THE ACHIEVEMENT OF AERODYNAMIC GOALS ON THE EH101 PROJECT THROUGH THE "SINGLE SITE" CONCEPT

C.Mazzucchelli, Costruzioni Aeronautiche G. Agusta, Milan, Italy
and
F.T. Wilson, Westland Helicopters Ltd., Yeovil, England

ABSTRACT

The paper describes how major aerodynamic targets for the EH-101 helicopter have been accomplished by a joint approach combining the resources of two companies in the " Single Site Concept ".

The fact that collaboration in development was a necessity, influenced by the expectation of time and cost savings associated with the reduced number of tests and components required in a combined operation, lead to the conclusion that a joint flight test development activity would be better than separate programmes and " Single Site " operation was conceived.

The first pre-production version of the EH-101 Helicopter, PP1, was transferred to Cascina Costa from Yeovil in December 1989, and the first flight test development period was conducted on this airfield, sharing the activity with the Italian made PP2 version. Specialists from both companies worked together on each aircraft to understand and attack the difficulties shown by the initial flights where several topics of aerodynamic concern were identified.

The aim of the aerodynamic development program was to optimize the aircraft as an integrated machine with the main and tail rotors, air frame and engines working effectively together throughout the flight envelope including, sideways/rear wards flight and high forward speeds. Areas to be considered were performance in hover and forward flight as well as handling (including aerodynamically induced vibrations), etc.

During the initial development period some key aerodynamic related issues were prominent, such as shuffle, pitch up and performance. The paper describes the systematic approach to the solution of these important problem areas, using scale model testing in the wind tunnels of both companies complimented by C.F.D. (Computational Fluid Dynamics) and simulation codes followed by confirmatory flight tests.

Single Site operation has undoubtably accelerated the aerodynamic development process and successful results are reported.

1. Introduction

The EH-101 project was initiated in 1981 as a *collaborative programme*, between Agusta and Westland, under the management of EHI, with the objective of developing 3 different variants: Civil, Naval and Utility. It evolved as a 5 bladed, 3 engined *machine with* a max weight of 14290 Kg and a max speed of 167 Kts.(**Ref.1**)

During the aircraft design process , weight minimisation and maintainability issues were paramount. Main rotor behaviour was well predicted, based on the large investment made in rotor technology in the past, ensuring that maximum performance/minimum weight targets were met in the design. Airframe aerodynamics, however, particularly interactional effects, were less quantifiable and often in direct conflict with the weight/maintainability objectives (since optimum aerodynamic design usually entails additional fairings). The design aim in this case therefore, was to address any airframe aerodynamic issues as and when they occured and to have contingency plans ready if needed.. From the aerodynamic viewpoint, the interactional problem was accentuated because of design for compactness required by the shipboard dimensional constraints. This lead to higher disk loading, which increased the energy levels in the main rotor wake and the consequent potential for aerodynamic interactional effects. (**Ref.2**)

In 1988 two basic prototypes of EH-101 were at the beginning of their flight activity, one at Yeovil (U.K.), and the other at Cascina Costa, Italy.(**Figs.1 & 2**). The first flight test phase is, generally, the most critical because all the initial problems are experienced simultaneously by the helicopter. Both EH-101 prototypes *have followed* this trend, showing several common areas where improvements were needed. At the outset of development activity, mechanical TBO's were low and the spares pool was increasing only slowly, leading to only limited flying time to deal with any aerodynamic problems suffered by the aircraft.

"Integration" was considered to be the best way to overcome these difficulties, so an integrated test activity and team of specialists was thought to be the solution for the EH-101 Programme, thus leading to the creation of "Single Site Operation". This paper, therefore, not only describes the operational aspects of "Single Site" but also deals with major aerodynamic issues in some detail.

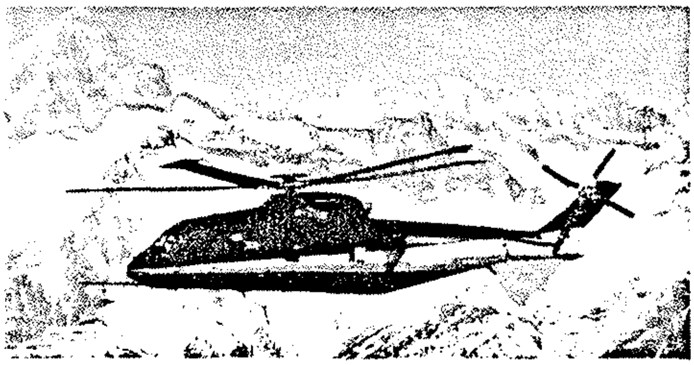


Fig.1 : PP1 IN ITALY

Fig.2 : PP2

2. Single Site Operation

Single Site Operation means that all basic Development activities should be performed in a unique location.

Initial Development activity was firstly shared between two Basic Prototypes, PP1 and PP2 located at Yeovil (U.K.) and Cascina Costa (I) respectively. To meet the Single Site requirement one of them had to be transferred; Cascina Costa was chosen mainly for the more stable weather conditions, and a dedicated team of ground and flight crew was transferred from the U.K. together with the PP1 Prototype at the end of 1988.

However Single Site had not only to cover these operational aspects. The main goal of the Single Site Concept was to find solutions to some undesirable characteristics exhibited by the helicopters in their early flights, ranging from performance to handling qualities, and involving the activity of a number of Departments from both companies such as: Aerodynamics, Dynamics, Vibration, Power Plant, Structures, Rotors, and so on. Therefore a dedicated Engineering Team with specialists from both Agusta and Westland was created and located at Cascina Costa.

