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Unconventional asymmetric design of Rutan Boomerang airplane

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ABSTRACT
Conceptual design phase plays a paramount role and is the commencement in designing of any airplane. The decisions which are made during this phase affects the later success of the airplane. The design of the airplane needs to meet certain challenging prerequisites which really affect the performance of the airplane. The main facets of design involve propulsion, aerodynamics, structures, etc. So, the designer is required to keep all these things in his/her mind before designing the airplane. The aircraft industries are coming up with novel designs for constructing planes which are capable of carrying heavy payloads, improving overall efficiency and performance. The asymmetric design of the airplane is being explicated in this paper; Rutan Boomerang is a multi-engine aircraft which is nifty when one of the engine founders to work properly. So, the other engine can be used in place of the failed one. The twin multi engine aircraft becomes difficult to modulate due to its asymmetric thrust. The wings are forward swept which means that the leading edge and quarter chord line sweeps forward. The asymmetrical design facilitates in increasing the speed of the airplane and also there is no need to use small engines. Many of the misadventures take place due to the engine failure. So, this airplane is very efficacious when one of the engines is inoperative and the second engine proffer redundancy.

Keywords:asymmetric design, P factor, efficiency, engine failure, twin engine.

I. INTRODUCTION

The Rutan 202 model Boomerang is designed and constructed by Burt Rutan. He constructed this plane for safety purport and as his sheer personal aircraft. He was the one who forged Voyager the first aircraft to fly without refueling. Rutan Boomerang was designed according to the Beechcraft Baron 58 one of the noted and twin-engine civilian aircraft and made certain evolutionary changes. Rutan Boomerang had its first flight on November 1996.The plane is set to enter production after the covenant with Oregon's based Morrow aircraft. Earlier, the designer Rutan was facing lack of financial backup but yet the monetary issue is not fully resolved. Rutan's Scaled Composites will construct a prototype and then it will undergo some certification tests. Morrow expect the plane to get certified within two to three years. Rutan Composites works would forge the all composites for assembly. Some changes will be made in the plane during production like it will be scaled to 15% payload will be increased to 20% and max gross weight will be around 2850 lb. Certain design changes will be that the hatch will be sufficiently large so that in can be converted into air ambulance or cargo configuration. One piece windshield will supersede Rutan spectacles. The plane looks little weird in appearance but is more efficient in performance. It is the greatest attainment in the aviation pedigree. It is the most safe and efficacious plane developed to evade mishaps in case of engine failure. In propeller driven planes, thrust is generated by propeller. Sometimes if the pilot is unversed in operating the airplane, the second engine will offer redundancy and is helpful in controlling the asymmetric thrust. The plane is safer to fly, faster and more fuel efficient than a similar sized twin aircraft. It has a discrete appearance. This plane helped in overcoming the asymmetric thrust. P factor which is the tendency of the aircraft to yaw to the left side with the propeller rotating clockwise and vice versa especially when the plane is flying at higher angle of attack or using a tail wheel. This plane counteracts the p factor by using counter gyrating propeller blades which will not cause asymmetric thrust. There is no need of critical engine which is used in case of engine failure in this plane. It is fitted with two engines having different power outputs. The engines are placed at two different locations. One is near to the fuselage and the other is mounted on the wing. This placing of the engines reduces the aerodynamic drag and improve lift. The right-hand engine is reposed in front of left-hand engine which alleviate asymmetric control problems.

The wings are forward swept which allows the plane to climb without stalling. The stall occurs at the wing root than the wing tip and help to maintain directional control. In case of engine failure, the propeller begins to create drag which dwindles the airspeed. An engine failure leads to downfall of 80 percent of climb performance. Hence Rutan Boomerang is very expedient in this case which will not cause thrust imbalance and prevent the airplane from yawing. If we Beechcraft Baron 58 with Rutan Boomerang is 40 kg lighter, has 92 percent greater range,47 mph faster cruise and a low stall speed. Minimum Control Speed is less than the stall speed which denotes that the plane can be modulated even in case of engine failure. It has not entered production yet because of money factors but still is one of the unconventional multi engine civilian aircraft.

