor to pitch and power changes, and a strong impression of deterioration in longitudinal static and dynamic stability

The increase in airframe vibration and the discomfort it incurs is noticeable usually above about 12,000 ft , but on two types of aircraft it is a factor to be considered above 9,000 ft The main limitation imposed by heavier vibration is upon maximum angles of bank for sustained turns at constant speeds (Ref 2) and therefore it is not serious in normal (*i e* , non-combat) manoeuvres

More serious in effect upon manoeuvre is the need for a change of flying technique at high altitudes because of the increased sensitivity of the rotor to pitch and power changes As you know, rotor speed increases with height for a constant pitch/power setting Conversely, for constant rotor r p m a progressive increase of collective pitch must be made on a constant power climb If power is reduced, collective pitch must be reduced to maintain constant rotor r p m , but as height is increased this pitch reduction for constant rotor r p m becomes relatively smaller This may sound harmless, but as an example of its effect in the worst case experienced, autorotative flight above 8,000 ft in a design overload condition was impossible without stopping the engine Full autorotation must be possible up to the designed maximum speed for height as the highest attainable rate of descent may be needed in icing conditions or combat manoeuvres

Towards the ceiling (say 18,000 ft) the effect of increased rotor r p m with height becomes very important for the rotor is then extremely sensitive to a pitch change or change of disc loading in acceleration The tendency of some rotors to throw *off* pitch with positive ' g ' adds further to the danger of racing rotor r p m at height Now the total power available near the ceiling on an internal combustion engine is obviously that given near the bottom of the power/speed curve, that is, any continued condition of powered flight other than a dive will only be possible near the speed for minimum power Therefore there is little power available for manoeuvre, while the rotor is extremely sensitive and needs coarse pitch changes to maintain constant or even limiting r p m This aspect alone introduces a relative change to flying technique with any appreciable increase of height The designer meets this by reducing the flight envelope with height, but restrictions on I A S , rotor speed and accelerations do not cover the case completely The pilot must still experience the increased sensitivity of the rotor in manoeuvres within the flight envelope, and then allow for it by a change of flying technique If his impression of the effect is interpreted incorrectly or he overcontrols through inexperience, the rotor r p m will soon exceed the top limit

I will now discuss the deterioration in stability The greatest changes to flight attitude in a helicopter are made in the pitching plane The usual cases considered are the assumption of auto-rotative flight following an engine failure and a rapid descent followed perhaps by a powered climb as an evasive manoeuvre Although longitudinal and lateral stability are somewhat interdependent, I shall here consider the longitudinal case separately in high altitude flight As you know, the longitudinal stability of the helicopter varies with speed and is partly dependent on the damping of rotor and fuselage (Refs 3 and 4) With reduced density at height it appears that the damping is reduced, and in any case, general operating indicated airspeeds are then usually below the stable speed range Stability characteristics can never be described as comfortably positive and any deterioration is therefore a serious matter This may of course be largely an impression of deterioration in stability, but as such, it is very forceful

To the apparent effect of reduced damping to disturbances is added the reduced controls response through lack of available power and the increased rotor sensitivity already described The pilot must avoid therefore, rapid and large changes of the flight condition or know his aeroplane extremely well If such a longitudinal change, of an order quite normal at low altitudes, is made near the ceiling the resultant pitching can become dangerously divergent

Each of the described effects is in itself a mild limitation, but together they form a serious restriction upon manoeuvrability There appears then to be a requirement for more detailed forms of high altitude manoeuvre boundaries than those at present given in designers' flight envelopes I would suggest that the parameters of speed, thrust and disc-loading are conditioned by controls response and translational rates during entry into manoeuvres, besides the effect of relative density at any height The laborious construction of some form of boundaries including this information, is needed in the endless quest for safety in flight

In emphasizing a few of the handling dangers in this particular extension to helicopter operations I have no intention of making a case against high flight, for in practice these effects need not be bogies at all, except in an emergency Handling in icing conditions, evasive manoeuvres, or following a sudden engine failure, are some of the cases to be considered as hazardous today at height