The flight test programme was defined by consideration of a specified list of topics together with their priorities and an indication, for each of these topics, of the Engineering Departments involved. A joint fortnightly meeting was convened and attended by all the involved groups, giving evidence of the progress achieved and making plans for future activities. The opportunity offered by these meetings to debate a single topic contemporarily with all interested parties, reduced the risk of disregarding any aspect of the problem, thus helping to find an acceptable practical solution to the integration problems. All engineers involved had visibility of the impact their activity made on the global development phase.

The best way to tackle any problem was jointly identified, taking into account the hardware capabilities and expertise provided by both companies, their effectiveness and availability. As an example, wind tunnel facilities of different dimensions were used for different purposes; global aerodynamic behaviour of the helicopter (drag breakdown, stability characteristics) was investigated on a 1/7th scale model in the Westland Wind Tunnel (**Fig.3**), while the Agusta facility was devoted to the optimization of specific items, studied on partial 1/5th scale models (Rear Fuselage, Tailplane, Fin) (**Fig.4**)

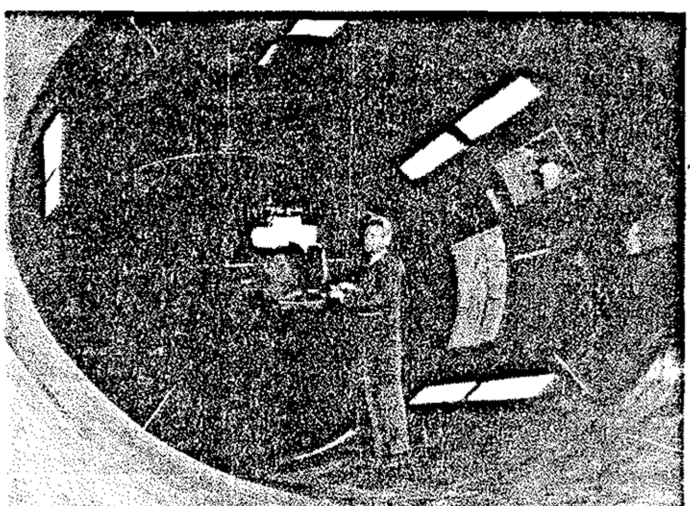


Fig.3 : EH101 MODEL IN WHL WIND TUNNEL

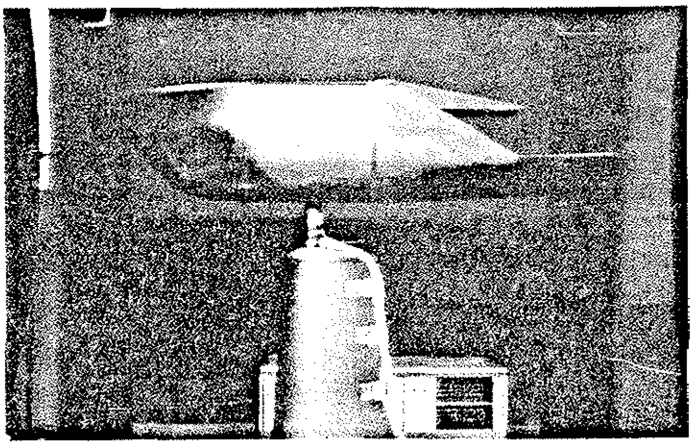


Fig.4 : UTILITY MODEL IN AGUSTA WIND TUNNEL

Once a promising solution to a problem had been identified, a dedicated flight test activity was performed to confirm the validity of the proposed solution which often necessitated the manufacture of various prototype components. The possibility provided by Single Site Operation of having both flying prototypes available, reduced the required number of components to be manufactured, since the same component could be alternatively tested on either PP1 or PP2, thus reducing the costs of various activities.

Furthermore, experimental flight test activity was accelerated because only rarely were both prototypes simultaneously grounded for lay-up; the availability of two prototypes making the flight test activity management much more effective. Another advantage could be found in the relatively short time required to provide the specialist team with the flight test results, thus reducing data analysis time, and improving communication aspects.

A measure of the effectiveness of the Single Site Operation concept, is the considerable amount of work performed and results achieved, from the aerodynamic viewpoint, in only two years of activity on two basic prototypes.

3. Aerodynamic Issues

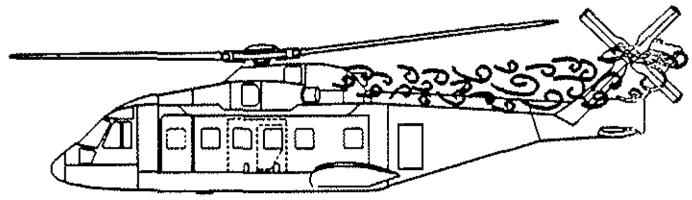
As previously stated, the original emphasis in EH101 airframe design was in weight minimisation, manitainability, fail safe design, blade and tail folding capabilities etc. This inevitably led to some aerodynamic problems in the early test flights.

These aerodynamic/interactional problem areas identified by the Single Site management were as follows, in order of priority:

1) Shuffle
2) Pitch-Up
3) Performance Optimization - Drag Reduction
4) Engine Exhaust Reingestion

3.1. Shuffle

"Shuffle" was identified as an aerodynamic excitation of the lateral fuselage bending mode resulting in an unpleasant random vibration centred on 7Hz frequency which became progressively worse with increasing speed. This "buffeting" was caused by the wake shedding from main rotor head and cowlings, and striking the vertical fin and tail rotor (**Fig.5 and Ref.3**).



