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The Design of Advanced N-250 Military Aircraft

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***Abstract*—This paper presents the configuration design of N-250 military version (N-250 TRD). The N-250 TRD is designed from its high speed predecessor, the N-250 civil version. Like its predecessor, the N-250 TRD is equipped with two 2,439 kW (3,271 shp) Rolls-Royce Allison AE 2100C turboprops, each driving a Dowty Rotol R384/6123-FX8 six-blade propeller. Its main different from N-250 (civil version) is N-250 TRD adopt beavertail after body (CN-235 type) instead of upswept after body. Its mission capabilities are troops transport mission, paratroops dropping mission, cargo and LAPES (Low Altitude Parachute Extraction System). This paper describes an investigation aimed to examine the suitability of aft-fuselage design, allowing for the use of beavertail after body (CN-235 type) to the N-250 aircraft. The paper describes the phenomenon of LAPES, configuration design and outlines the aft-fuselage design process. Description is then given of the aerodynamic design of an aft-fuselage incorporated with an beavertail after body and aircraft performances. It concludes with a discussion of the results and recommendations for future work.**

Keywords—military transport aircraft; troops transport & dropping mission; LAPES (Low Altitude Parachute Extraction System); beavertail after body; aircraft design; aerodynamic configuration

I. INTRODUCTION

Similar to any other aircraft manufacturers, to maximize the use-ability of their aircraft [1, 2, 3, 4 and 5], Indonesian Aerospace (IAe/IPTN) have contemplated to convert the N-250 civil version into military transport version (i.e. Tactical Transport Aircraft, N-250 TRD).

This conversion exercise is unique, because the N-250 design was never intended for military transportation purposes. The first difficulty faced is due to its height to sill is too high (1.645 m) as compared to existing IAe's military transport aircraft, CN-235 (height to sill of 1.22 m), with the N-250's fuselage using a circular cross-section (diameter = 2.9 m) instead of the CN-235's fuselage which uses the same diameter flattened circular cross-section. The second difficulty faced, especially for LAPES mission, is in the N-250's fuselage has no cargo ramp/door incorporated in it.

To solve the two mentioned problems, the original aft fuselage of N-250 is replaced by a new aft fuselage with upswept rear end incorporating cargo ramp/door.

For this study, two types of new aft fuselage were studied. The first is the beavertail after body (similar to CN-235) and the second is the high crown after body (similar to C-141).

To enable paratroopers dropping mission, aft exit doors at both sides are replaced by a flight operable paratroops door (900 mm x 1,752 mm).

Another modification performed is for the environmental control system (ECS) to be moved from behind the aft fuselage pressure bulkhead to the under floor space behind the main landing gear stowage.

This paper describes the involvement of the author as the leader of aircraft configuration design department at IAe during designing the N-250 TRD with beavertail after body (CN-235 type) [6].

II. LAPES

Low Altitude Parachute Extraction System (LAPES) is a tactical military airlift delivery technique where a fixed-wing cargo aircraft can drop supplies whenever landing is not an option and when the targeted area that is too small to accurately parachute supplies from a higher altitude. This method was first developed by the 109th Quartermaster Company (Air Drop) of the United States Military in 1964. In May 1965 a detachment of the 109th was converted into the 383rd Quartermaster (Aerial Supply) Detachment and was sent to Viet Nam, followed by the whole 109th company, the following year, eventually taking operational control of the 383rd. Both these units provided Air Drop and LAPES support during the Siege of Khe Sanh in the Vietnam War. LAPES was used to supplying heavy loads into Khe Sahn since air drop is not capable to handle that size of cargo. Eventually, the LAPES practice was perfected at Mactan Air Base in Cebu, the Philippines [7].

LAPES requires loading of supplies in planes on a special pallet. Figure 1 shows how LAPES works from a C130 demonstration. Once the plane reaches the desired drop point, the pilot descends to a very low altitude, typically under 2-m. At this altitude, the cargo hatch is opened and the extraction parachute is deployed as shown in Figure 1 (a). Figure 1 (b), (c), (d), (e), (f) and (g) show how once the parachute catches the wind outside the craft, it pulls the connected supplies out of the plane and on to the ground. Once the delivery is accomplished, the pilot ascends to normal cruising altitude and returns to base.

