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THE TIGER ...NEW POTENTIALS FOR A NEW HELICOPTER

BY

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THE TIGER ...

NEW POTENTIALS FOR A NEW HELICOPTER

1. INTRODUCTION

TIGER is a multi-mission helicopter developed in France and Germany to meet the needs of the French ALAT and German HEERESFLIEGER (Army Air Corps) (Ref. 1). MBB and AEROSPATIALE Helicopter Divisions, the two companies tasked with this development, merged to form EUROCOPTER in 1991. The milestones of the TIGER development programme were :

- December 1987: Signature of development contract by the two governments

- April 1991: First flight of the first of five prototypes (Ref. 2)

To date, 4 prototypes have flown 850 hours and the first flight of the fifth is scheduled for the first quarter of 1996

Two significantly different versions of the same helicopter were developed to perform different missions, these are:

1) the support/escort version HAP (Hélicoptère d'Appui et Protection) for the French ALAT. This helicopter shall attack troops and vehicles on the ground with a 30 mm mobile pod gun and rockets; it shall also fight other helicopters and aircraft with the same 30 mm gun and MISTRAL air-to-air missiles (Fig. 1)

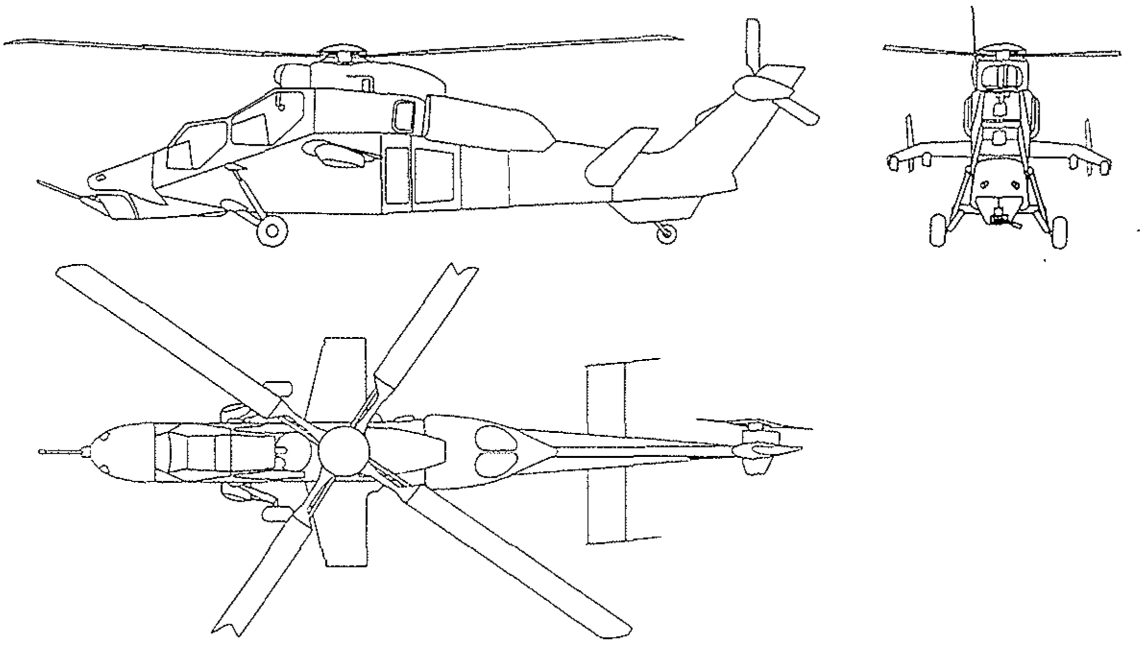

fig.1 SUPPORT / ESCORT VERSION OF TIGER

2) the anti-tank version, HAC (Helicoptère Anti-Char) for the French Army and UHU (Unterstützungshubschrauber) for the German Army. The prime mission is here anti-tank combat by night and day with an IR night vision system as well as TRIGAT fire and forget missiles. In addition, UHU can also support troops on the ground with rockets and a 12.7 mm pod gun replacing missiles (Fig. 2)

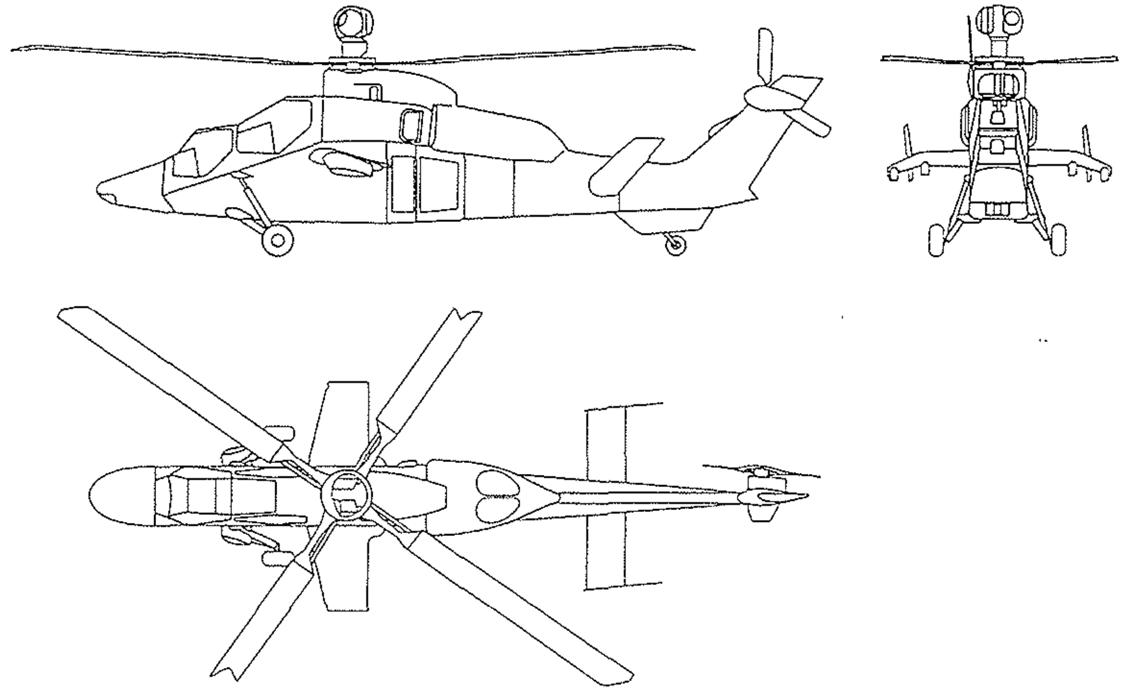

fig.2 ANTI-TANK VERSION OF TIGER

To those two versions meeting French and German needs are to be added variants intended for export but performing more or less the same missions i.e.