1. Case study on the disruptive design Of Rutan Boomerang

The design regime follows thePI-CS-E format:

The inimitable asymmetric design has enhanced performance in terms of speed and range. Rutan Boomerang has enhanced safety and more fuel efficiency analogous to other twin-engine aircrafts. Rutan has designed various aircrafts in his career but Boomerang is his favourite one among all the aircrafts he has constructed.

Parameter Identification	Ameliorate the engine safety and reduce cabin noise as compared to the analogous twin engine arrangement. This is done by moving the engines in an asymmetric manner to the fuselage and then away from the cabin. conventional twin-engine configurations (e.g., Beech Baron 58) by relocating the engines asymmetrically to the fuselage and away from the cabin.
Creative Synthesis	The left engine is transposed outboard to generate asymmetric layout.
Evaluation	Minimum control speed is steep which denotes that if the right engine fails then it would generate extreme yawing moment
PE	Reduce Minimum Control Speed by relocating both the engines inboard
CS	The right engine is transposed inboard and ahead while the left engine is relocated inboard to balance each other.
E	The right engine is not bolstered properly by the right wing and the problem arises where the left propeller intervenes with the fuselage.
PE	Unravel these issues by slanting both wings and keeping the engines in their existing positions.
CS	The wings are swerved to bolster the engines and dwindle the left engine intervention
E	A sail –plane akin disposition with high Lift to drag ratio is desirable for better performance in terms of speed and range
PE	Making the wings lean by using composite materials which will ensure strength and rigidity required.
CS	By designing high aspect ratio wings the configuration become heavy at the nose. To counter this issue, left wing is swept forward which in turn move the centre of pressure ahead.
E	Even after doing this. The plane is still nose heavy
PE	Fuselage requires to be made of composite to reduce the weight which will which permit the usage of small engines. The tail area is reduced to lower the amount of drag generated earlier.
CS	Fuselage is designed by employing carbon fibre

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	which will help in making lighter and small engines. Additionally, tail area is also reduced to lower the drag.
E	Now the issue arises because of the high aspect ratio tail which may have flutter.
PE	Strengthen the tail by augmenting tail support.
CS	Nacelle beam is complemented.
E	More baggage space is now available in the boom but still cost, weight and drag produced is steep.
PE	The above stated problem will be resolved by transposing the right engine to the fuselage.
CS	The right engine is situated in the fuselage and the entire wing is shifted to the left side for balancing the plane laterally.
E	MCS is now below stall by the above configurated but the left engine is contiguous to the fuselage, generating propeller interference and cabin noise as well.
PE	Transpose the left engine outboard
CS	The left engine is moved outboard and the entire wing is shifted left for attaining balance.
E	Handling at low speed is satisfactory.
PE	To counter it, complement vertical tail surface to ameliorate handling
CS	Dual small vertical tails are employed in place of the massive single surface are used instead of the large single surface which results in a bulbous fuselage and some other intricacies are also amended.
E	The design is now gratifying.

2. Problem encountered while designing Boomerang: Aerodynamic Stall

It is crucial to apprehend the concept of stall. It was the major issue faced by Rutan while designing Boomerang.

Stall is a phenomenon in which the wing loses its capability to generate lift because air does not flow smoothly over the surface of the wing. It is impossible and unrealistic for an aircraft to fly or hoven without generating lift. Stall leads to drag generation and slow down the speed of the aircraft. Stalls are precarious while operating aircrafts at low altitudes like while landing or during take-off. A perilous spin is usually ascribed by stall. Pilot require some time to set right the stall generated.

The question is why does stall occur? What is the major cause behind it?