This technique keeps planes in motion and enemy forces will face difficulties in targeting it for destruction, while still succeeding in delivering cargo, timely and efficiently. However, no margin of pilot error is allowed due to the low altitude drop sequence and plane can crash easily. While performing the LAPES demo on July 1st 1987 during a Capabilities Exercise (CAPEX), a USAF C-130E (68-10945 c/n 4325) crashed at the Sicily Drop Zone, on Ft. Bragg. The pilot of the C-130 had successfully performed the same extreme rate of descent LAPES drop 2 days earlier during a practice run. The crash killed 3 on board, 1 soldier on the ground and injured 2 crews [7].

a. *Drogue parachute is ejected into the airstream*

b. *Cluster of parachutes extracted from deployment bag*

c. *Cluster parachutes inflating*

d. *Payload moving*

e. *Payload just before tipoff*

f. *Payload extraction*

g. *Payload landed at target area*

Fig. 1. *A C130 performing a Low Altitude Parachute Extraction n*

III. AIRCRAFT COMPETITORS

Fixed-wing transport aircraft are defined in terms of their range capability as strategic airlift or tactical airlift to reflect the needs of the land forces which they most often support. These roughly correspond to the commercial flight length distinctions. Table 1 shows active fixed-wing medium-transport aircraft with maximum-take-off weight (MTOW) between 20 – 30 ton [8].

TABLE I. ACTIVE FIXED-WING MEDIUM-TRANSPORT AIRCRAFT

Manufacturer	Model	first flight	max Payload (ton)	Cruise (km/h)	max range (km)	MTOW (ton)
Antonov	An-26	1969	5.5	440	2,550	24
Antonov	An-32	1976	6.7	480	2,500	26.9
Bell/Boeing	V-22 Osprey	1989	6.8	396	1,627	27.4
CASA	C-295	1998	9.3	481	5,630	23.2
Grumman	C-2 Greyhound	1964	4.5	465	2,400	24.7
Fairchild	C-123 Provider	1949	11	367	1,666	27
Ilyushin	Il-112	2011	5.9	550	5,000	20

IV. N-250 TRD CONFIGURATIONS

A fuselage with rear loading after bodies generally has an after body which sweeps up sharply on the lower surface and has a flat section which swings down to serve as a loading ramp. The requirement for load clearance at the extreme end of the loading door often results in a fuselage which has virtually no lateral contraction. That is, the aft fuselage does not contract when seen from the top.

The structural design objectives of a rear loading after body are generally directed in minimizing weight, length, ramp angle, and ramp complexity. In addition "straight-in" loading and airdrop capability are usually desired. These objectives have generally been met with a beavertail after body design (no lateral contraction with large camber ratio and small contraction ratio). Such after bodies are found in almost all cargo helicopters and in some cargo aircraft such as the CN-235, the C-130 (Hercules) and Caribou transports.

The general arrangement of N-250 TRD with beavertail after body (CN-235 type) is shown in Figure 2. To accommodate the auxiliary power unit (APU), the aft part of the aft fuselage needs to be enlarged, shown in Figure 3.

Figure 4 shows how paratroopers can be accommodated on side wall folding seats with safety harness that are installed on the mounting provisions attached to the frame structures. This aircraft can accommodate 60 paratroopers.

Dropping can be performed by using static line or free fall. The static line will be installed to the aircraft structure.

Paratrooper doors shall be sited at the rear left and right. These 900 mm X 1,750mm two doors shall have an inward sliding opening to the rear.

To accommodate a higher number of paratroopers, middle seats can be installed in a different configuration. Cabin layout for solely-paratroopers transport mission which can accommodate 76 paratroopers is shown in Figure 5 instead.