- air-to-ground and air-to-air combat

- day/night anti-tank combat

2. MISSION PROFILES AND FLIGHT ENVELOPE

A combat helicopter shall always prove itself superior, whatever the mission to be performed may be, by demonstrating the superiority of its own operating range i.e. flight envelope and its weapon system's operating range.

As explained above, these are optimized as far as TIGER is concerned along two main axes:

- Nap-Of-the-Earth (NOE) for anti-tank combat and ground support

- air-to-air combat for escort missions i.e. anti-helicopter and aircraft missions

These requirements are different and even, sometimes, contradictory as far as the flight envelope is concerned.

2.1 Anti-tank mission and NOE

In this type of mission, the helicopter is flying very low (at tree top level) and hiding behind obstacles. This mission is performed at moderate speed and often in hover out of ground effect whatever the wind direction may be; it is in those conditions that targets are acquired and the weapon system is operated. Pace is changed quickly and accurately. The vehicle's stability is to allow adequate sighting. The characteristics necessary to translate those operational requirements into flight mechanics terms are:

a) a power reserve in hover OGE and quick reaction times for the helicopter and its engines

b) manoeuvrability i.e. the capability to remain in hover whatever the wind direction may be and up to high values as well as the stability of the associated platform (Ref. 2)

c) the capability to change heading rapidly and accurately to face an unexpected threat

d) the capability to accelerate and decelerate rapidly to change observation or firing positions

e) the ability to fly over and around obstacles (DOLPHIN and SLALOM type manoeuvres respectively) or to complete 180° turns (Ref. 3); 180° turns are also practised as air-to-air combat manoeuvres

2.2 Air-to-air combat

Air-to-air combat is a relatively new mission assigned to helicopters by military staffs. None of the combat helicopters currently in service (SA 342 Gazelle, Bo 105, Cobra, Apache, Mi 24 etc.) has been designed for this type of mission. Some capabilities (gun, sight, missiles) were sometimes added but only as retrofits. The U.S. Army experimented with air-to-air combat (Ref. 4) and even used EUROCOPTER helicopters (BK 117 and SA 365M) to this end. One of the French Army (ALAT) units also operates Gazelle helicopters with guns.

Experience today shows that to perform this type of mission, the helicopter is to be able to move very quickly in the vertical plane. The characteristics necessary to translate those operational requirements into flight mechanics terms are:

a) power reserve to climb and accelerate rapidly

b) high speed in forward flight (V_H) associated to high speeds in dive (VNE)

c) high positive and negative load factors

d) high angular roll and pitch speeds for conventional aerobatics (loop, reversal, pushover etc.)

e) stability and a vibration level compatible with accurate sighting with the helmet-mounted sight and head-up display

2.3 External configurations and mission

Anti-tank (NOE) and air-to-air combat requirements are, as explained above, different and sometimes contradictory* and to these are to be added highly specific mission equipments that have an influence on the flight envelope. HAC/UHU has a large mast-mounted sight and TRIGAT missile pods whereas HAP in the air-to air configuration only has a gun mounted in the nose and MISTRAL missiles. As a consequence, there are highly significant drag differences as well as noticeable c.g. differences between the two versions (see Fig. 3 and 4).

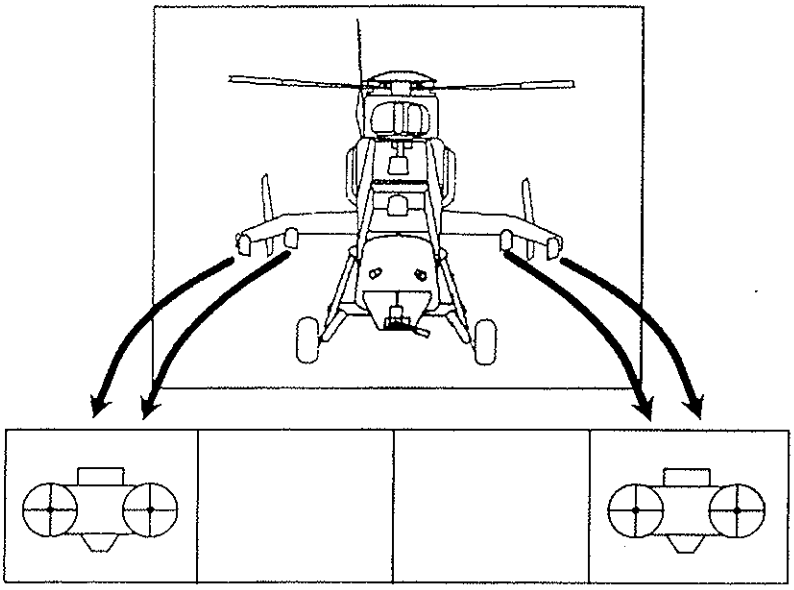

fig.3 EXTERNAL STORES FOR AIR-AIR COMBAT

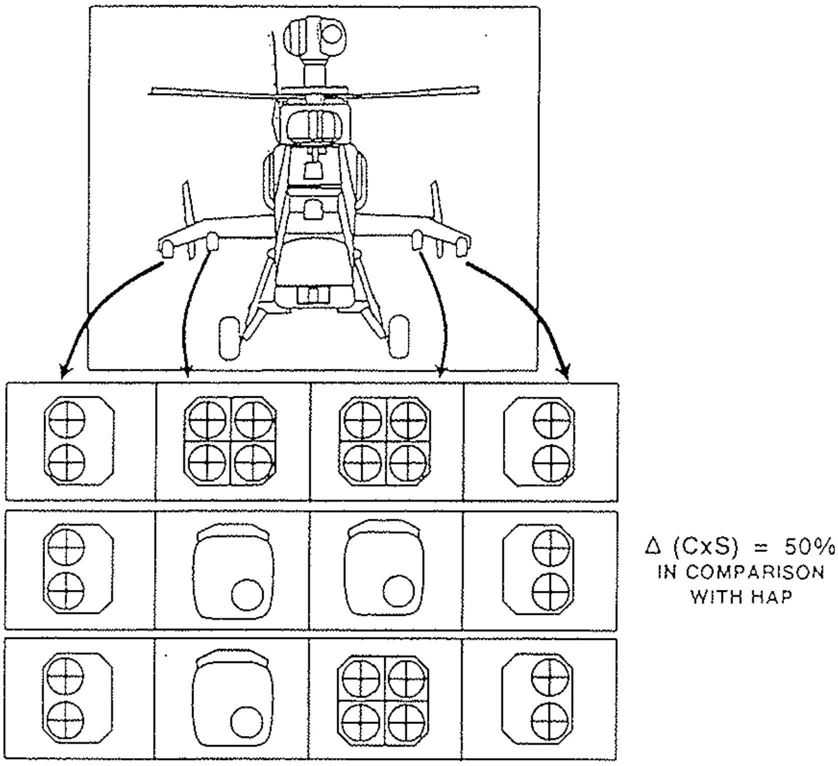

fig.4 EXTERNAL STORES FOR ANTI-TANK MISSION

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* e.g. it is important to have a large and very efficient tail rotor when flying NOE (hover, yaw speed); this rotor is not necessary in air-to-air combat and can even produce an undesirable high drag.

