New Design Approach of Compound Helicopter

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Abstract: - Current trends in the design of helicopter have shown that in order to be economically viable and competitive it is necessary to investigate new design concept which may give an improvement in performance and operational flexibility goal and expanding the flight envelope of rotorcraft, but must be shown to be cost-effective. The helicopter has carved a niche for itself as an efficient vertical take-off and landing aircraft, but have limitation on its cruising speed due to restrictions of retreating blade stall and advancing blade compressibility on the rotor in edgewise flight. This is a challenging task, which might be solved by the use of new design approach. It is believed that the application of a compound helicopter design concept would assist in achieving such a task. This paper describes an investigation aimed to examine the suitability of a compound helicopter design concept, allowing for the use of a combined conventional fix-wing aircraft with single propeller in the nose and conventional helicopter to satisfy the above objectives. The paper describes the phenomenon of presents VTOL (vertical take-off and landing) aircraft. It then discusses the benefits and penalties of the presents concept. Description is then given of the concept proposed compound helicopter which incorporated combines main rotor-wing-auxiliary propeller. It concludes with a discussion of the results and recommendations for future work.

Key-Words: - compound helicopter, VTOL (vertical take-off and landing), high speed helicopter, aircraft design

1 Introduction

The operational benefits of an ability to take off and landing vertically are self-evident. Conventional aircraft must operate from a relatively small number of airports or airbases with long paved runways. For commercial transportation, the airport is rarely where you actually wish to go, and is usually crowded, causing delays in the air and on the ground.

The military airbases is highly vulnerable to attack, and during a wartime situation the time expended cruising to and from the in-the-rear airbase increase the required aircraft range and also increases the amount of time it takes for the aircraft to respond to a call for support.

The first type of VTOL heavier than air aircraft was the helicopter, whish was conceived by Leonardo da Vinci but not regularly used until shortly after World War II. The Helicopter rapidly proved its worth for rescue operations and short-range point-to-point transportation, but its inherent speed and range limitations restricted its application.

VTOL refers to a capability for Vertical Take Off and landing, as opposed to Conventional Take Off and Landing (CTOL). An aircraft, which has the flexibility to perform either vertical or short take off landings, is said to have Vertical or Short Take off and Landing (VSTOL) capability. An aircraft that has insufficient lift for vertical flight at take off weight but which can land vertically at landing weight is called a Sort Take off and Vertical Landing (STOVL).

Table 1 [1] shows the Methods of Transition for Various V/STOL Concepts. This table also shows there are two fundamental problems stand out because they tend to have greatest impact upon the selection of a VTOL propulsion concept and upon the design and sizing of the aircraft. They are balance and thrust matching.