There seems to be little likelihood that operating heights much greater than those quoted will be required in near future helicopters, but it is disturbing to encounter such a degree of difference to handling characteristics over such medium increases of altitude Besides these handling changes, other complementary problems have been met at height These include the control of engine operating temperatures, cabin heating and the misting of transparencies, and there is always the forseeable problem of airframe de-icing. In all, there appears to be a requirement for considerable development along these lines, with the aim of reducing as far as possible, yet another limitation to the helicopter

INSTRUMENT FLIGHT CLEARANCES

If any aeroplane is to be utilised completely, instrument and night flying must be possible within the full limits of the machine I will discuss here a few handling considerations affecting the clearance of a helicopter today for flight under instrument flight rules (I F R), and give the reasons as I see them, why restrictions in operation are going to be necessary for some time to come

The need for development of flight instruments is well recognised and is common to all branches of aviation Perhaps helicopter requirements in this field do not hold the highest priority, but they have been stated and we must now await developments In the meantime progress must be made with the instruments now available If the scope of helicopter operations can be extended safely in any way we must not delay in taking advantage of the possibility I would suggest that today we should be aiming at a basic standard in training, presentation and procedure which, while allowing an acceptable measure of instrument flight now, would be capable of adaption to likely developments and eventually to unrestricted blind operation

Until a minimum standard of instrument flight (I F) training for pilots is compulsory, I feel a type clearance for I F cannot be given with full safety I would suggest that the tests we apply to a type at Boscombe Down might be given to a pilot as part-examination of his proficiency for flight under I F R This would assure some immediate measure of operating safety in place of the present haphazard position wherein any pilot may fly in any weather condition without proper restraint

Generally speaking, the restrictions on helicopter instrument flight today are due to flight instrument limitations and the inherent instability of the machine in manoeuvre

A standard form of instrument presentation and layout has been accepted recently by all interested users (Ref 5) Experience so far indicates that until new or developed instruments are available this panel is satisfactory, with perhaps one reservation which I will mention later Therefore, for the present we must accept differential pressure indications for some important readings This means that we must accept lag in indication of some flight state changes, some large position errors (P E), changes of P E with changes of flight state and, particularly in the very low speed range, the relatively enormous effects of turbulence and gusts on indicated values The problem is then, to determine the limits within which we might fly with safety

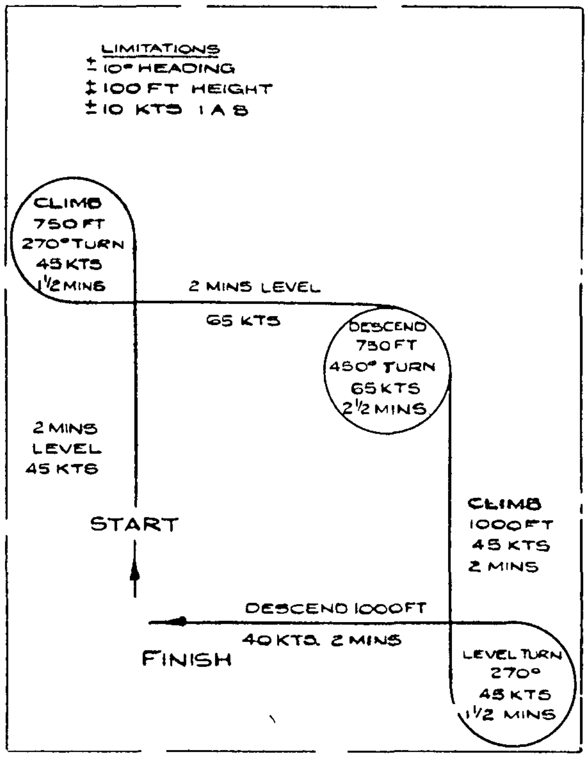
Consider first, the effects of stability , the stability of the single-rotor helicopter in manoeuvre can be considered as satisfactory at speeds above that for minimum power (V_{imp}) Below the V_{imp}, and particularly in the very low speed range, large divergencies from the flight path can occur very quickly Longitudinally some aircraft rely on aerodynamic stabilisers to assist the stick free stability and below the V_{imp} these can be considered as useless in effect Directionally, the stability of a single-rotor machine may be reasonably positive throughout the cruise speed range, but in rough air a characteristic helicopter oscillatory motion is set up This varies in magnitude more or less directly with the degree of turbulence and is caused particularly by the effect of gusts on lateral rather than longitudinal stability (Ref 6) As speed is reduced, the rate of turn for a given angle of bank increases so that small lateral displacements caused by rough air, at a low speed, can produce rapid deviations from heading Therefore a constant heading at slow speed in rough air cannot be held accurately, and all corrective controls movements in slow speed manoeuvres are larger and more frequent than at speeds above say the V_{imp} In any changing flight state, the differential pressure instruments lag, therefore the condition to be corrected is in advance of the indication As a result, slow speed flight under blind conditions is usually affected by coarse control movements which lead to over-corrected and inaccurate flight This is extremely fatiguing to the pilot and can be continued for short periods only