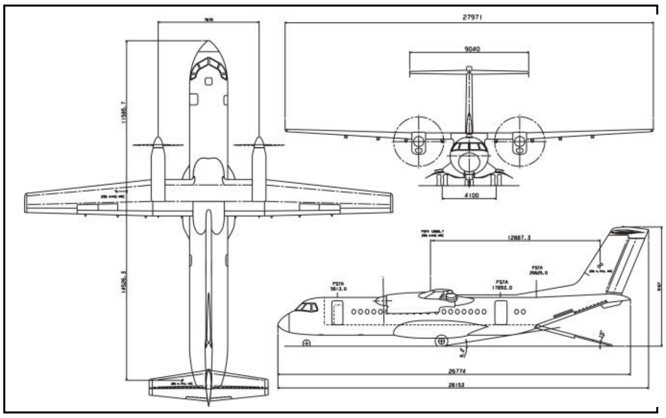

Fig. 2. *The general arrangement of N-250 TRD*

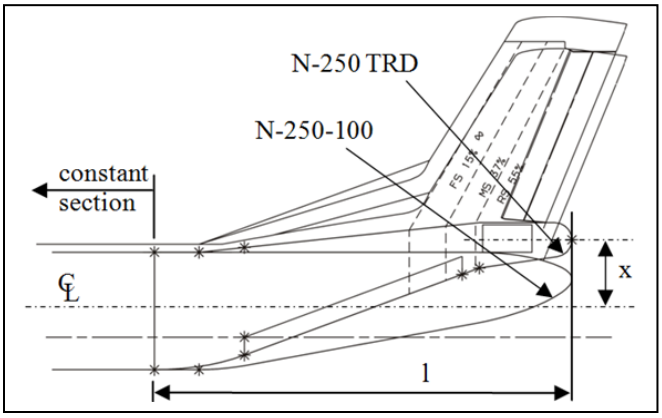

Fig. 3. *The aft fuselage of N-250 TRD development*

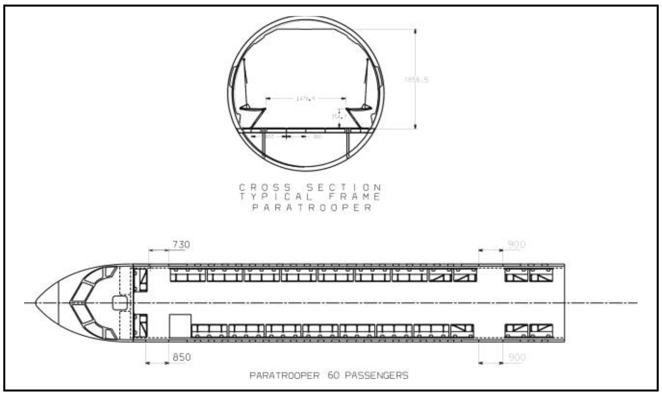

Fig. 4. *Cabin layout for 60 paratroops*

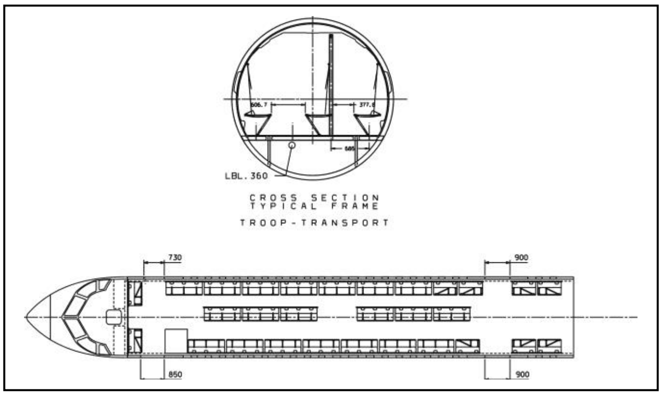

Fig. 5. *Cabin layout for 76 troops*

Figure 6, on the other hand, shows how the cabin layout for cargo transport mission which can accommodate 7 LD3.

Figures 7 and 8 shows the N-250 TRD and CN-235 during LAPES configuration respectively.