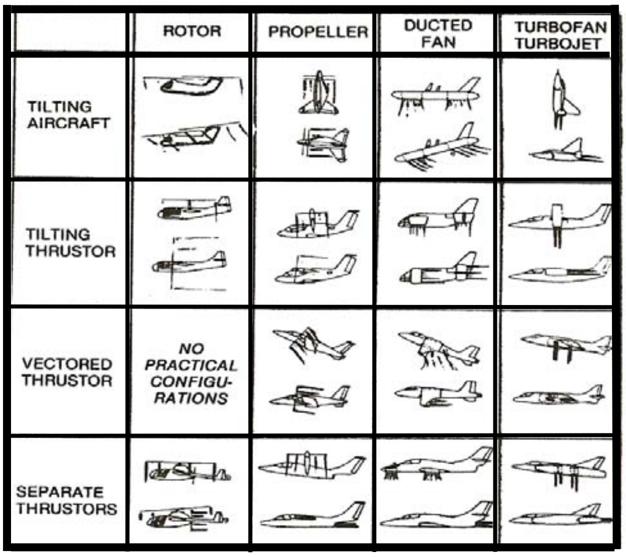

Table 1 Methods of Transition for various V/STOL concepts

VTOL Concept	Helicopter	Compound	Compound	Compound	Compound
Feature		tail rotor + Aux Prop	Advancing Blade Concept	Vectored Thrust Open Prop	Vectored Thrust Ducted Prop
Example	AH-64	AH-56	Sikorsky XH-59	Sikorsky AAFSS	Piasecki VTDP
Hover efficiency	**Best**	**good**	**good**	**good**	**good**
Cruise max speed	low	**> helicopter**	**> helicopter**	**> helicopter**	**> helicopter**
Cruise Efficiency (range)	lowest	low	low	low	low
Low speed maneuverability	**good**	**good**	**good**	**good**	**good**
High speed maneuverability	limited	**good**	**good**	**good**	**good**
Empty weight	**low**	increased	increased	increased	increased
Vibration equipment	highest	high	very high	high	high
Complexity (no. of thrusters)	2 fixed	3 fixed	2 fixed	1 fixed + 1 vectored	1 fixed + 1 vectored
VTOL Concept	Tilt Rotor	Tilt Wing	Canard Rotor Wing	Fan-in-wing	Jet Lift
Feature					
Example	XV-3, V-22, BA609	CL-84, TW-68	Boeing CRW	XV-5, Grumman ACAS	AV-8B
Hover efficiency	good	fair	low	low	poor
Cruise max speed	good	> tilt rotor	high	high	highest
Cruise Efficiency (range)	good	good	good	good	highest
Low speed maneuverability	good	fair	limited	limited	limited
High speed maneuverability	good	good	good	good	excellent
Empty weight	increased	increased	increased	high	moderate
Vibration equipment	moderate	-	moderate	low	low
Complexity (no. of thrusters)	2 vectored	1 fixed + 2 vectored	Convertible engine	3 vectored	1 thruster + 8 nozzles

Table 2. Comparison of Different Types of V/STOL Platforms

Table 2 [1] shows the performance comparison of Different Types of V/STOL Platforms. Its shows that helicopter has the best efficiency during take off, landing and hover conditions, but have limitations in high speed and range limitation.

The conventional helicopter is limited in forward flight performance by the aerodynamic lift and propulsion limitations of the main rotor. These rotor limits arise because of compressibility effects on the advancing blade, as well as stall on the retreating blade. In addition, the relatively high parasite drag [2, 3 & 4] of the rotor hub and other airframe component leads to relatively poor overall lift-to-drag ratio of the helicopter. This generally limits performance of conventional helicopters to level-flight cruise speeds in the range of 150 kts, with dash speeds up to 200 kts. Although somewhat higher flight speeds are possible with compound designs, which use auxiliary propulsion devices and wings to offload the rotor, this is always at the expense of much higher power required and the fuel burned than would be necessary with a fixed-wing aircraft of the same gross weight and cruise speed.

This paper describes the involvement of the author as the leader of aircraft configuration design department at Indonesian Aerospace (IAe) during the LCH 2002 project in cooperation with Loper Company [5].

2 Competitor

This section outlines briefly the previous design for compound helicopter.

2.1 Piasecki X-49

The Piasecki X-49 (as shown in Figure 1) is a four-bladed, twin-engined, experimental compound helicopter under development by Piasecki Aircraft. The X-49A is based on the airframe of a Sikorsky YSH-60F Seahawk, but utilizes Piasecki's proprietary vectored thrust ducted propeller (VTDP) design and includes the addition of lifting wings. The concept of the experimental program is to apply the VTDP technology to a production military helicopter to determine any benefit gained through increases in performance or useful load.

"Speedhawk" is a concept aircraft based on applying X-49A compounding concepts to a production UH-60 Black Hawk offering better performance, range, and increases in useful load. The "Speedhawk" aircraft includes an SPU (third engine), high forward-swept wing concept, a 45 inch cabin extending fuselage "plug", and several other drag reducing and performance-oriented improvements, including a rotorhead fairing, landing gear streamlining, and a fly-by-wire flight control system.

The X-49A flight demonstrator is being developed with funding from the US Army's Aviation Applied Technology Division to demonstrate the ability to increase the speed of existing helicopters to 200 kt (360 km/h) or more. The flight demonstrator has been updated with a lifting wing taken from an Aerostar FJ-100 business jet. A ring tail has been added and the helicopter drive train modified to accommodate VTDP. Piasecki conducted integrated tests of the modified drive train at the Navy's helicopter transmission test facility.

The cockpit controls are modified with the addition of a manual prop pitch override on the collective for the ring tail. This is the only visible change to the aircraft's existing mechanical controls in the cockpit. The other controls needed to operate the compound helicopter's systems are integrated into the aircraft's existing mechanical controls to reduce pilot workload. The weight added to the X-49A demonstrator aircraft is estimated at about 1,600 lb (725 kg) due to the requirement to not modify the existing mechanical control system.

Figure 1. X-49A Speedhawk VTDP Technology Demonstrator in flight

2.2 Sikorsky X2 Demonstrator

The Sikorsky X2 Demonstrator is an experimental compound co-axial helicopter under development by Sikorsky Aircraft (as shown in Figure 2).