Turbulent wake from pylon/rotor head area affects fin/tail rotor

Fig.5 : ORIGIN OF SHUFFLE

The minimization of this effect was conceived to be achievable by two lines of approach, viz:

* Drag Reduction of rotor hub and cowls, thus reducing flow unsteadiness at the. empennage location.

* Flow deflection, bringing a more stable airflow to the fin and tail rotor area (**Fig.6**).

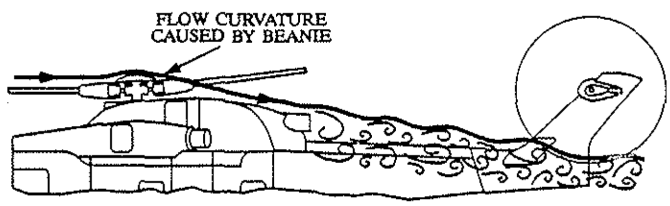


Fig.6 : EFFECT OF BEANIE ON WAKE

The first method will be discussed more fully in the Performance Section of this Paper, but it can be said here that drag reduction modifications such as an extended centre engine cowling and rotor hub fairing produced significant reductions in the Shuffle effect. (**Fig.7**)

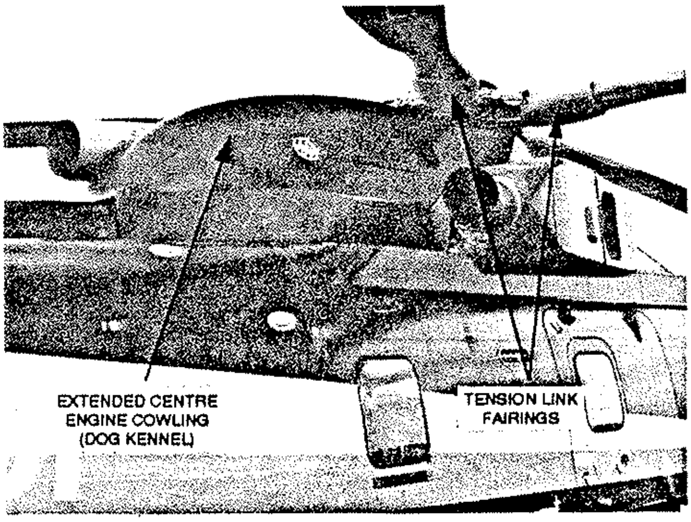


Fig.7 : DOG KENNEL AND TENSION LINK FAIRING

The second method involved the use of standard lift producing devices such as beanies or horse collar (**Fig.8**). Other less well known devices were also tried with varying success (such as winglets on the engine nacelles and vortex generators).

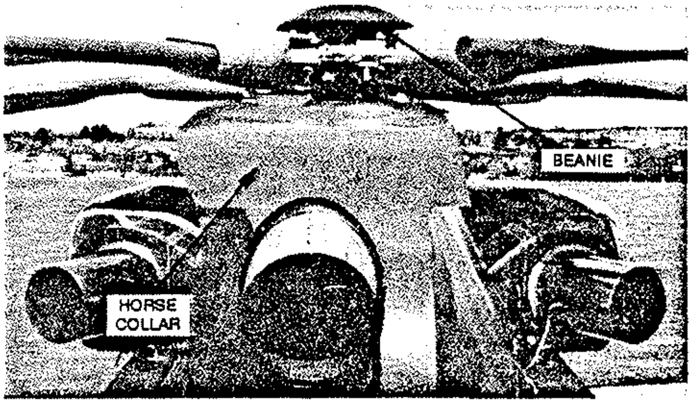


Fig.8 : BEANIE AND HORSE COLLAR

The first priority was to find an acceptable "shuffle reduction package" which would allow general flight testing to be performed up to high speeds. This initial solution was found to be given by the following configuration:

* Large Beanie
* Complete Tension Link Fairings
* Horse Collar and Forward Pylon Fairing
* Nose-Up Tailplane Setting

Operational requirements for the production aircraft prohibited the use of the Large Beanie, and Complete Tension Link fairing for shipboard stowage and blade folding considerations respectively. Therefore a more acceptable configuration had to be found for operational use.

During the drag reduction/performance testing it was found that the rear pylon extension (colloquially known as the "Dog Kennel") produced a very marked reduction in the Shuffle vibration even without a large beanie. This meant that a small beanie could now be fitted, facilitating shipboard stowage.

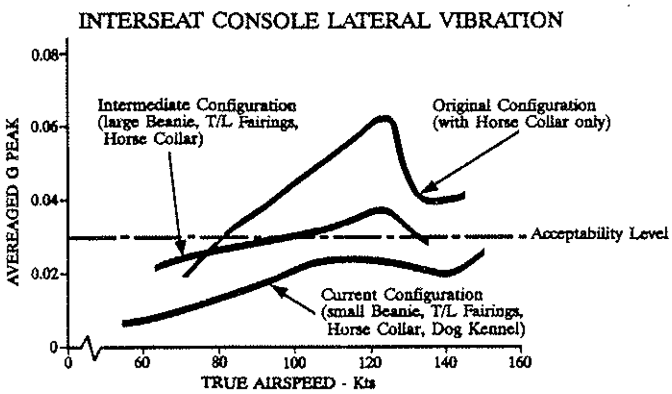


Fig.9 : SHUFFLE RESULTS

Fig.9 shows peak average lateral "g" levels measured at the pilot interseat console location. Initial shuffle effects measured on PP2 indicated unacceptably high vibration levels and the shuffle "package", first employed, reduced this phenomenon down to an acceptable level but the dog kennel effect, by reducing cowls drag significantly, was more marked even without the use of the large beanie.