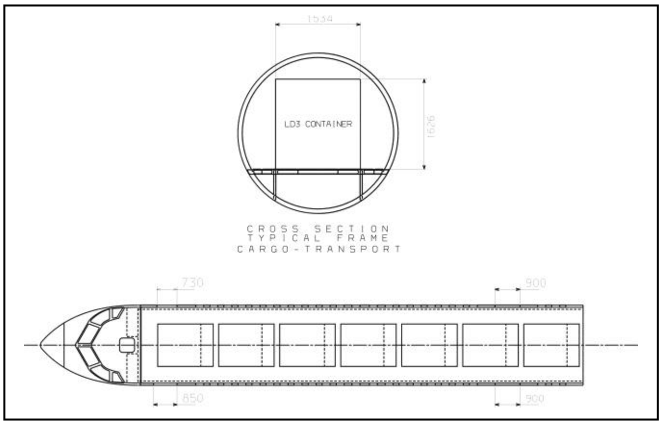

Fig. 6. *Cabin layout for 7 LD3*

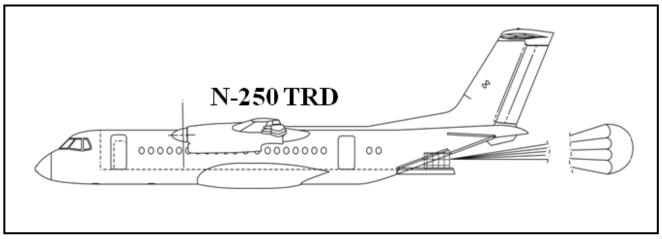

Fig. 7. *N-250 TRD during LAPES*

Fig. 8. *CN-235 during LAPES*

V. N-250 TRD DESIGN WEIGHT

The maximum take-off weight (MTOW) of N-250 TRD is kept similar to its predecessor at 24800 kg. The big difference comes from the structure of aft fuselage, which means that the N-250 TRD would have extra initial weight compared to the N-250-100, this will effects the operating empty weight (OEW) and MPLW (maximum payload weight).

The design weight of N-250 TRD is shown below.

MTOW = maximum take-off weight = 24800 kg

MFW = maximum fuel weight = 4200 kg

MZFW = maximum zero fuel weight = 21900 kg

MLW = maximum landing weight = 24600 kg

Troops transport:

OEW = operating empty weight = 14610 KG

MPLW = maximum pay-load weight = 7290 KG

Paratroops dropping:

OEW = 14570 KG

MPLW = 7330 KG

Cargo : 7 LD3 container

OEW = 14670 KG

MPLW = 7230 KG

VI. FUSELAGE

V/STOL (Vertical/Short Take-off and Landing) aircraft fuselages generally deviate considerably from an optimum streamline shape. This is due to the conflicting desires to maximize internal cargo volume and to provide an adequate ramp for loading the cargo while minimizing the overall length to reduce airframe weight [6].

A. *Beavertail After-body*

This type of fuselage generally has an after-body which sweeps up sharply on the lower surface and has a flat section which swings down to serve as a loading ramp. The requirement for load clearance at the extreme end of the loading door often results in a fuselage which has virtually no lateral contraction. That is, the aft fuselage does not contract when viewed from the top. For this work, this type of after-body will often be referred to as a "beavertail" after-body (as shown in Figure 9) [6]. Fuselages of this type have been found to have a large amount of pressure drag caused by the after-body. A study made by Gabriel, E.A. [9] of a fuselage of this type (CH-47 helicopter) showed that 1/3 of the fuselage drag was due to after-body pressure drag.

The general effect of after-body camber on induced drag is shown in Figure 10 [6 and 9], after-body camber ratio = x/D, where D = equivalent diameter of fuselage constant section (see Figure 3). The shift in zero lift angle and the minimum drag point was about 40 for the standard CH-47 (x/D = 0.275).

Fig. 9. *A "beavertail" after-body*

This is for a fuselage alone however, and the wing downwash would add a negative increment to the local flow angle at the after-body with a corresponding induced drag penalty. The best approach to minimizing this induced drag penalty would be to design the after-body with lateral contraction. In other words, almost no drag penalty is paid for after-body camber if considerable lateral contraction is incorporated.