EUROCOPTER thus had to demonstrate a very large flight envelope during development to ensure that the requirements particular to both versions could be met by a common vehicle.

3. FLIGHT ENVELOPE ASSOCIATED TO NOE AND ANTI-TANK MISSION

3.1 Hover

Hover OGE can be maintained without wind, at 1000 m, 25°C and 5400 kg AUW with a 17% margin between the power necessary for flight and the power effectively available. Fig. 5 shows the envelope explored with reduced coordinates **($W/\delta = f(M/\delta)$**. It has been demonstrated that the 17% margin selected as a criterion by the French and German Official Services corresponds practically to the capability to climb vertically at take-off power and V_Z = 1000 ft/mn; this is the criterion usually retained for combat helicopters (Ref. 6).

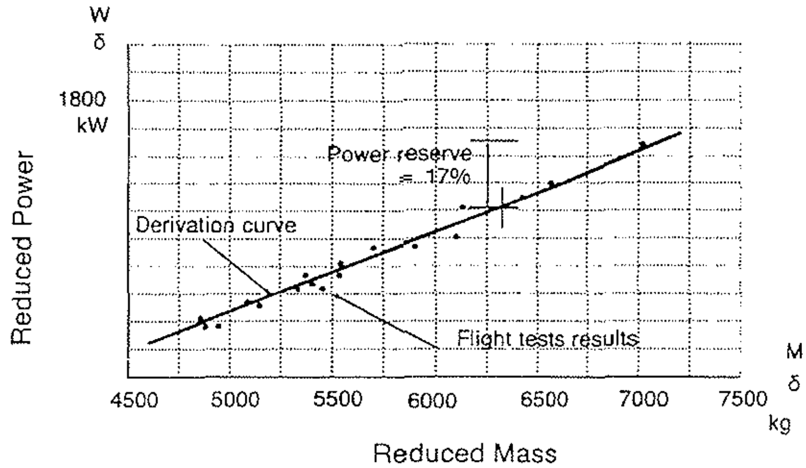


fig.5 HOVER PERFORMANCE (OUT OF GROUND EFFECT)

3.2 Manoeuvrability

Hover performances are to be maintained whatever the wind direction and force may be. The limitations in this case are power or control margins related with respect to rudder pedals' stops, in particular. With TIGER at 5400 kg AUW, as shown in Fig. 6, 60 kt winds were demonstrated for every heading and even 70 kt winds aft with accurate heading and height control. This envelope was the result of a high tail rotor thrust and very efficient air intakes that are protected against exhaust gaz reingestion.

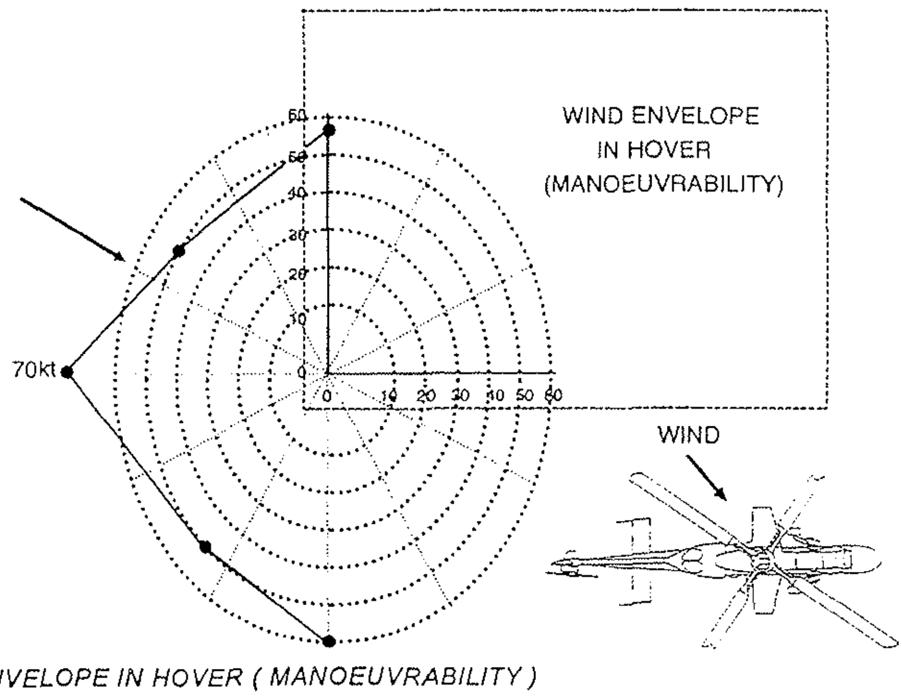


fig.6 WIND ENVELOPE IN HOVER (MANOEUVRABILITY)

Forward flight i.e. head wind induces only slight variations (2° approx.) in longitudinal attitude with a low 4 per rev. vibration level allowing for accurate sighting (<0.1 g)

3.3 Yaw handling

To face a threat in hover or at low speed, one must have a high yaw speed over a rudder scale either to move or stop the helicopter accurately at a given heading.

As shown in Fig. 7 and 8, yaw speeds up to 120°/s to the left and to the right can be reached thanks to the high tail rotor thrust associated to a quick engine response at a given power input.

TO THE LEFT

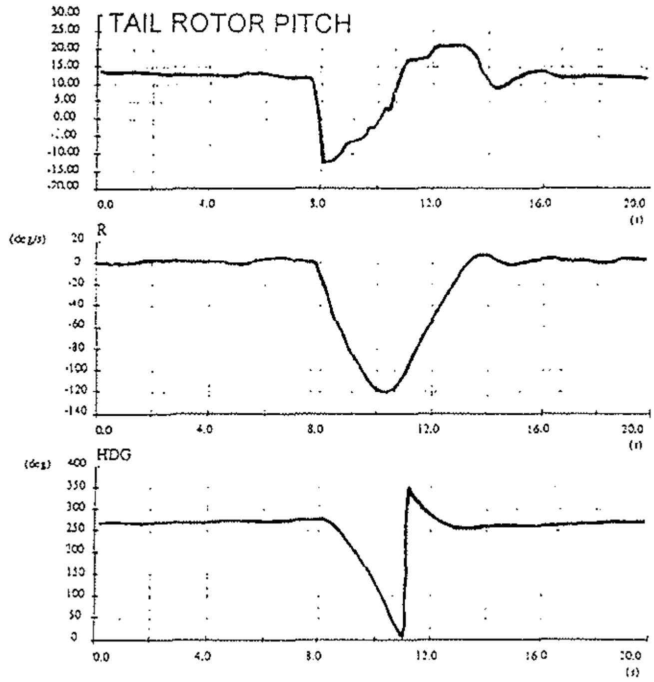


fig.7 SPOT TURN (I.G.E.)