The question of foldable tension link fairings was not addressed at Single Site but is the subject of continuing investigation. However confidence is high that the "Shuffle" problem is now a thing of the past, and, operationally, will not constitute a problem.

3.2. Pitch up

Initial flight tests indicated an unacceptably high nose up pitch increase, as the aircraft moved forwards from the hover. This was caused by the main rotor wake impinging suddenly onto the tailplane surfaces, causing a high download at the rear of the aircraft. The amount of pitch -up depends on the tailplane area and position, rotor downwash distribution and rotor head control power.(**Fig.10**).This is a problem often encountered in helicopters with fixed low set tailplanes, (a symmetrical low set tailplane was the initial EH-101 configuration) and has traditionally been cured by using either a high set tailplane or an adjustable stabilator (as used on the Black Hawk or Apache) (**Ref.4**). The latter device swivels to effectively minimize frontal area in the critical flight regime,and was originally considered as a possible fall-back solution for EH101, but lack of clearance in flares ruled this out. Also, this approach requires additional weight, complication and cost and a more simple solution was sought for EH-101.

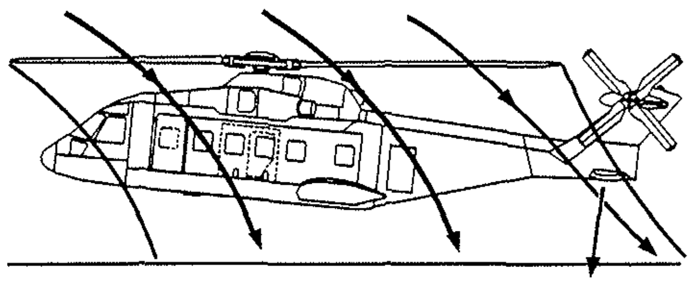


Fig.10 : ORIGIN OF PITCH UP

The simplest way to solve the problem would seem to have been tailplane area reduction but this decrease would have degraded the helicopter dynamic stability characteristics, which were considered to be quite acceptable with the original tailplane - ASE out. These characteristics influenced by two main parameters: tailplane surface area, and aspect ratio.

A compromise solution had to be achieved.

The work to achieve this solution was divided in two phases:

a) Definition of the minimum tailplane surface area, providing an acceptable pitch-up behaviour at low-speed

b) Optimization of the planform shape by increasing aspect ratio as much as possible.

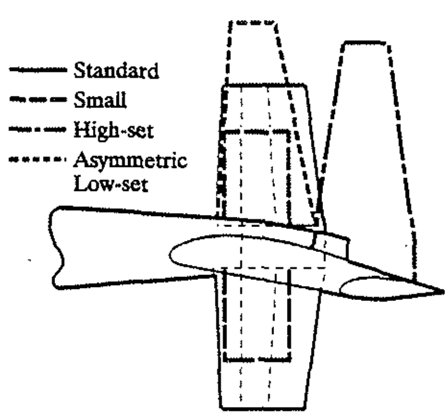


Fig.11 : TAILPLANE CONFIGURATIONS

Phase a) was performed comparing flight data results of various tailplane surfaces with different areas (**Fig.11**), and a final value was defined. During this phase, a high set configuration was also tested, providing the best results, both in terms of pitch-up and dynamic stability characteristics, but operational requirements, such as tail folding, necessitated an alternative solution.

LOADING ON SYMMETRICAL TAILPLANE

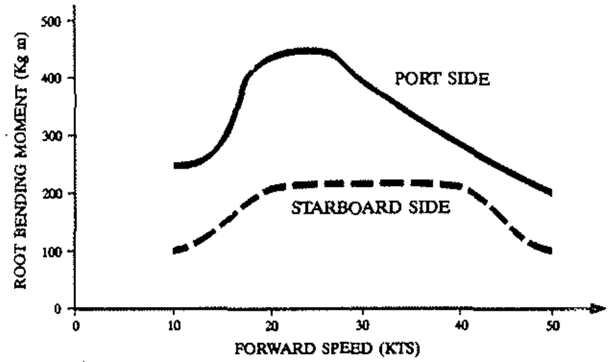


Fig.12 : ROOT BENDING MOMENT

At this point it was realised, after studying tailplane root bending moment data (**Fig 12**) that the majority of the tailplane download at low forward speed was concentrated on the port side of the symmetrical low set tailplane and the single sided, low set , high aspect ratio tailplane appeared to be a viable solution. Maximum pitch-up levels were subsequently found to be acceptable (although slightly greater than those for the high set tailplane) (**Fig 13**). Also wind tunnel testing showed the tailplane effectiveness at high speed was equal to that of the higher area, symmetric tailplane suggesting that high speed characteristics would be acceptable.