Gyroscopic instruments are a real assistance to flight accuracy at speeds above the V_{imp} As speed is reduced below the V_{imp}, the change of fuselage attitude and the deterioration of manoeuvre stability increase progressively The artificial horizon does not give a real picture of these changes in pitch, therefore relatively more reliance is placed on differential pressure indications at slow speeds The acceptable low speed limit for instrument flight is then practically conditioned, in pitch, by controllability on the limited panel presentation (*i e*, with gyro instruments " out ") A further consideration in slow-speed flight is that of P E correction changes with changes of flight condition On one type this is—11 knots between a steady climb and steady autorotation at 20 knots I A S An emergency autorotation from the climb at that speed would be dangerously slow for any reasonable directional control These few considerations indicate that instrument flight should not be continued below the V_{imp}

The V_{imp} on the pure helicopter is usually about 0 45 of the maximum permissible speed (V_{max}) and if this was the lowest cleared limit for instrument flight it would represent a big restriction, particularly on the controlled or aided steep night approach The normal power/speed curve indicates relatively small changes of power between say 0 7 and 1 3 V_{imp} It seems reasonable therefore to reckon on safe instrument flight down to 0 7 V_{imp} as the lower speed limit

Determination of the upper speed limit is more definite On helicopters in service today, the longitudinal static stability, stick fixed in level flight is positive throughout the cruise speed range, but becomes neutral or exhibits a slight reversal at about and above 0 85 V_{max} The aircraft then becomes sensitive to turbulence or longitudinal control movements, and the consequent divergent pitching tendency needs close attention Usually other characteristics such as stick shake or increased airframe vibration become apparent at about this speed, and on one type the cyclic control is nearing the forward stops under certain aft c g loadings Therefore it would seem to be convenient to limit the top speed under I F R to 0 8 V_{max} on single rotor aircraft today

The next step is to consider some aspects of control in the acceptable speed range Since the stability characteristics at best are poor by fixed-wing standards, even in a steady flight condition the pilot can never relax from constant instrument interpretation He is subjected, therefore to constant extra concentration, increasing in degree with time and resulting in earlier fatigue If this strain can be relieved in any way the period of possible continuous accurate I F will be increased Conversely, any objectionable aspect of control, no matter how small it may be, will soon become a disproportionate fatiguing element The advantage given by a measure of longitudinal and lateral stick-free stability, however it is produced, is a good example of this, and if it is absent the adverse effect on flight accuracy is soon apparent A further illustration is in the effect of positive stick force gradients opposing controls displacements longitudinally and laterally These introduce " feel " into control, and a consequent sense of stability Extremely light stick forces can appear to be negative if any pre-load is necessary to overcome friction This and the absence of positive stick centering result in a marked sense of instability However, where there is a positive gradient it must be possible to trim out all stick forces completely A residual force which might be quite insignificant in contact flight will soon become most objectionable in I F I would suggest that positive longitudinal and lateral stick free



static stability, positive stick force gradients and ample trimming range are requirements for an I F clearance to service aircraft

Power failure to the gyroscopic instruments and complete engine failure are the emergency cases to be considered In the former case, gentle manoeuvres should be possible using the ball and compass A better stand-by indicator of lateral level is needed, but the suction turn and slip needles are hopeless in any turbulence The electric instrument seems to be much more suitable, and there may be a good case for its inclusion on the interim standard I F panel Rapid transition from powered to autorotative flight must be possible on instruments In practice this is an uncomfortable manoeuvre as it takes a little time to re-orientate panel