TO THE RIGHT

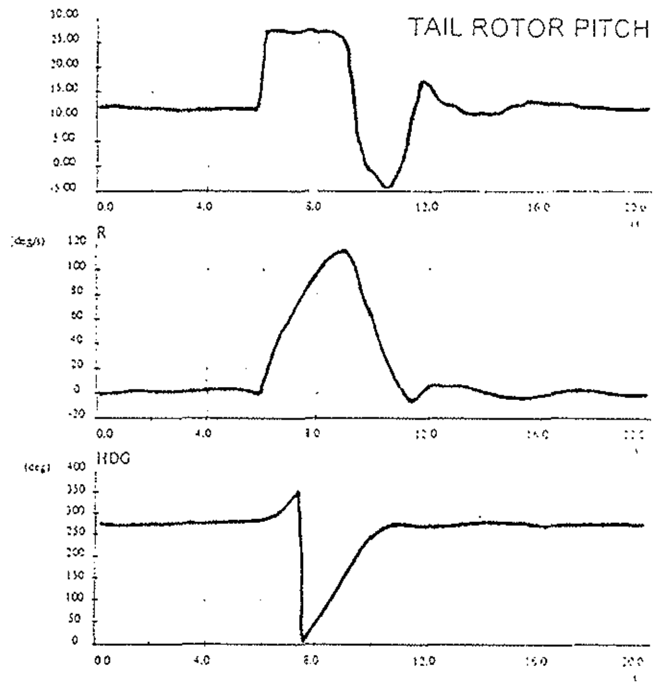


fig.8 SPOT TURN (I.G.E.)

3.4 Accelerations and decelerations

The capability to reach a given speed very quickly from hover depends on the power margin and aircraft handling. Fig. 9 shows that an acceleration from hover to 60 kt is possible in less than 8 seconds.

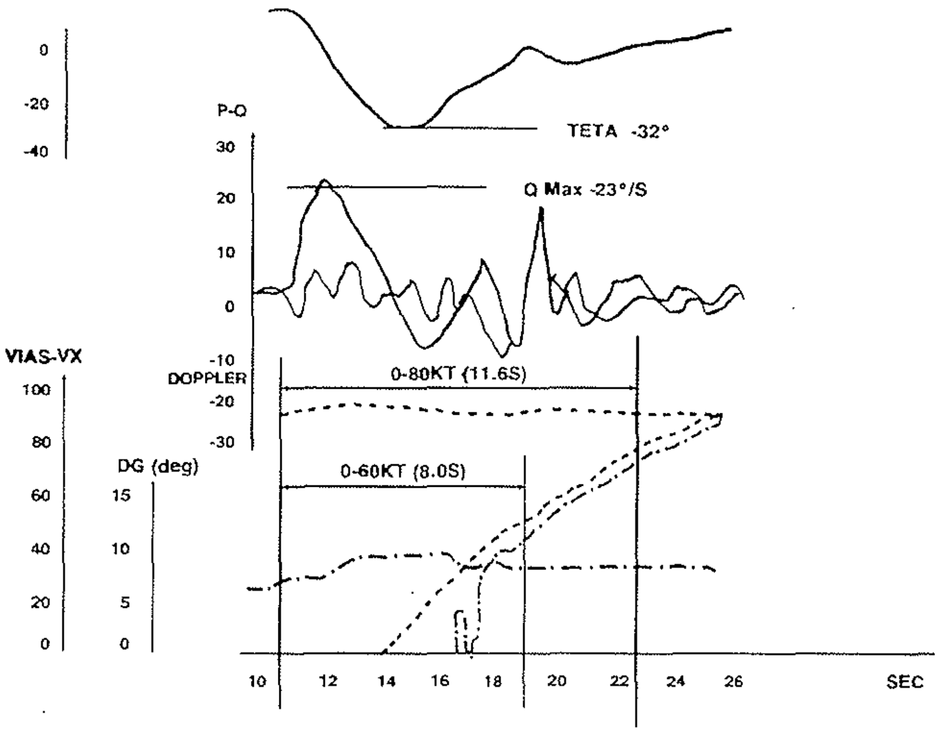


fig.9 ACCELERATION FAST TRANSITION FROM HOVER TO FORWARD FLIGHT

The deceleration values obtained are mainly related to the rotor inertia which allows high quick stops without imposing a very delicate rotor speed control and with satisfactory engine reactions. Deceleration from 60 kt to hover in 11 seconds is possible .It is to be noted that helicopter drag is only a secondary effect in this type of performance (Fig. 10)