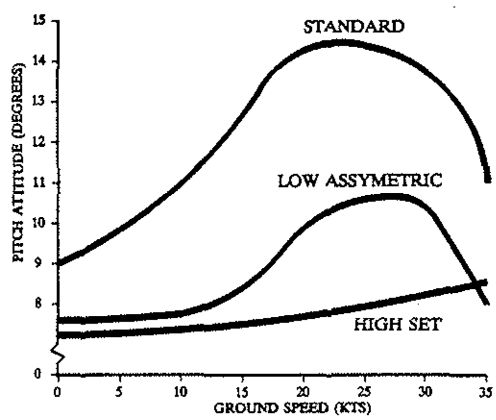


Fig.13 : PITCH UP DATA

Finally to confirm the viability of the new design, its dynamic stability characteristics were computed by the C81 simulation code.These were assessed from the root loci of the longitudinal modes as they varied with the stability derivatives; the latter were used to calculate the "Short Period Stability Parameter" that gives a rating to predict the helicopter Handling Qualities level (Cooper-Harper). This rating is rapidly degraded when the short period stability parameter becomes negative. In case of AFCS failure, the aircraft must remain flyable without excessive pilot workload. To satisfy this condition the Cooper-Harper rating should be no greater than 3.5 to 4.5 at the normal cruise speeds, (**Ref.5**) and the asymmetric tailplane met these requirements.

The success of this design, in reducing pitch-up, was due, not only to a reduction in overall surface area, but also to the location of all this area on the lee side of the main rotor downwash at the tail location, thus reducing tail download in the critical flight phase. Moreover the higher aspect ratio of the revised tailplane results in acceptable high speed stick slope/static stability behaviour similar to those achieved with the original symmetrical tailplane. It must be remembered, also, that the design had to be compatible with tail folding and tail cone strength requirements - a complex design challenge by any standard!

The new tailplane was proved in the successful ship landing trials carried out in the Mediterranean (**Fig 14**).

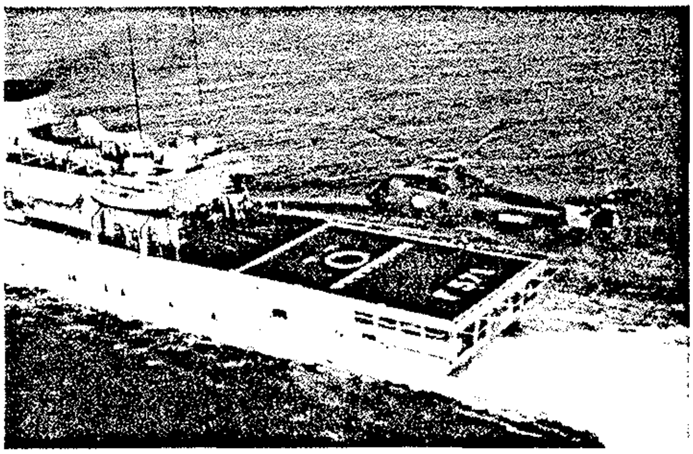


Fig.14 : PP2 - SHIP LANDING TRIALS

3.3. Performance

3.3.1. Hover Initial measurements of hover power required, when projected into the normalised weight range of the naval specification, showed a significant increase over that predicted (probably due to a misestimation of the fuselage download) and a concerted effort was then applied to find a solution to this problem.

In the period between the blade geometry freeze on the EH101 and first flight, anhedral had been developed for the production version of the Lynx BERP blade. Anhedral offers, at least a 2% increase in hover figure of merit, and it was therefore decided to adopt if for the EH101 rotor. The resulting improvement formed the major part of the solution to the hover performance problem.

Other factors affecting hover performance were (**Ref.6**):

* Tail rotor/Fin interaction
* Download of the fuselage due to the rotor wake
* Re-ingestion of exhaust gasses

Tail Rotor / Fin Interaction

Tail rotor fin interaction was treated in the initial design, by means of a canted fin which maximises fin/tail rotor clearance for reduced blockage in the hover. A re-examination of the fin interference effect indicated that a further 50HP could be saved by a trailing edge truncation of 30% chord. However, the resulting cut back fin, reduced the fin offset load in high speed flight, resulting in the need for increased tail rotor thrust. This needed to be restored and confidence is now high that this can be achieved.

Wind Tunnel testing has shown that the use of a specially designed trailing edge, in conjunction with an increased dynamic pressure at the fin location (due to drag reduction measures) and with a redesigned tail rotor gear box fairing can restore the original side load given by the cambered fin at zero yaw. (**Fig.15**). These devices are yet to be flight tested.

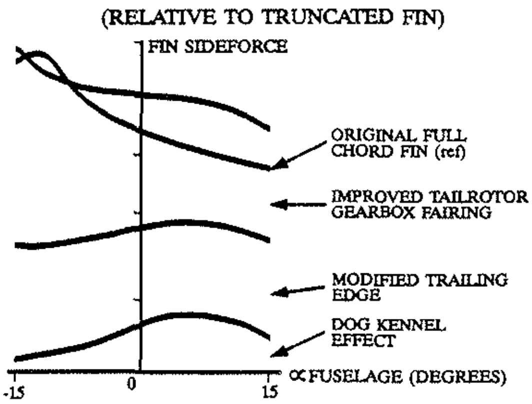


Fig.15 : FIN SIDE LOAD DATA

Fuselage Download

Extensive wind tunnel testing by Agusta showed that tail boom download (which was conceived to be the greatest contribution to download) could extensively be reduced by fitting so called "skirts" to the lower edges of the tailboom. These reduce download by displacing the separation vortices, on the lower corners of the tailboom, vertically downward which reduces base suction. Flight testing with skirts fitted did indeed prove the effectiveness of this device in the hover but prior to acceptance into the production configuration, more thorough flight testing will be required.

Re-ingestion

A succeeding chapter on a re-ingestion will cover this subject more fully, but efforts to reduce re-ingestion to acceptable levels in sideways flight also reduced significantly intake temperatures in hover, thus increasing available power both in and out of ground effect.