Sikorsky will incorporate decades of company research and development into X2 Technology helicopters, including: the S-69/XH-59A Advancing Blade Concept Demonstrator which showed high speed was possible with a coaxial helicopter and auxiliary propulsion, the Cypher UAV which expanded company knowledge of the unique aspects of flight control laws in a fly by wire aircraft that employed coaxial rotors, and the RAH-66 Comanche, which developed expertise in composite rotors and advanced transmission design.[2]

The X2 first flew on 27 August 2008 from Schweizer Aircraft's facility at Horseheads, New York. The flight lasted 30 minutes and began the flight test program.

Figure 2. Concept of the Sikorsky X2 Demonstrator

2.3 Piasecki 16H-1 Pathfinder

The Piasecki Aircraft 16H was a series of compound helicopters produced in the 1960s (as shown in Figure 3). The first version of the Pathfinder, the -1 version, first flew in 1962. The similar but larger Pathfinder II, the 16H-1A, was completed in 1965.

Figure 3. Piasecki 16H-1 Pathfinder

2.4 AH-56 Cheyenne

The AH-56 Cheyenne (as shown in Figure 4) was a four-bladed, single-engine attack helicopter developed by Lockheed for the United States Army's Advanced Aerial Fire Support System (AAFSS) program to produce the Army's first, dedicated attack helicopter. Lockheed designed the AH-56 utilizing a rigid-rotor and configured the aircraft as a compound helicopter; with low-mounted wings and a tail-mounted thrusting propeller. The compound helicopter design was intended to provide a 212-knot (393 km/h) dash capability in order to serve as an armed escort to the Army's transport helicopters, such as the UH-1 Iroquois. The AH-56 was armed with a 30 mm cannon in a belly turret and either a 7.62 mm minigun or a 40 mm grenade launcher in a nose turret. Two hardpoints under each wing were capable of mounting 2.75 inch (70 mm) rocket launchers and TOW missiles. Two additional hardpoints under the fuselage carried external fuel tanks.

Figure 4. AH-56 Cheyenne during testing

In 1966, the Army awarded Lockheed a contract to develop 10 prototypes of the AH-56. Lockheed presented the first prototype to the Army on 3 May 1967, and the first flight of an AH-56 occurred on 21 September 1967. In January 1968, the Army awarded Lockheed a production contract for 375 aircraft, based on flight testing progress. A fatal crash and technical problems affecting performance put the development program behind schedule, resulting in the production contract being canceled on 19 May 1969 Cheyenne development continued in the hope that the helicopter would eventually enter service. On 9 August 1972, the Army canceled the Cheyenne program. Controversy over the Cheyenne's role in combat, as well as the political climate regarding military acquisition programs, had caused the Army to amend the service's attack helicopter requirements in favor of a conventional helicopter; viewed as less technical and more survivable The Army announced a new program for an Advanced Army Helicopter on 17 August 1972.

3 The Design Approach

The helicopter has carved a niche for itself as an efficient vertical take-off and landing aircraft. As with any aircraft, however, there is the continuing desire to expand the performance capabilities of the helicopter, particularly its speed. In the case of the helicopter, it is fundamentally limited in the maximum velocity obtainable though by the restrictions of retreating blade stall and advancing blade compressibility on the rotor in edgewise flight. This is created by the combination of the rotor's rotational velocity and the forward motion of the aircraft.

The conventional helicopter is limited in forward flight performance by the aerodynamic lift and propulsion limitations of the main rotor. These rotor limits arise because of compressibility effects on the advancing blade, as well as stall on the retreating blade. In addition, the relatively high parasite drag of the rotor hub and other airframe component leads to relatively poor overall lift-to-drag ratio of the helicopter. This generally limits performance of conventional helicopters to level-flight cruise speeds in the range of 150 kts, with dash speeds up to 200 kts. Although somewhat higher flight speeds are possible with compound designs, which use auxiliary propulsion devices and wings to offload the rotor, this is always at the expense of much higher power required and the fuel burned than would be necessary with a fixed-wing aircraft of the same gross weight and cruise speed.

To achieve higher forward velocities alterations to the configuration of the helicopter, to alleviate the problems of retreating blade stall and compressibility effects on the advancing blade at high speed are necessary. One method used to achieve this is to rotate the rotor(s) forward to use them as propellers, while using a wing to provide the lift - the Tilt Rotor. A somewhat less radical solution is to modify the existing helicopter configuration, augmenting the rotor as a form of lift and thrust with the addition of a wing and an auxiliary propulsion source - creating the Compound Helicopter.