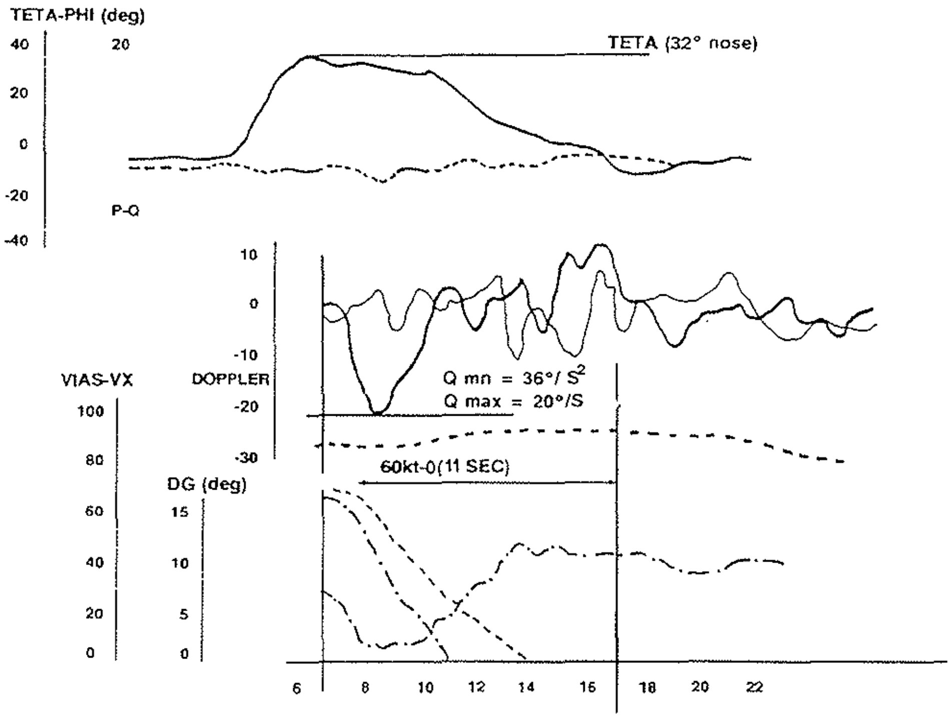


fig.10 DECELERATION FAST TRANSTION FROM 60 kt TO HOVER

3.5 Ability to avoid obstacles

Typical manoeuvres give a qualitative indication of the helicopter's ability to avoid obstacles (Ref. 3). Fig. 11 shows how the Dolphin helicopter is flown over regularly spaced obstacles. The rotor handling capability helps obtain 2 to 0 load factors very rapidly. The ability of the different sub-systems to withstand negative load factors allows performing this manoeuvre with a high degree of safety.

Fig. 11 shows the slalom (horizontal obstacle avoidance) manoeuvre. In this manoeuvre, as with angle holds in the wind, the tail rotor thrust allows manoeuvring with short distances between obstacles.

Fig. 11 shows a half-turn from 120 kt. This manoeuvre is associated to the ability to hold load factors in turn at a constant altitude, and its performance is mainly determined by the power reserve available at the speed considered.

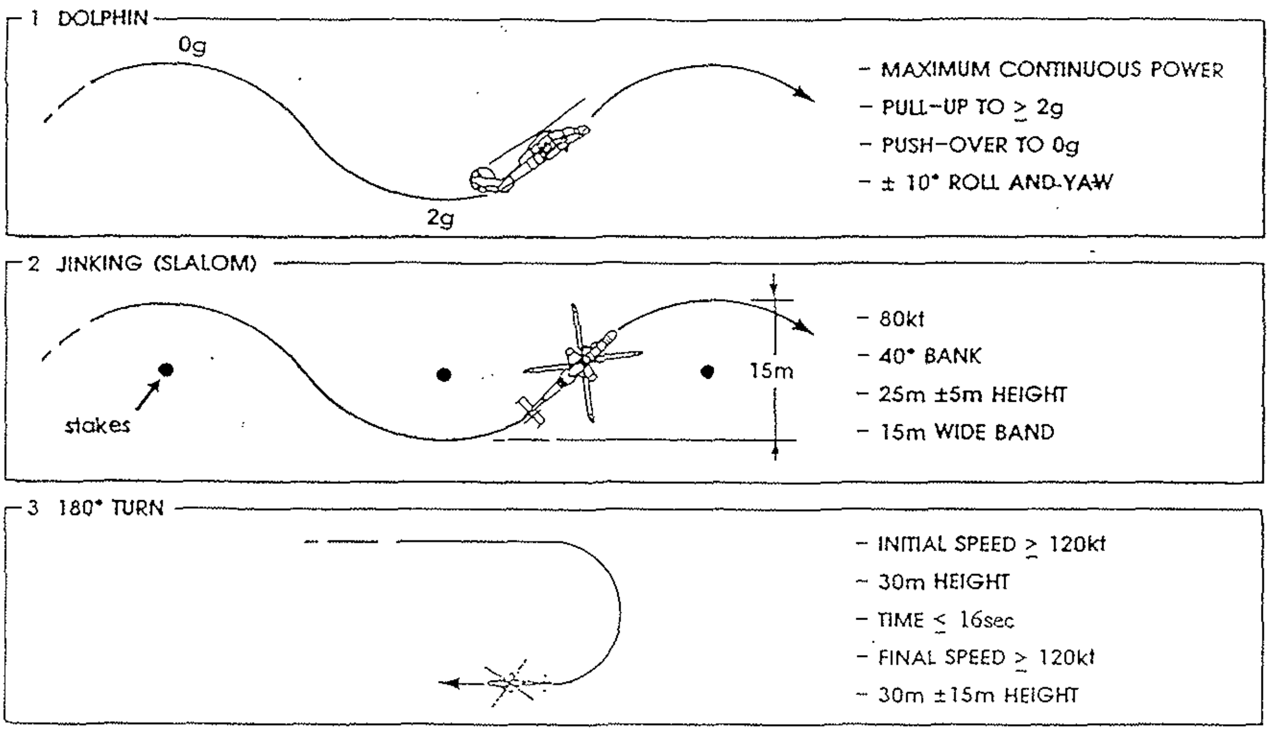


fig. 11 AGRESSIVES MANOEUVRES (MISSION TASK ELEMENTS)

4. FLIGHT ENVELOPE ASSOCIATED TO AIR-TO-AIR COMBAT AND FIRE SUPPORT

4.1 Power reserve associated to a quick engine response

TIGER engines and transmissions limitations ensure 1500 kW power up to 1500 m ISA + 20°C. This helps obtain high climb speeds (2500 ft/mn approx. in the conditions described above) and furthermore, the FADEC governor available with MTR 390 engines allows quick pitch increases throughout the altitude and temperature envelope (from autorotation to 95% take-off power in 1 s at sea level).

4.2 Speed envelope

True airspeed in level flight is almost constant in the HAP configuration and equal to 155 kt at 5400 kg mission weight whatever the altitude may be. As shown in Fig. 12, V_D (111% VNE) was demonstrated throughout the altitude envelope. It must also be reported that this was also demonstrated in the configuration with mast mounted sight (HAC or UHU); a high dive speed can prove an advantage when UHU is flying a ground support mission.