Subsequent to the introduction of anhedral BERP tips on the rotor and the adoption of a truncated fin, the aircraft is now achieving better than its original predicted hover performance.

3.3.2. Sideways Flight Many helicopters are subject to limitations in sideways flight and quartering flight capability due to the excessive sideloads (*which oppose the* tail rotor force) generated on the tailboom by the combined effects of rotor downwash and sideways speed. Initial design considerations were to optimally configure the tail boom cross section to reduce this effect but structural and other considerations precluded this option, leaving the contingency solution of a tailboom strake, (as so successfully employed on the Sea King) (**Ref** 7) combined with a *fin* area *reduction if required.* The strake works by separating the flow on the port side of the tailboom thus reducing the suction and associated sideload and relieving the tail rotor force (**Fig** 16).

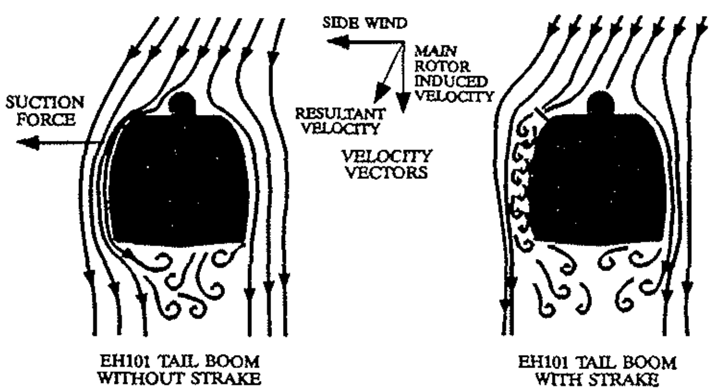


Fig.16 : TAILBOOM STRAKE EFFECT

A *similar* device was *developed in* wind tunnel testing and has been successfully employed on PP2 during Single Site activities allowing the complete flight envelope to be covered. Further optimization of this component is ongoing.

3.3.3. High Speed The main factors *affecting* high speed performance are Drag and Intake Pressure recovery (affecting engine power available).

Extensive testing had been going on in both Wind Tunnels for some years prior to the setting-up of the "Single Site". The objectives were to locate potential problem areas and optimize aircraft geometry where possible. However, the airframe design was aimed at minimising weight and maximising accessibility and consequently the aircraft deviated from the optimum configuration dictated by wind tunnel testing.

The main areas of deviation were

* Unfaired rotor head components
* Truncated cowlings
* Cowling/ventilation arrangement
* Interference drag
* Sponson configuration

One of the first activities, therefore, at Single Site was to supplement this work with in-flight flow visualization. A few flow separation areas were identified, giving a basis for future development activities.

Initial projected airframe drag *estimates* for all variants indicated unacceptable levels, so a comprehensive drag reduction plan was launched at "Single Site" in late 1988 with the objective of reaching prescribed drag targets needed to meet aircraft performance standards. Proposed specified modifications were Wind Tunnel tested and consultations with design, (taking into account such design issues as weight and maintainability), ensured the eventual *viability* of such *proposed* geometry changes.

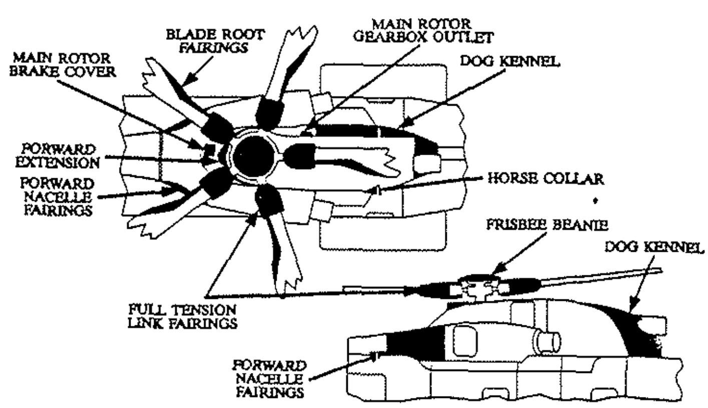


Fig.17 : DRAG REDUCTION MODIFICATIONS 1

Experience from wind tunnel testing led us to a number of major changes which are listed as follows, and are shown in **Figs.17 and 18:**

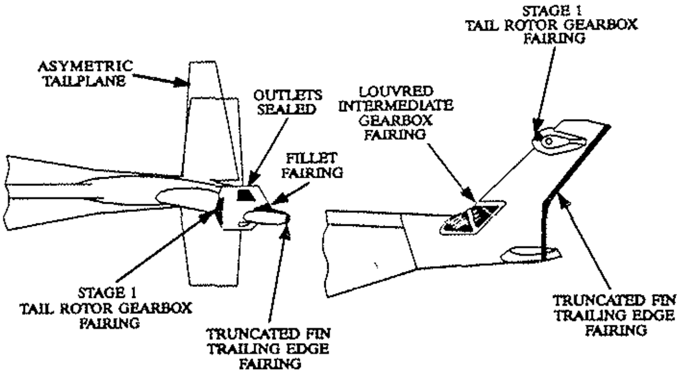


Fig.18 : DRAG REDUCTION MODIFICATIONS 2

* Engine Cowlings geometry changes
* Small Beanie
* Tension Link Fairings
* Blade Root fairings
* Tail Rotor Gear Box fairing geometry changes
* Reduction of cooling drag
* Miscellaneous fairings