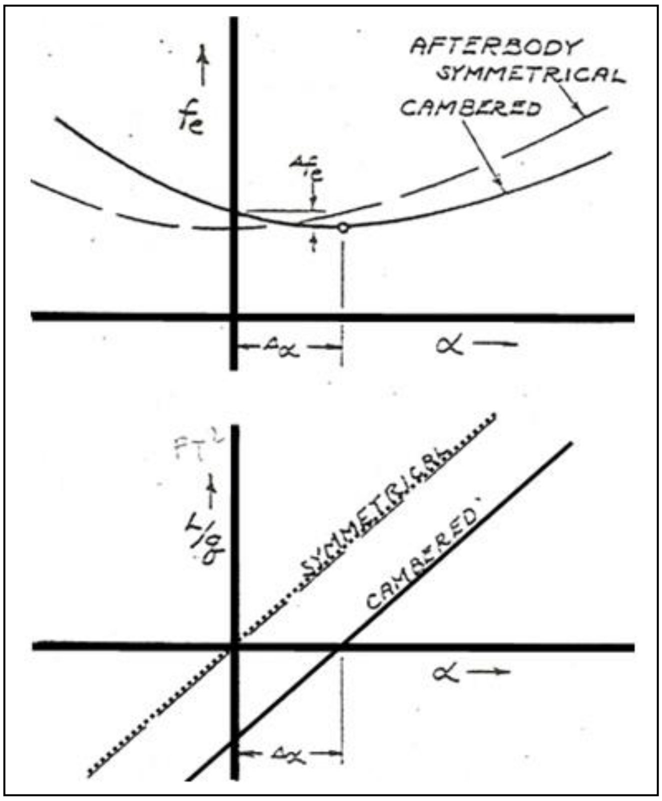

Fig. 10. *Effect of camber beavertail after-body*

B. High-Crown After-body

The structural design objectives of a rear loading after-body are generally directed to minimizing weight, length, ramp angle, and ramp complexity. In addition “straight-in” loading and air drop capability are usually desired. These objectives have generally been met with a beavertail after-body design (no lateral contraction with large camber ratio and small contraction ratio (l/D), see Figure 3) [6]. Such after-body is found in almost all cargo helicopters and in some cargo aircraft such as the C-130 and Caribou transports.

It was shown that these after-bodies have very large pressure drag. This drag could be minimized by increasing the contraction ratio and the lateral contraction and by reducing the camber ratio. In doing this however, the design objectives mentioned above would be seriously compromised [6]. In reference [9] the writer reported on the results of a study of this problem and recommended a “high-crown” after-body as the best compromise between structural and aerodynamic objectives.

An examination of fluorescent oil flow visualization studies of beavertail after-bodies revealed that streamlines at the side of the after-body are pulled down at an angle of 200 to 250 to the free stream. This was attributed to the low static pressure which exists underneath the rear ramp due to the curvature of the body lines and due to the flow separation which occurs there. This is illustrated for a typical beavertail after-body in Figure 11 (Edi, et. al. 2002 and Gabriel, E.A. 1967). The fuselage cross section shape in the local flow direction is seen to be rather bluffed (Edi, et. al. 2002). Figure 12 shows a modification which transforms the beavertail after-body into a high crown after-body and maintains the same loading clearance, ramp loading angle, ground clearance for landing flare, and the same primary structure for supporting the tail. The streamlining of the cross section shape in the local flow direction is improved by placing a bulge on top of the after-body and extending the rear doors.