A wing increases in lifting effectiveness with increasing velocity, which complements the decreasing effectiveness of the rotor on a Compound Helicopter, off-loading its thrust requirements. The auxiliary thrust of a Compound Helicopter also off-loads the rotor of its thrust requirements, but more importantly eliminates the need for the aircraft to tilt forward in flight to supply a rearward component of rotor thrust. The reduction in rotor thrust therefore reduces the required rotor collective pitch and hence moves the boundaries of stall and compressibility to higher overall aircraft velocities. By keeping the large diameter rotor the compound helicopter also maintains the helicopters good hover and low speed maneuverability characteristics, unlike the tilt rotor aircraft. The combination of the rotor and wing also give the compound helicopter two sources of lift to call upon at high speed, so the aircraft has improved maneuverability over its conventional helicopter cousin. In addition the off-loading of the rotor reduces the main vibration induction at its source, much reduced levels of vibration being achievable, which should result in significant reductions in maintenance costs and crew fatigue. The Compound Helicopter has the advantage over the tilt rotor aircraft that it is a straight evolution of the conventional helicopter design and hence the technical difficulties should be less.

The addition of the wing adds weight and rotor wake blockage to the aircraft for the hovering portion of the flight, which can impact on the payload that can be lifted - critical for aircraft productivity. There is also the added complexity of the wing structure and the transmission or power supply for the auxiliary propulsion source. The Compound Helicopter designer also has to deal with the complexities of the interactions between the rotor, wing and stabilizer, which can severely affect the performance of the wing in particular if care is not taken. Hence, the Compound Helicopter designer's task is to minimize hover and payload penalties and the increase in complexity over the conventional helicopter, whilst also maximizing the cruising speed, maneuverability and range of the aircraft to give it a distinct advantage.

The LCH Compound Helicopter combined conventional fix-wing aircraft with single propeller in the nose and conventional helicopter. This configuration had chosen because of the difficulty and failure that occur on Tilt Rotor Configurations. Combine the conventional airplane and helicopter is making reasonable to have a possible and safe configurations. During cruise-flight conditions, the tractor type propeller would use approximately 70% of the power available under cruise condition to produce a cruising speed 250 kts. max speed would be approximately 275 kts. As the air speed increased from 150 kts to 250 kts the main/tail rotor speed is auto-gyrating, while the wing carry 70 % of the lift.

Several new technologies will incorporate into the compound helicopter design. They are :

- Advanced Aerodynamics, incorporating a high lift devices, rotor – wing interactions.
- Composite and special metal materials to reach the lightweight of structure.
- New concept of transmission system that transmit power to main rotor, tail rotor, and propeller.
- New concept of flight control system that accommodates helicopter mode and airplane mode control systems.

The LCH compound helicopter combines the best of existing technologies, with its inherent ability to auto rotate as a conventional helicopter or glide as an airplane it offers a high degree flight safety and crash survivability in relation to other non-conventional helicopter technologies such as tilt rotors.

The use of light weight materials, composites, fly by wire, LCD and digital instrument, navigation, communication and flight controls coupled with highly advanced composite propeller technology provide a breakthrough in compound helicopter design performance. The LCH compound helicopter combines the best of existing technologies, with its inherent ability to auto rotate as a conventional helicopter or glide as an airplane it offers a high degree flight safety and crash survivability in relation to other non-conventional helicopter technologies such as tilt rotors.

LCH is maintenance and pilot friendly offering outstanding maneuverability and speed.

3.1 Requirement

The major objective of this compound helicopter design is to combine a conventional helicopter with a conventional propeller driven aircraft. This compound helicopter will have hover capability like and helicopter, and have cruise performance like a propeller driven aircraft. The hover capability and high speed in cruising condition is major requirement of the design.

The penalties of this design are increasing of empty weight, reduced of hover performance, transmission system to distribute the power from engine to rotor or propeller. To eliminate this penalties will used newest technology, like new material for structure, fly by wire system, efficient high lift device to reduce wing vertical drag, and new engine and transmission system.

3.2 Potential Mission

The potential mission of the compound helicopter is more like a conventional helicopter, but with addition in flight range and time to reach its destination. It can have mission as VIP aircraft, regular transportation used by airline, SAR/EMS even as a military transportation or war machine.

3.3 LCH Design Feature

- Maximum cruise speed : 250 knots
- Maximum range : 700 nm
- Cabin can accommodate 12 economic class passengers. Pressurized cabin to reach service ceiling of 25000 ft.
- Wing have high-deflected flap to reduce vertical drag during hover condition.
- Transmission system can transfer power from engine to main-rotor during hover and low speed flight condition and to propeller during cruise condition.