These changes were expected to reduce overall aircraft drag area by about 1 m^2. PP1 was equipped with all the drag reduction measures and resulting flight testing verified the anticipated power savings (**Fig.19**), thus substantiating the wind tunnel derived drag reduction work. PP1's maximum speed was increased by about 15Kts on power limits, and because, at a given speed the power was reduced, the result could be seen in lower rotor stresses

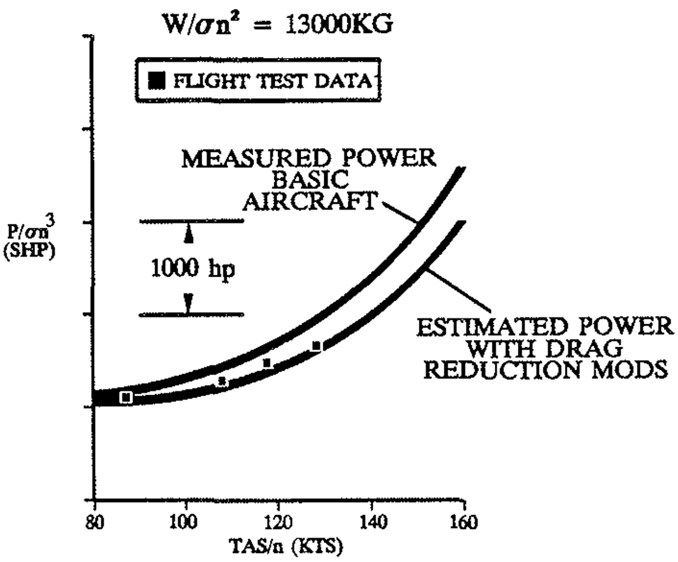


Fig.19 : EFFECT OF DRAG MODIFICATIONS

As well as intensive efforts by aerodynamics and wind tunnel staff to develop effective modifications, the drag reduction programme required a large joint effort of the design, stress and manufacturing departments of both companies to produce required one-off components on-time to meet programme schedules.

3.4. Reingestion

Initial trials on PP1 at "Single Site" indicated some intake temperature increases (although not serious) in Hover, mainly IGE. These temperature changes could also be seen in terms of a low level of engine torque fluctuations.

The origin of the problem lies in the peculiar flow generated within the rotor core. This consists of an upward air current generated by the inboard blade shed vortices, which operate in the opposite sense to the outboard vortices (**Fig.20**)

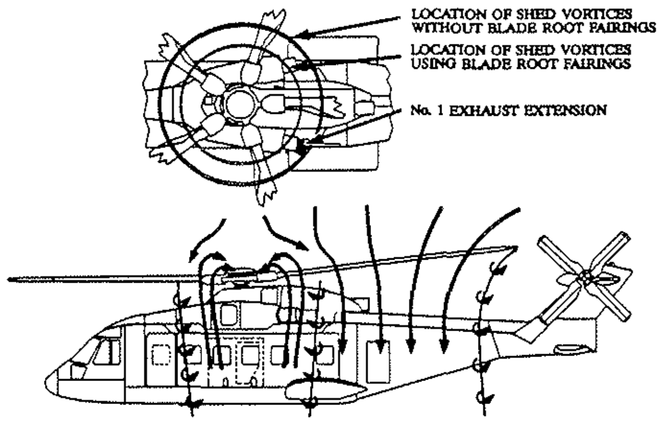


Fig.20 : ROTOR DOWNWASH IN HOVER

Exhaust gases generated within this core are swept upwards by this current thus raising the temperature of the air entering the intakes (which all lie within this core).

Blade root fairings (by extending inboard the location of the inboard shed vortex) and extension of the exhaust pipes reduce this effect, (by ensuring that the exhaust gases reached the main rotor downwash and are swept away from the aircraft) as does increasing exhaust velocity.

At this stage no sideways flight or other low speed manoeuvres, with the specific aim of assessing reingestion, had been performed. Such testing took place for the first time with the "dog Kennel" and the chamfered, enlarged diameter exhaust pipe fitted to number 2 engine cowl at which time an engine surge problem was identified in sideways flight and rear quartering flight to starboard. The problem appeared to be due to a reduction in exhaust jet velocity which allowed the side wind to deflect exhaust gases to the port side of the cowl. The problem seemed to be compounded by the presence of the tailboom strake at the forward end of the tailboom. Since the "Dog Kennel" was, by now, regarded as a necessity, for performance and shuffle reduction, further efforts were made to eliminate the new problem.

Flow visualization, using oil smoke from the exhaust pipes, was used during flight testing to understand the ingestion problem and facilitate the development of suitable solutions.