DENSITY ALTITUDE / TRUE AIRSPEED

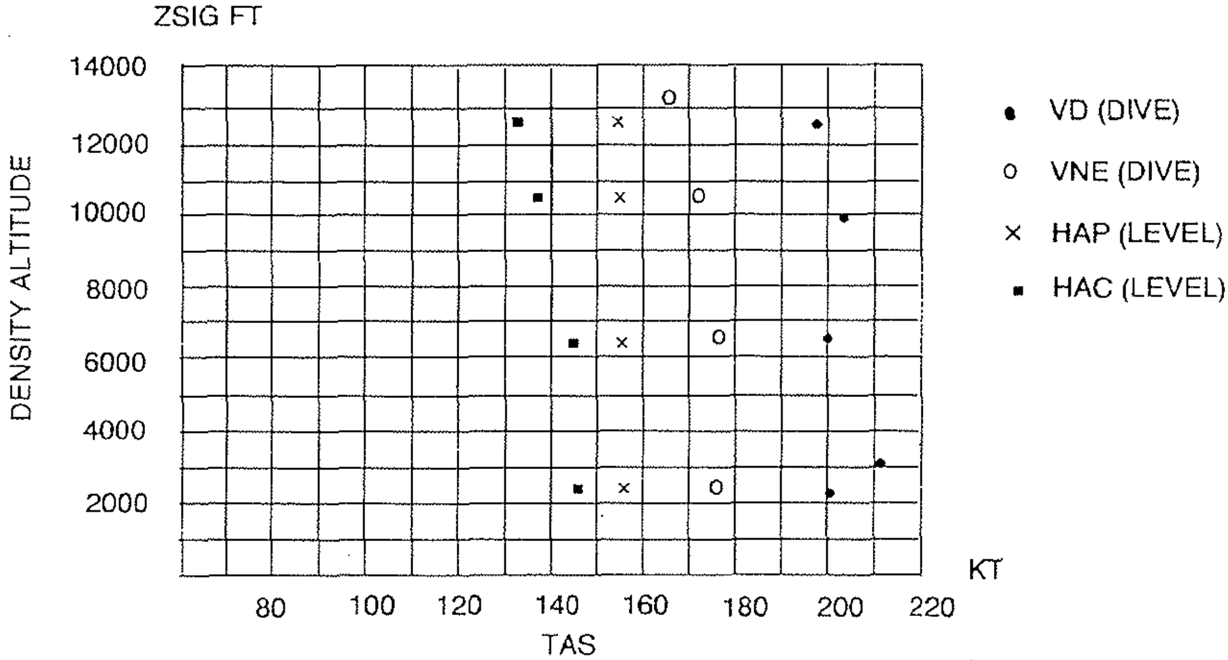


fig.12 FLIGHT ENVELOPE

4.3 Load factor

Selecting new generation blade airfoils helped demonstrate high manoeuvre limitations. Fig. 13 shows with the usual parameters $C_T/\sigma = f(\mu)$ the maximum (stall) values in descent with stable load factor and constant speed. Negative load factors can be obtained with combined cyclic pitch movements forward and collective pitch reductions. One should remember that TIGER hydraulic, fuel and engine/transmission lubrication systems were designed to operate without limitation at $n < 0$. Having a 10% flapping hinge offset with a rigid rotor helps retain an excellent controllability in this type of manoeuvre, but it is in the next point that this characteristic is most useful.

Ref. for load factors: 5,4t 0m ISA, Nr=329 rpm

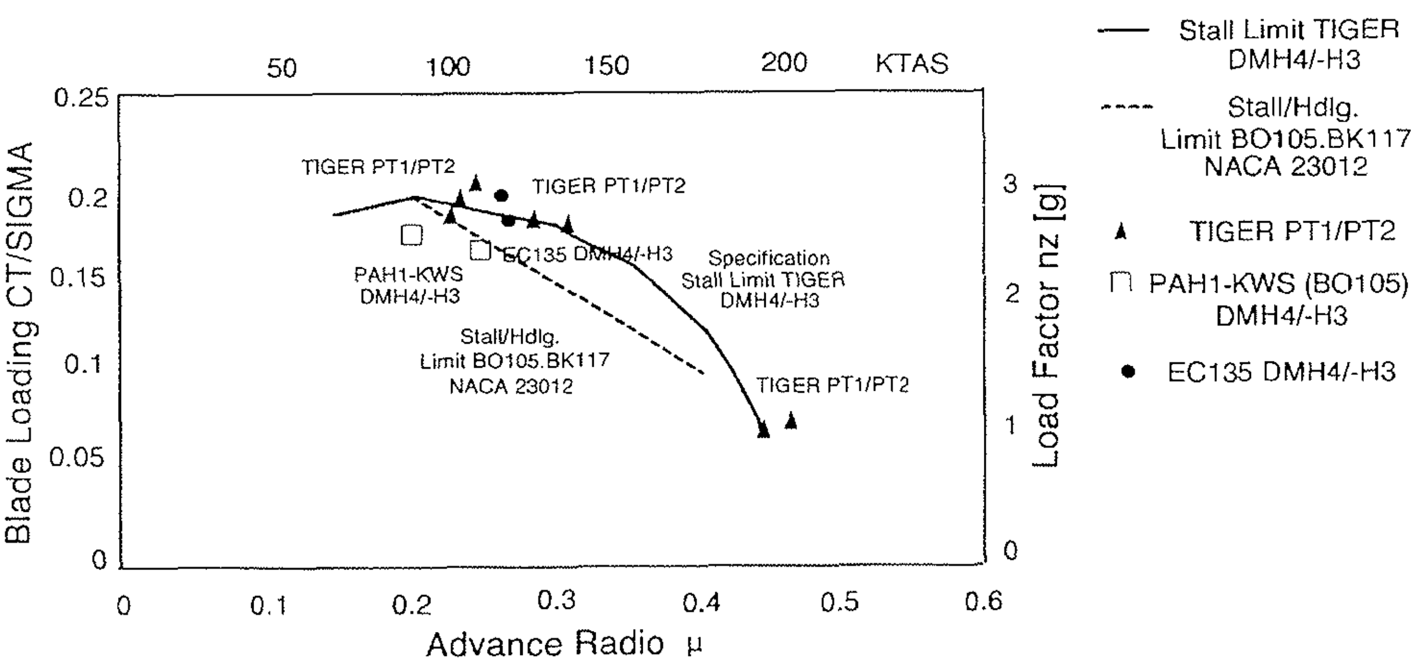
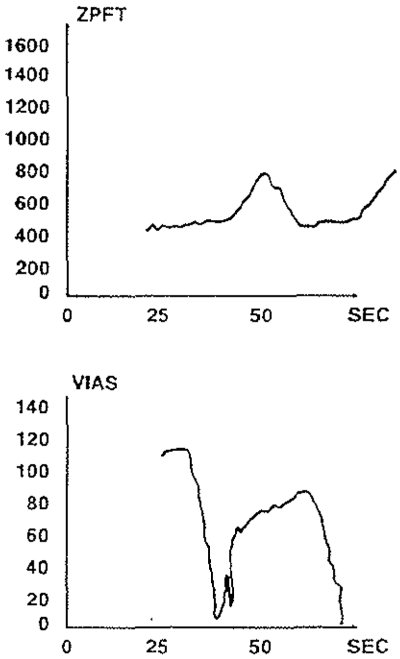


fig.13 BLADE LOADING ENVELOPE

4.4 High angular pitch and roll speeds

The high control power associated with the rigid rotor allows performing aerobatics (loop, reversal,pushover barrel etc). In the loop it is, for example, noted that pitch speeds are significantly higher than in helicopters with hinged rotors (e = 3.8%) (Ref. 4). Fig. 14 shows the evolution of the different parameters and demonstrates the capability to perform the manoeuvre concerned without losing altitude.