3.4 "Tractor vs. Pusher" Theory

Tractor Propeller:

- Those type of propeller mounted on the upstream end of the drive shaft in front of the supporting structure.
- A major advantage of the tractor propeller is that relatively low stresses are induced in the propeller as it rotates in relatively undisturbed air.
- Most aircraft are equipped with this type of propeller.

Pusher Propeller:

- Mounted on the rear end of the engine behind the supporting structure.
- Seaplanes and amphibians use a greater percentage of pushers than do other kinds of aircraft.
- On landplanes, where propeller-to-ground clearance is less than propeller-to-water clearance of the watercraft, pusher propeller is subject to more damage than tractor propellers. Rocks, gravel, and small objects dislodged by the wheels, quite often may be thrown or drawn into pusher propeller.
- Similarly, seaplanes with pusher propellers are apt to encounter propeller damage from water spray thrown up by the hull during landing and take off. Consequently, the pusher propeller quite often is mounted above and behind the wings to prevent such damage.
- On helicopters angle of attack during steep approach to landing create the hazard of ground or obstacle contact.
- To provide adequate yaw control at low speed and hover a complex rotor system or use of large ducts and vanes must be devised to counter act torque when using a "pusher" type propulsion system.

4 Technologies

To achieve the optimum design of this compound helicopter, several newest technologies will be applied.

4.1 Aerodynamics

The aerodynamics major problems that occur in compound helicopter design are wing blockage effect during hovering and main rotor drag during cruising. The best effort to eliminated wing blockage is rotate wing 90^o, but with complexity in structure mechanism and increase weight, so this concept not applied. In this design, to reduce the wing blockage during hover will be used high deflected flap (df = 80^o) and "umbrella" installed in wing leading edge. With this configuration, the vertical drag of wing reduces until 30%. Main rotor will auto gyrating during high speed cruising. to reduce main rotor drag will be used blade pitch control.

4.2 Structure

Compound helicopter has the empty weight heavier than pure helicopter because of installed wing, transmission system, and reinforced structure. The structure must be reinforced to accommodate transmission torque. The 3000 shp that transfer from powerplant to nose installed propeller make the under floor structure more complex and heavy. To reduce empty weight will used composite material to replace metal material in all possible places. Wing, front fuselage, aft fuselage, and empennage will use composite material. The possibility of using composite material in center fuselage is under calculation.

4.3 Propulsions

Because of additional drag, both of vertical and horizontal drag, this aircraft need more power compare to pure helicopter or conventional airplane. To reduce fuel consumption and increase cruise efficiency, will used newest engine that most efficient. Beside that, engine reliability also the critical problem, because of one engine out condition. This compound has a saver configuration compare to tilt rotor, because have auto rotate capability during all engine out, since its can landing safely.

New concept of transmission system that transmit power to main rotor, tail rotor, and propeller.

4.4 Systems

This compound helicopter will used fly by wire system. The system is used to make the pilot jobs easier, because of complexity of this aircraft transition mode from helicopter to airplane.

New concept of flight control system that accommodates helicopter mode and airplane mode control systems.

5 LCH Configurations

The LCH Compound Helicopter combined conventional fix-wing aircraft with single propeller in the nose and conventional helicopter. This configuration had chosen because of the difficulty and failure that occur on Tilt Rotor Configurations. Combine the conventional airplane and helicopter is making reasonable to have a possible and safe configurations.

This specification describes the Compound Helicopter with a twin-engine design for 12 passengers, 700 nm range, and 250 knots cruising.

General arrangement of LCH Compound Helicopter is shown in Figure 5.

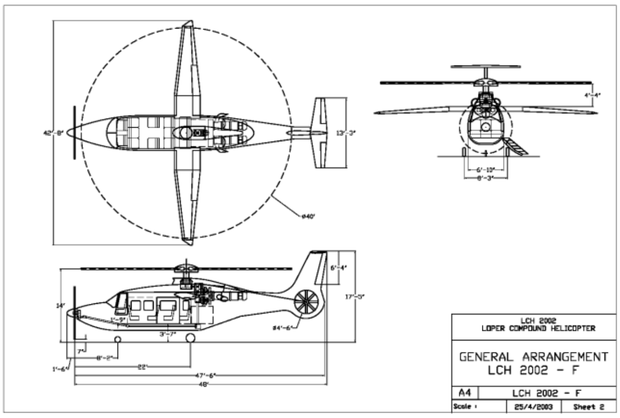

Figure 5. General arrangement of LCH Compound Helicopter

During cruise-flight conditions, the tractor type propeller would use approximately 70% of the power available under cruise condition to produce a cruising speed 250 kts, max speed would be approximately 275 kts. As the air speed increased from 150 kts to 250 kts the main/tail rotor speed is auto-gyrating to approximately 70% NR, while the wing and horizontal stabilizer would carry 70 % of the lift, as shown in Figure 6.