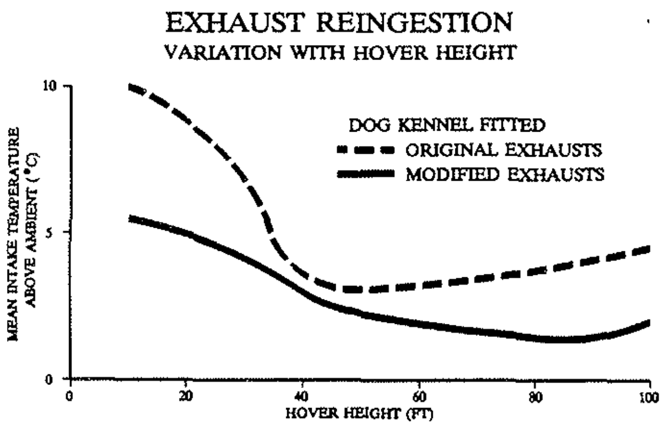


Fig.21 : REINGESTION DATA - HOVER

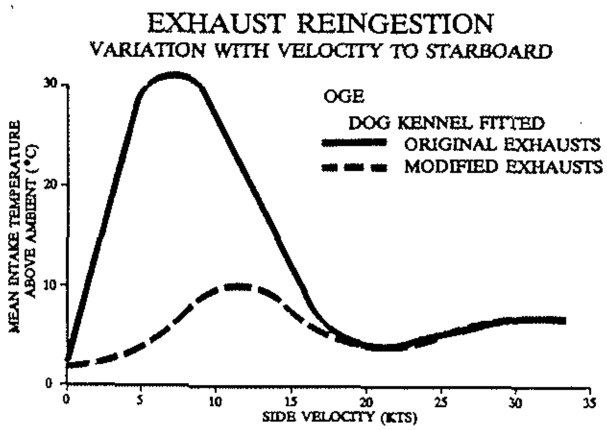


Fig.22 : REINGESTION DATA - SIDEWAYS FLIGHT

Figs.21 & 22 show the dramatic improvements which have now been made to overcome that problem. These have been achieved by removing the chamfer and reducing exhaust pipe diameter to increase exhaust velocity by around 30% (this is expected to increase engine back pressure by the equivalent of less than 1% power loss - equivalent to about 1°C intake temperature rise making the trade-off most advantageous). The forward end of the strake has also been removed.

Torque splits are now minimal, engine surges non existent and engine stability is excellent. Exhaust gas re-ingestion in hover is now considered close to optimum (which results in improved performance) with only small weight and engine back pressure penalties. The aircraft has also been tested in various manoeuvres in IGE and OGE with no adverse effects. EH101 is now a three engined helicopter without a re-ingestion problem.

4. Conclusion

The "Single Site" concept has proved to be an ideal solution to the tackling of initial significant problems experienced during early development flying of the first two EH-101 prototypes.The paper has shown, in particular, how the major aerodynamic problems have been solved as part of "Single Site" activities (enabling other engineering programmes to be pursued). The effectiveness of the solutions to these major aerodynamic problems, was assessed and endorsed by the Official Test Centres of the two countries, in a most successful joint preview at the end of Single Site Operations.

The co-operative spirit, between the two companies, engendered during this period has led to mutually agreed test programmes which consequently, have accelerated the development process but given that the initial operational difficulties have been overcome, and a strong joint approach to the resolution of problems has been forged, the need for co-located development has now diminished and Single Site has been disbanded. Solutions obtained during this initial period will now be applied to the other seven prototypes, each dedicated to a specific task in the development programme, which now continues in Italy and the U.K.

"Single Site" has played its significant role in the development of the EH-101 helicopter, resulting not only in the early resolution of problems, but also in the fostering of strong engineering links, enabling further development activities to proceed effectively at the two sites, Yeovil and Cosina Costa.

5. References

1. B.J.Main and P.Alli, EH-101 Design - A Collaborative Programme,**Forum Proceedings of the 8th European Rotorcraft and Powered Lift Forum,** Paper No 1.3, Sept. 1982

2. P.S.Sheridan and R.P.Smith, Interactional Aerodynamics - A new challenge to helicopter technology, **Forum Proceedings of the 35th AHS Forum,** May 1979

3. B.J.Main and F.Mussi, EH-101 - Development Status Report, **Forum Proceedings of the 16th European Rotorcraft and Powered Lift Forum,** Paper No III.2.1, Sept. 1990

4. R.W.Prouty, Importance of Aerodynamics on Handling Qualities, **AHS Specialist Meeting on Aerodynamics and Aeroacoustics,** Artington 1987

5. R.W.Prouty, **Helicopter Performance, Stability, and Control,** PWS Engineering Boston

6. F.T.Wilson and S.R.Ahmed, Fuselage aerodynamic design issues and rotor/fuselage interactional aerodynamics (Part 1), **AGARD Publication 781 - Aerodynamics of Rotorcraft,** Nov.1990

7. A.Brocklehurst, A Significant Improvement to the Low Speed control of the Sea-King Helicopter using a Tail Boom Strake, **Forum Proceedings of the 11th European Rotorcraft and Powered lift Forum,** Paper No. 32, Sept. 1985

8. FIGURES AND VIEWGRAPHS

Figures (Slides):

1) PP1
2) PP2
3) WHL W.T. Model
4) AG W.T. Partial Model
5) SHUFFLE (As Viewgraph 4)
6) WAKE DISPLACEMENT
7) DOG KENNEL & T.L. FAIRING
8) BEANIE & HORSE COLLAR
9) SHUFFLE RESULTS
10) PITCH-UP (As Viewgraph 5)
11) TAILPLANES CONFIGURATIONS
12) ROOT BENDING MOMENT
13) PITCH-UP RESULTS
14) PP2 SHIP LANDING
15) SIDE LOAD FOR FIN MODIFICATIONS
16) STRAKE
17) DRAG REDUCTION MODS 1
18) DRAG REDUCTION MODS 2
19) POWER REDUCTION (Given by these mods)
20) REINGESTION PHENOMENON
21) HOVER INTAKE TEMPERATURE (Reingestion Results)
22) SIDEWAYS FLIGHT INTAKE TEMPERATURE (")

Viewgraph:

1) INTRODUCTION (TITLE)
2) JOINT TEAM
3) MAIN OBJECTIVES
4) SHUFFLE
5) PITCH-UP
6) FIN / TAILROTOR INTERACTION
7) SMOKE VISUALIZATION FOR REINGESTION