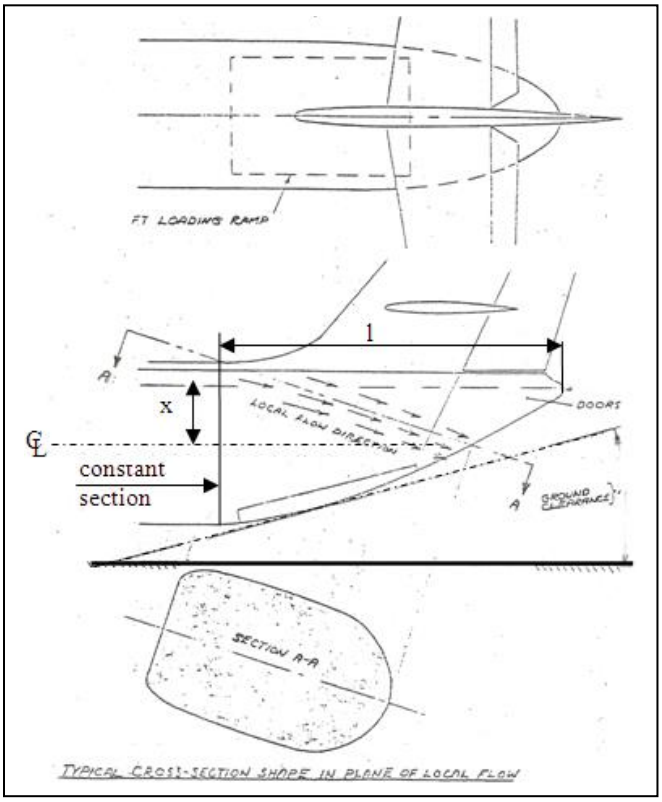

Fig. 11. *Local flow direction on typical beavertail after-bodies*

These modifications should also reduce the static pressure on the top surface and increase it on the bottom surface thereby reducing the inclination of the local flow angle. The amount of lateral contraction is increased. It is estimated that the high crown after-body in Figure 12 would reduce the after-body pressure drag about 2/3 [6 and 9].

The comparative drag polar for the high crown (C-141), beavertail (C-130), and a symmetrical after-body are shown in Figure 13. The high-crown after-body is seen to incur no drag penalty at cruise CL when compared with the symmetrical after-body. Although some drag penalty exists at low CL, the climb and loiter drag (at high CL) of the high-crown after-body is actually less than the symmetrical after-body. The C-130 drag is about 15% above the C-141 at CL = 0.40.

The effect of cross section shape is one of the factors in the after-body drag calculation [6 and 9]. The relationship of after-body drag and cross section shape is shown in Figure 14 using the circular shape as a reference. This trend information is presented here to assist both in analysis and design. The design of a high crown after-body should incorporate a deep keel, as much as possible, in the rear door area behind the ramp. This will improve the shape in the local flow direction as shown in Figure 12.