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indications following the negative " g " There is generally an immediate change of P E to be allowed for here, and the pilot must take care not to induce any violent pitching when rectifying the difference

All the above considerations apply to I F at low altitudes   As expected, height produced additional limitations The low operating indicated airspeeds, lack of available power and the impression of reduced damping can make I F near the ceiling quite unpleasant, and the helicopter need not be in cloud at say 15,000 ft to be in blind conditions, for the large perspex areas are ideal for frosting, inside and out   I would make a plea here for close-fitting draught-proof doors and effective cabin heating, if only to reduce the miniature snow-storms which can brew-up in the cabin

The effects of increase of height on handling may be met as low as 8,000 ft I C A N , or just above the full throttle height at 1-hour power for the aircraft types considered in this paper   To ensure full safety of operation, I suggest that an I F clearance today should be limited to that height   This would not be a great disadvantage at present, but it should not be allowed to exist for too long

The pre-requisite to safe instrument flight within any aircraft limits will always be a suitable standard of pilot training   It appears that fixed-wing instrument rating training forms a sound basis for such flight in a helicopter Under suitably limited conditions, the helicopter can be flown safely in all manoeuvres compliant with present requirements and much in the manner of an unstable fixed-wing machine   Nearly all helicopter pilots have had training in instrument flight in their basic fixed-wing flying, but pilots of helicopters only, will have to attain a suitable standard by some other means I am sure that a reasonable instrument rating scheme could be framed soon as a move towards the fuller use of helicopters

Conclusions

Summarising then —the natural extension of helicopter requirements introduces handling problems at high altitudes and under instrument flight conditions

High Altitude Flight

Limitations to helicopter manoeuvre increase with increase of height to become severe near the ceiling (say 15- 19,000 ft) and the conditions which then can be induced by mishandling or in an emergency may endanger the safe operation of the aircraft

If helicopter operation at height is to be made with safety, the pilot must be acquainted with the limitations of his machine in terms of manoeuvre boundaries   These should include the normal information of limiting air and rotor speeds for height and the permissable accelerations, but superimposed on this should be information on the effects of various rate-changes of the flight condition

Instrument Flight

For cleared safety of operation on instruments, I feel that speeds should be restricted for the present to those between 0 7 V_{imp} and 0 8 V_{max}, up to a height of 8,000 ft , provided that a suitable standard of pilot training can be assured, and there can be little safe reduction to these suggested limitations while we must still rely on differential pressure indications for some important readings

As for the future

Some lines of instrument development which do not rely on the character of any airstream show considerable promise It would seem that successful instrument flight at very slow speeds will only be possible on " wandering spot " type of indicators

The attainment of pure vertical flight and high altitude flight on instruments and under pilot control must be the constant aim Some auto-pilot devices may meet these conditions now, but there will be many helicopters unable to accept the weight penalty of such equipment

Before the helicopter can be accepted as an indispensible vehicle in war or peace, present-day operating limitations must be reduced considerably The cases I have discussed in this paper would seem to present an opportunity for fairly early results in line with this aim

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THE CHAIRMAN

Thank you, Squadron Leader GELLATLY, for a most interesting and, if I may say so, a very well informed paper You have certainly put your finger on problems associated with altitude and instrument flying, and I am sure the research work in which you are engaged will lead to satisfactory results in due course

Our third speaker is Captain J A CAMERON, of the British European Airways Helicopter Experimental Unit, which he joined on its formation in 1947 Captain CAMERON, who learned to fly with the Inverness Flying Club in 1938, joined the R A F in 1940, and gained his wings and commission in South Africa in 1943 After a two-year period with Coastal Command in India on Liberators, he was posted to the Air Sea Warfare Development Unit at Thorney Island where he was converted to helicopters With 2,200 pilot hours behind him, no less than 1,800 hours have been on various types of helicopters Captain CAMERON, who is a most experienced operational pilot played a major part in contributing to the very successful outcome of the Helicopter Unit's night and blind flying experimental activities