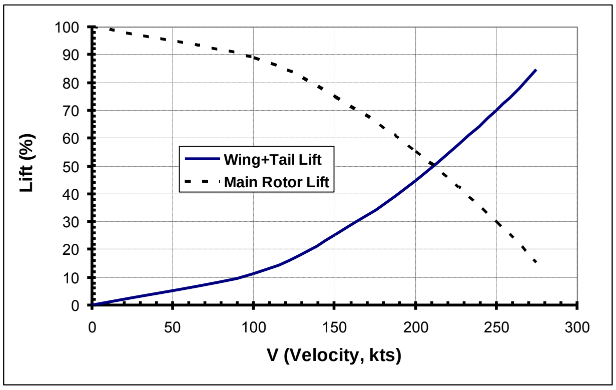

Figure 6. Lift distribution

5.1 LCH Specifications

A. Dimension (external)

Main rotor diameter	40 ft
Tail rotor diameter	4 ft 6 in
Length overall (w/o spinner)	48 ft
Height overall	18 ft 8 in
Wing span	42 ft 8 in
Wing aspect ratio	10
Tail plane span	13ft 3 in
Propeller diameter	10 ft
Propeller ground clearance	1 ft

B. Dimension (internal)

Cabin: Length (excl. cockpit)	12 ft
Max width	6 ft
Max height	6 ft
Seats arrangement	3-2-3-3 abreast

C. Areas

Wings, gross	161.5 sq ft
Vertical tail plane	31.7 sq ft
Horizontal tail plane	31.47 sq ft
Main rotor disc	1256 sq ft
Tail rotor disc	15.9 sq ft

D. Weights

Maximum take-off weight	14000	lbs
Empty weight	9000	lbs
Useful Load	5000	lbs
Crew weight	400	lbs
Passengers weight	2000	lbs

Fuel weight	2600	lbs
Reserve fuel	650	lbs
Mission fuel	1950	lbs

E. Performances

Max speed (helicopter mode)	175 kts
Max cruising speed (helicopter mode)	160 kts
Max cruising speed (airplane mode)	275 kts
Max range (airplane mode)	700 nm
Service ceiling (airplane mode)	25000 ft
Hovering ceiling (over ground effect)	10000 ft

The payload-range diagram is shown in Figure 7.

F. Powerplants

PWC PT6C-67D twin or Rolls Royce twin pack CT800-50

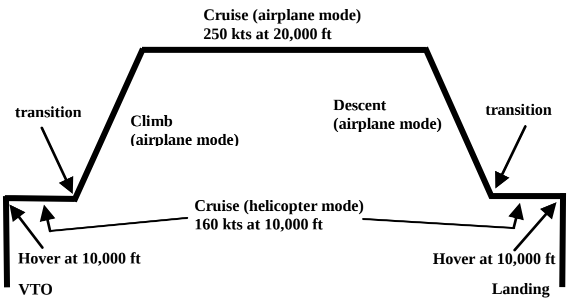

Figure 7. Mission Profile

5.2 Aerodynamics & Flight Control Systems

Wing will be carrying out 70 % lift during cruise condition. Beside the main rotor that carries out 30% lift while outogyrating. Cantilever high wing installed above cabin. Wing aspect ratio is 10 to reduce induced drag during cruise in high speed. Wing area is 161.5 sq ft. Wing incidence is 3 deg. to reach C_L required during cruise. This wing only designed for cruising condition, see Figure 8 and Table 3. Flap design based on the need of low vertical drag during hover condition, see Figure 9.

Wing section is NACA 653-218. This aerofoil have aerodynamics characteristics :

- Low profile drag at trim c_l , (c_d = 0.007 at c_l = 0.4)
- High $c_{l\,max}$ = 1.5
- Gentle trailing edge stall characteristics
- Sufficient maximum thickness (18 percent) and favorable chord wise thickness distribution for structural efficiency and low weight.