	TIGER	AH 64
ENTRY SPEED	120Kt	140 Kt
LOAD FACTOR	2.6/2.4	2/2.6
MANOEUVER DURATION	16 SEC	19 SEC
Δ ALTITUDE	0	- 170 ft

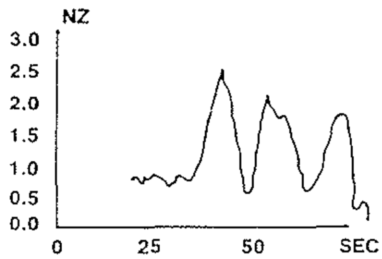


fig.14 LOOP COMPARISON RIGID / ARTICULED ROTOR

In roll, the high control power is illustrated with the angular speeds obtained during turn reversal (Fig. 15).

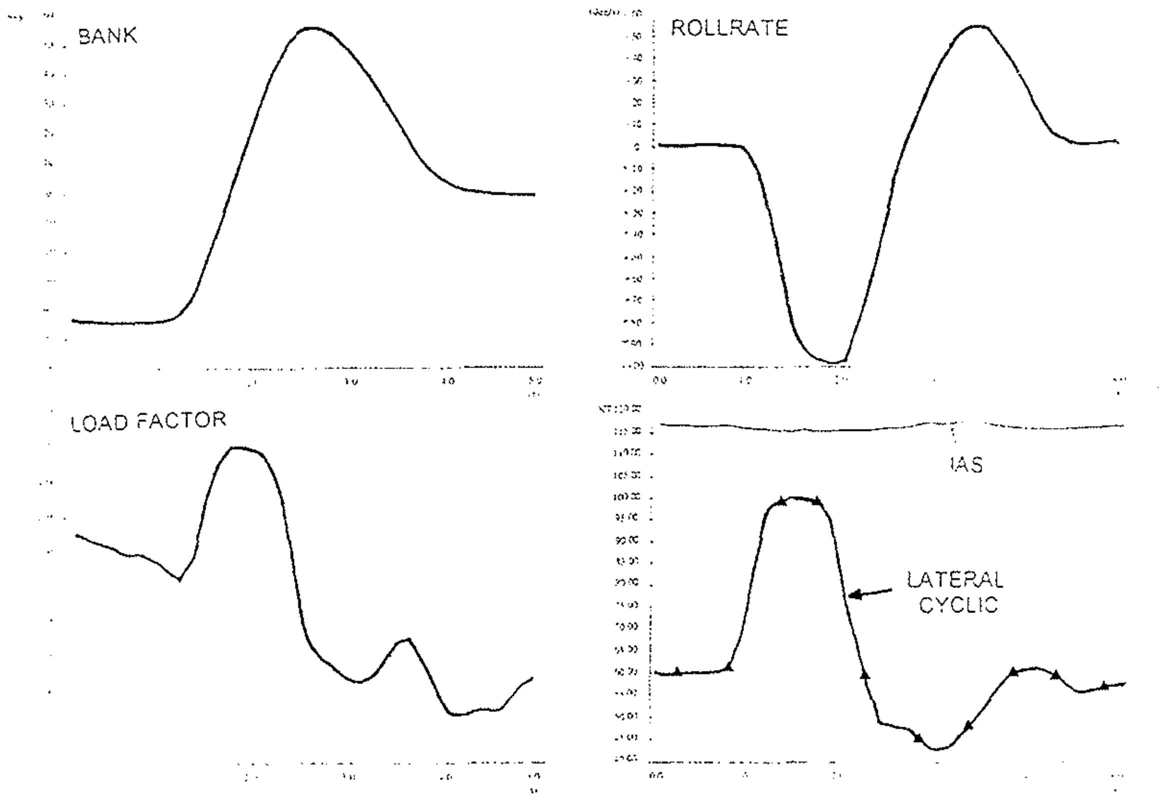


fig.15 ROLL MANIABILITY (REVERSAL)

4.5 Handling qualities - Vibration level

TIGER is operated with a duplex AFCS which always remains on in flight. The stabilization obtained at high speed allows for a satisfactory sighting accuracy with the head-up display (HUD) or helmet-mounted sight display (HMSD). Sighting is also made easier by the <0.1 g, 4 per rev vibration level in the cabin up to VD.

5. ADVANCED ROTOR TECHNOLOGY - ORIGIN OF TIGER MISSION CAPABILITIES

An optimized power transmission excepted, the subsequent application of avanced main and tail rotor technology have also played a part in TIGER's excellent agility as required in the missions discussed above.

Their main features are:

- The use of modern rotor blade airfoils (DLR DMH4/H3 series for the main rotor and ONERA 0A313, EC S102Z for the tail rotor)

- The FEL (Faser - Elastomerlager) main rotor system, an evolution of the BÖLKOW hingeless main rotor including a damage tolerant hub made of composite materials

- The SARIB anti-vibration system i.e. a suspension with soft bending moment and stiff torque for the main gear box / main rotor mast assembly

Excellent high lift, high drag divergence Mach number and improved flapping stability close to stall are DMH4/H3 design requirements that were demonstrated during flight tests. High 210 KTAS speed in dive, 16 KTAS beyond the limit speed specified for structural design, were reached during VNE exploration flight tests without reaching the rotor loading or aircraft control limits. Furthermore, TIGER's capability to withstand a 2.9 g load factor in sustained turns at 119 kt with collective fixed (5400 kg AUW at sea level) was evidenced during flight tests and demonstrated, amongst other things, a progress in rotor aeromechanical technology with stationary blade loading equal to:

$$C_T/\sigma = 0.2 \text{ with an advance ratio } \mu = 0.2 \text{ (Fig. 13)}$$

The first indications of this blade loading in stationary manoeuvres became apparent during the development flight tests undertaken with the upgraded BO105/PAH1 - KWS and EC 135 main rotors, both of which have the same airfoil technology as TIGER.

An excellent angular agility about TIGER's body axes is provided by the FEL hingeless main rotor that offers a high 10% equivalent hinge offset.