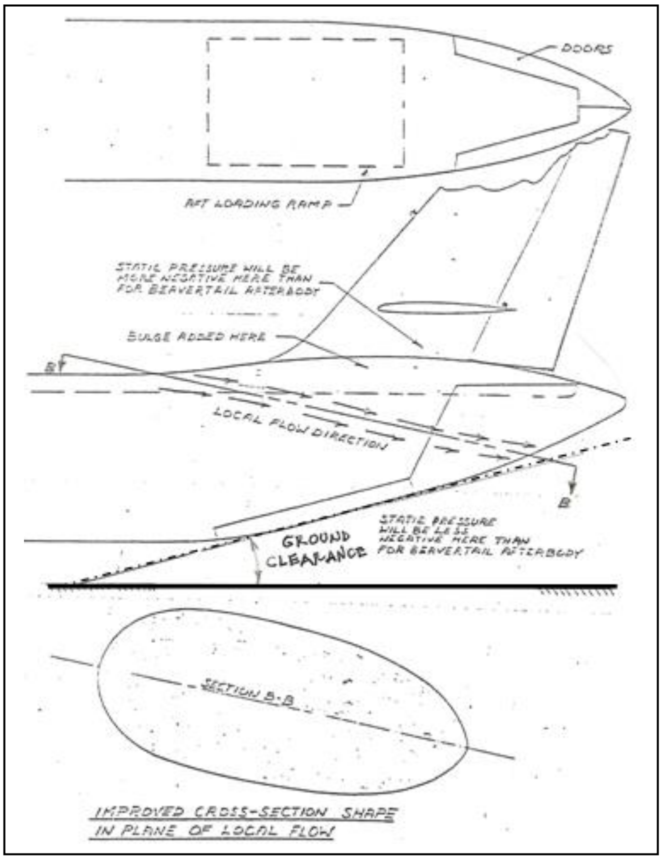

Fig. 12. *Local flow direction on typical high crown after-bodies*

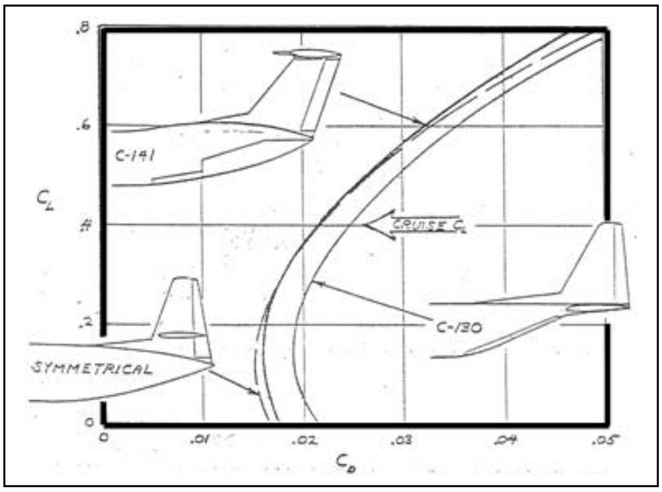

Fig. 13. *Comparative drag polar : high crown, beavertail and symmetrical after-bodies*

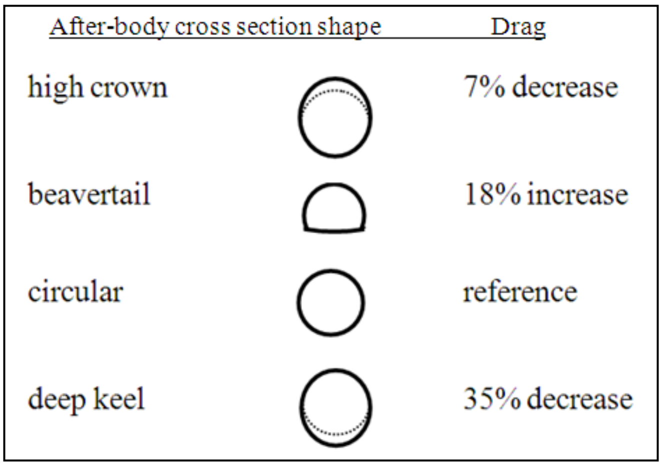

Fig. 14. *The effect of cross section shape on the after-body drag*

VII. WING AERODYNAMICS

In order to improve its performances, two airfoils were selected, MS-0317 for the wing root and MS-0313 for the wing tip. The aerodynamic performance of airfoil sections can be studied most easily by reference to the pressure distribution over the airfoil. The pressure distributions of the above airfoils are predicted using XFOIL 1.0 code. XFOIL 1.0 was written by Mark Drela in 1986. XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils. The pressure distribution of the above two airfoils are shown in Figure 15 and 16 respectively.