During hover condition, there are two alternative of flaps configuration :

a. Wing with 35.3 % chord single slotted flap deflected 80 deg. This configuration will reduce vertical drag 30% compare with bare wing. This configuration has simple mechanism to move flap.

b. Wing with leading edge flap and 30 % chord plain flap with "umbrella". This configuration will reduce drag 70 – 75% compare with bare wing. However, have penalty in complexity of mechanism.

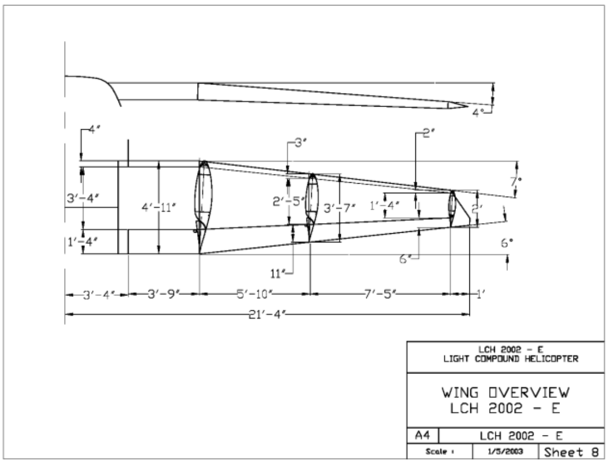

Figure 8. Wing Layout of LCH Compound Helicopter

	Wing.	Vertical Tail	Horizontal Tail
Area	161.5 ft^2	31.7 ft^2	31.47 ft^2
Span	42 ft 8 in	7 ft 3 in	13ft 3 in
Aspect ratio	10	1.66	5.6
Taper ratio	0.4	0.56	0.5
Root chord	4 ft 11 in	5 ft 7 in	3 ft 2 in
Tip chord	2 ft	3 ft 2 in	1 ft 7 in
M A C	3 ft 9.4in	4 ft 4.5 in	2 ft 2.5 in
Incidence angle	3°	0 °	0 °
Twist	0 °	0 °	0 °
Leading edge sweep angle	7 °	27°	9 °
Aerofoil	653-218	63A012	63A012
High Lift device	35.3%	25%	-
Max. HLD deflection	+80°	±25°	±25°

Table 3. Geometry characteristic of wing, vertical tail plane and horizontal tail plane.

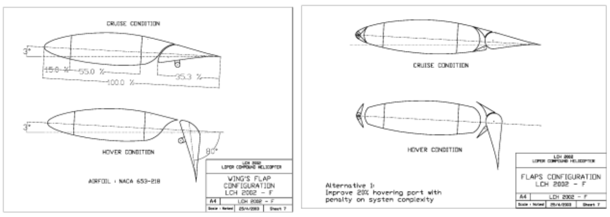

Figure 9. Two alternative of flaps configuration

5.3 Propulsion & Drive Train Configuration

The Drive Train system that transfers power from powerplant to propeller, main rotor and tail rotor is shown in Figure 10.

5.3.1 Engine

The engine would either be Rolls Royce twin CT800-50, or twin Pratts & Whitney PT6C- 67D, located on aft-top of the fuselage, aft of the main rotor shaft. Engine air intake will be located on top left and right side above the engine fairings. Exhaust will be located on left and right side of the engine.

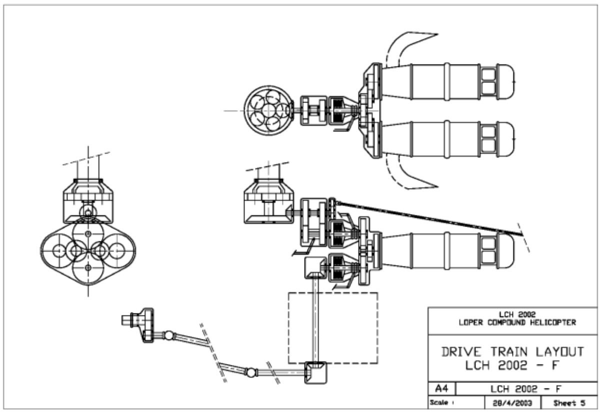

Figure 10. Powerplant and transmission system

5.3.2 Propeller

Unlike other compound helicopter concepts the propeller on the LCH 2002 is nose mounted, state-of-the-art technology, 10 feet diameter, 6 composite blades, and installed slightly forward of the main rotor blade tip to prevent contact under high flap angles.

5.3.3 Fuel Tank

The fuel tank with capacity of 2600 lbs is placed well behind the cabin.

In order to optimize the CG distributions, as well as the power plant and drive train compactness, the vertical shaft is located behind the cabin compartment, this also eliminate any obstruction in the cabin.