A preliminary evaluation of AFCS development flight tests as regards handling qualities as listed in ADS 33C (tracking task) has shown level 2 (roll axis) and level 2 to 1 (pitch axis) assessment locations in bandwidth with low phase delays (see Fig. 16 and 17)

TIGER's agility with a faster pitch response after a longitudinal control input compared to that of a helicopter with lower hinge offset (e.g. 3.8%) is apparent (see Fig. 18)

Although the main rotor blades were tuned to reduce the transmission of 3 and 5/rev hub moments, the fuselage vibration level is further improved with the SARIB system which allows for robust and reproducible anti-vbration tuning at the main gear box / fuselage interface. As a result, TIGER vibrations are very low (less than 0.1 g at 200 kt) at the crew stations

TARGET ACQUISITION AND TRACKING AND AIR COMBAT MTEs
TIGER PT2 (UGR), 5748kg, xcg 7.07m 100kts, Step input
AH-64, 120kts

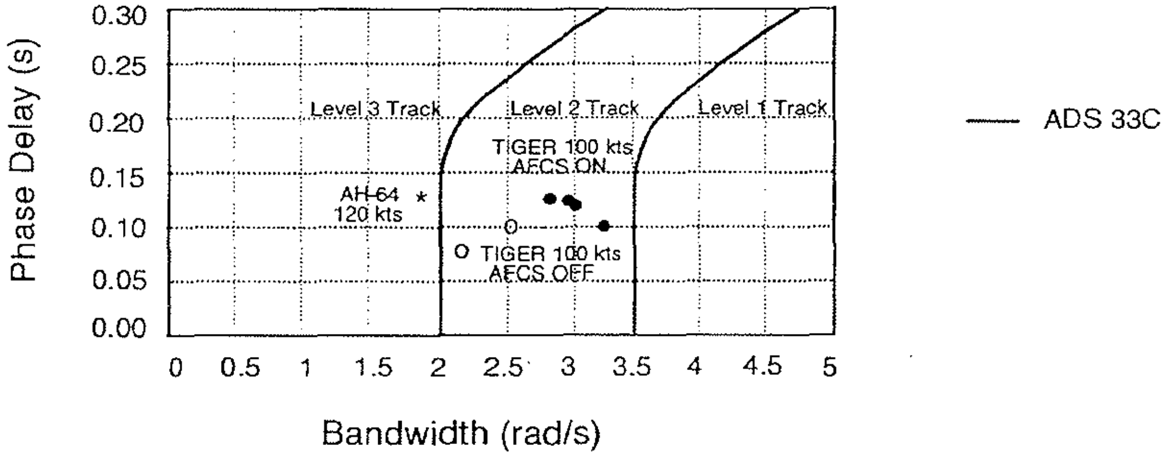


fig.16 ROLL AXIS PHASE DELAY VS BANDWIDTH

TARGET ACQUISITION AND TRACKING AND AIR COMBAT MTEs
TIGER PT2 (UGR), 5748kg, xcg 7.07m 100kts, Step input
AH-64, 120kts

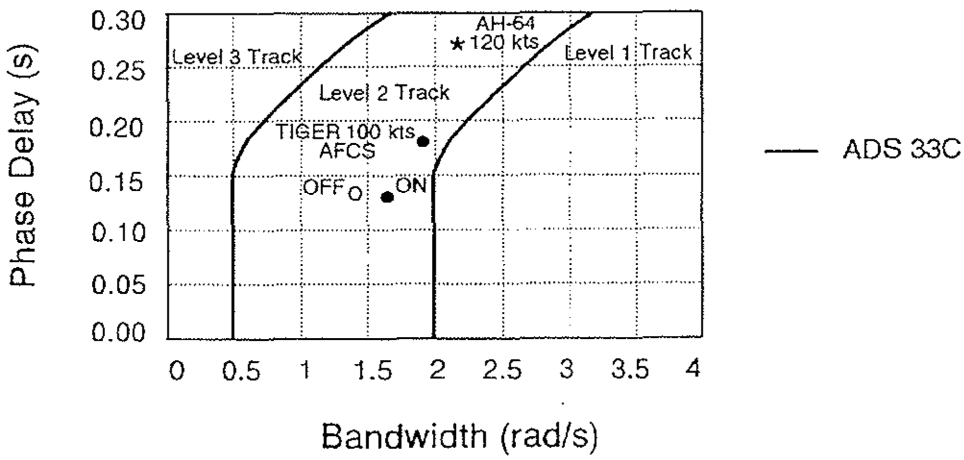


fig.17 PITCH AXIS PHASE DELAY VS BANDWIDTH

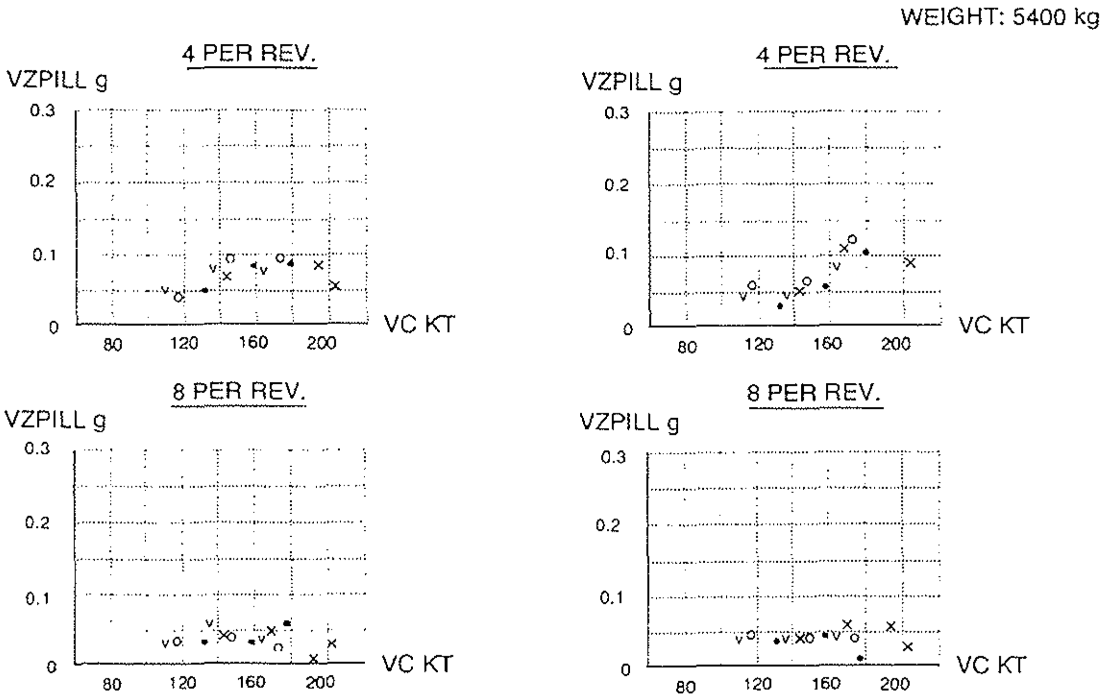


fig.18 VIBRATION LEVEL 4 AND 8/ REV LEVEL FLIGHT AND DIVE

6. CONCLUSION

The design and development of a common vehicle for the TIGER anti-tank and anti-helicopter versions are materialized by a high speed, load factor, angular speed, power variation etc. envelope. Considering its agility, performances and wide operating range, TIGER is a suitable platform for very different weapon systems common to every combat helicopter missions.

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