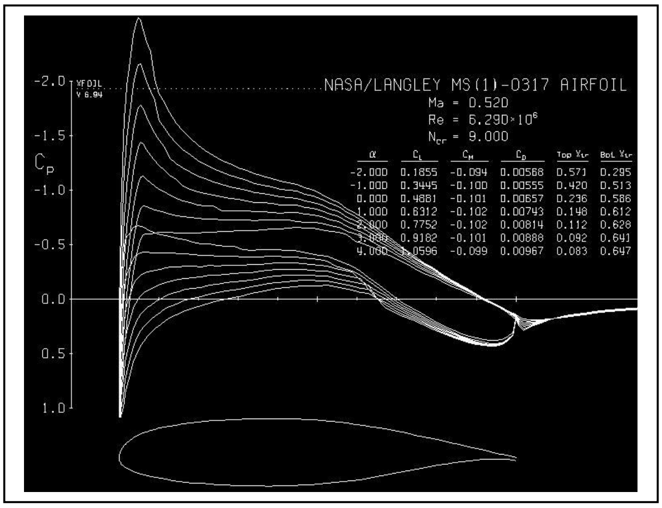

Fig. 15. *The pressure distribution of MS-0317 airfoil*

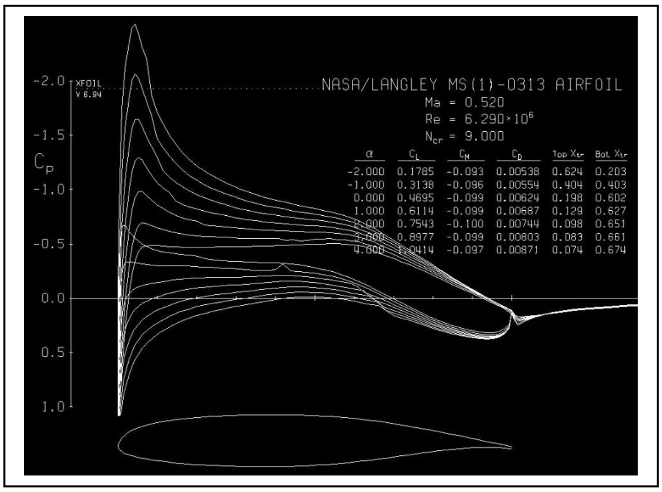

Fig. 16. *The pressure distribution of MS-0313 airfoil*

VIII. N-250 TRD PERFORMANCES

The prediction of the N-250 TRD performance is based on the same maximum take-off weight of N-250-100. The difference in the shape of aft fuselage means that the N-250 TRD has an extra drag compared to the N-250-100.

The payload-range performance of N-250 TRD is as shown in Figure 17, while the payload-range performance of N-250-100 is shown in Figure 18 [6].

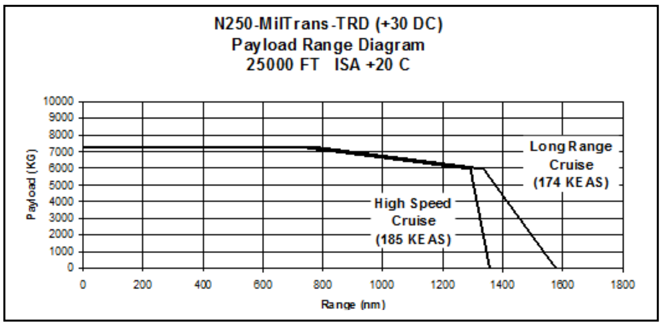

Fig. 17. *The payload-range performance of N-250 TRD*

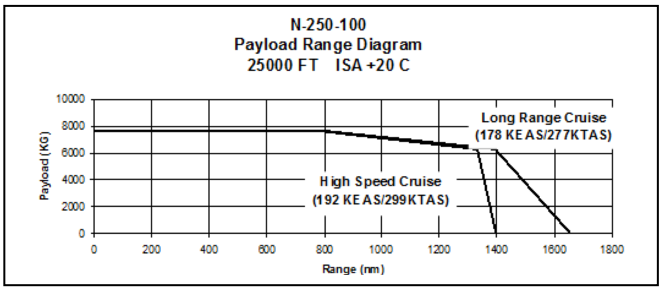

Fig. 18. *The payload-range performance of N-250-100*

Field length at S/L & ISA +200 C.

Take-off = 1373 m (4500 ft) at MTOW (maximum take-off weight)

Landing = 1373 m (4500 ft) at MLW (maximum landing weight)

Cruise speed at 25000 ft & ISA +200 C.

N-250 TRD

Long range 174 KEAS (knots true air speed) / 271 KTAS (knots equivalent airspeed)

High speed 185 KEAS / 288 KTAS

N-250 -100

Long range 178 KEAS / 277 KTAS

High speed 192 KEAS / 299 KTAS

IX. DISCUSSION

Besides the advantages in having easy loading and unloading for the cargo; it is very clear that incorporating the ramp for loading the cargo to the N-250 TRD will increase its operating empty weight and drag force, while decreasing the maximum payload weight.

The above snowball effect eventually will decrease both the cruise speed and the payload-range performance of N-250 TRD compared to its predecessor (N-250-100).

X. CONCLUSION

From the study conducted, the N-250 TRD was found to be technically feasible to be employed as a military tactical transport aircraft, with the same reservation that applies to all new aircraft project, i.e. the economical concern; the market demand for it. However, to ensure a greater result and success, large multidisciplinary research efforts are needed in order to master the structure and aerodynamic aspects of the aft fuselage with cargo ramp/door incorporated into.

It is recommended that for the future derivatives, the N-250 TRD should incorporate a high-crown after-body with deep keel, as much as possible, to improve the new aircraft performance. In order to have lower its height to sill (equal to CN-235 height to sill of 1.22 m), it is recommended that for the future derivatives, the N-250 TRD should adopt the CN-235's fuselage flattened circular cross-section instead of full circular cross-section (diameter = 2.9 m).

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