5.3.4 Drive Train system

The following describes each component of the Drive Train system :

a. Combined Gearbox

This gearbox consists of two pairs of spur gears giving the total reduction ratio of about 3.5 to 1, reducing the power turbine speed to 6000 rpm (100% N2) on two vertically split output shafts. The first stage gear also serves as freewheeling clutch to accommodate single engine operation. The gearbox also provides some accessory drive pads for supporting the power off take requirement, such as the hydraulic pumps and electrical generators.

b. Hydraulically Actuated Multidisc Clutch

Two identical clutches are connected directly at the Combined Gearbox output shafts. The first clutch on top transmits power to the main rotor, while the bottom clutch transmits power to the 10 feet diameter propeller disk. This clutch provides the disconnection of power transmission when it is required; by applying such hydraulic pressure to the piston chamber to override the spring load, therefore, the disengagement only capable when the hydraulic system has been pressurized to such level.

c. Transmission Gearbox

From output of the top clutch, power goes to the two-speed transmission gearbox, where the speed is either reduced to 67% or 100% speed, which depends on the gear selector control located in the cockpit. The shifting mechanism also utilizes the pressure from the hydraulic system.

d. Main Rotor Gearbox

This gearbox consists of a bevel gear (90 degree) reduction and a planetary reduction giving the total reduction ratio of 16.67 to 1. This will produce a rotor speed of 360 rpm at 100% N2 with gear selector at ‘High’ or 240 rpm at 100% N2 at ‘Low’ gear. This type of gearbox is common to most helicopters.

e. Bevel Gear

Two pairs bevel gears are used on this application. One bevel gears on top of fuselage, transverses the output shaft from the second clutch to the vertical shaft. The second bevel gear located in the belly transverse the vertical shaft to horizontal shaft to power the propeller. The shaft speed is still maintained at 6000 rpm (100% N2) to optimize the shaft against the stiffness and size, as higher speed shaft means lower torque (at the same SHP), thus it will be of smaller shaft diameter. However, too small shaft will induce vibration as it may rotate above its critical speed.

f. Universal Coupling

To raise the horizontal shaft under the floor to the propeller waterline, two universal couplings are required. These coupling will allow deflection of the shaft while transmitting power.

g. Propeller Gearbox

The PGB consists of a single stage reduction gear with ratio 4.28 to 1, producing a propeller output of 1400 rpm at 100% N2. The PGB also provides mounting pad for the Propeller Control Unit (PCU), an Overspeed Governor and a High Pressure Oil pump for PCU operation as well as gears lubrication.

6 Discussion
Probably the most critical subject on designing this compound helicopter are the complexity of this aircraft transition mode from helicopter to airplane mode and to define/develop a new concept of flight control system that accommodates helicopter mode and airplane mode control systems.

7 Conclusion
A new design approach has been developed for the design of compound helicopter, allowing for the helicopter to cruise at higher speed.

The conclusion can be drawn, that the compound Helicopters concepts is feasible for a transport aircraft from aerodynamic and configuration point of view, with the reservations that the economic and safety aspects depend on aerodynamic, performance and operational data.

Before the compound Helicopters can be used as a transport aircraft, a large multidisciplinary research effort is needed in order to master the concept and demonstrate it as flying test-beds and in-service operational tests.

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References:
[1] R. W. Prouty, *Helicopter Performance, Stability, and Control*, PWS Engineering, Boston, Massachusetts, USA, 1986.
[2] Prasetyo Edi, "The Development of N-250 Military Version," *WSEAS TRANSACTIONS on Fluid Mechanics*, Issue 8, Volume 1, August 2006, ISSN 1790-5087, page 832-837.
[3] W.H. Li, J. Sun and X.Z. Zhang, "Quadrupole Dielectrophoretic Device for Particle Trapping : A Numerical Study," *WSEAS TRANSACTIONS on Fluid Mechanics*, Issue 8, Volume 1, August 2006, ISSN 1790-5087, page 825-831.
[4] Prasetyo Edi, "A Flow Control for a High Subsonic Regional Aircraft Exploiting a Variable Camber Wing with Hybrid Laminar Flow Control," *WSEAS/IASME TRANSACTIONS Journal on Fluid Mechanics and Aerodynamics*, Issue 6, Volume 2, August 2005, ISSN 1790-031X, page 927-936.
[5] LCH 2002 group of Indonesian Aerospace (IAe), *Conceptual Design of a Loper Compound Helicopter LCH 2002*, Doc. No. LCH 2002-101, 2002.