The answer is very simple. The wing of the aircraft has a certain configuration called air foil which is specially design to be in contact with the air. As long as air foil is in contact with the air, the wing is able to generate lift. But it needs to be operated with an ambit of positions. If it operates outside this gamut the air foil founder to provide the desired lift which leads to the deviation of the airplane in some other direction. So, the pilot needs to operate the airplane below a certain angle of attack called the critical angle of attack. Once it goes beyond this critical angle of attack, the wing goes into stall. At a very high angle of attack, airspeed reduces because the air is not able to flow sleekly over the surface of the wing which leads to stall. So, the pilot needs to be wary of not causing the aircraft to go into stall.

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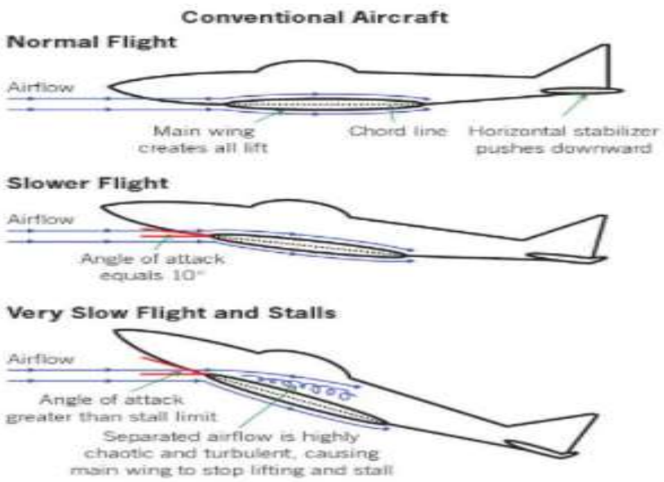

Fig 1. Three views of a conventional aircraft flying level and straight but at distinct speeds [1]

Panacea to Surmount the Issue: The Canard Configuration.

Rutan resolved to rule out the perils caused by stall by designing them out of the plane efficaciously with a canard configuration. In this arrangement he mounted a small tail at the nose instead of the backend of the fuselage akin on most of the aircrafts. The canard configuration helps in reducing the gross darg as well help in improving control of the aircraft. The prime advantage of canard is that even though angle of attack is high, the wing will not stall first. The canard will stall before the wing due to its design. The nose is not able to move up as the canard stall and it does not permit wing to stall. This curbs the angle of attack and keep it intact. Canard also aid in reducing the wing loading and maintaining the stability of the aircraft.

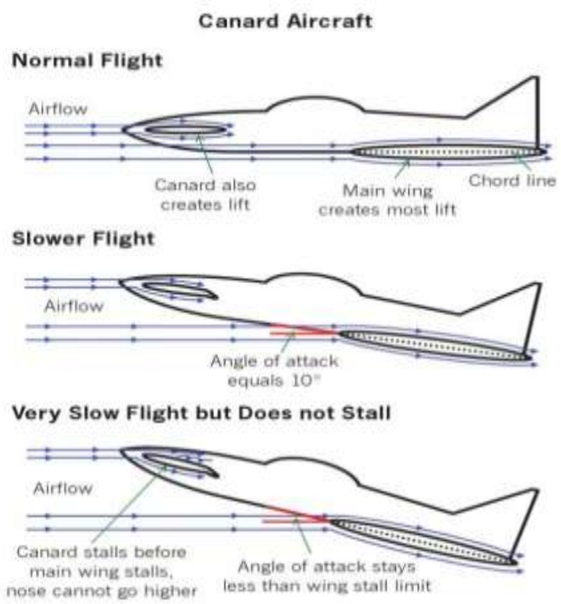

Fig 2. Canard aircraft that is flying straight and level [1]

3. Design of the airplane

The design of the airplane is similar to multi engine aircraft but it has certain exceptional performance parameters. There is something diametrical about this plane most noticeably its design. The plane can fly faster than any other twin aircraft without the use of rudder pedals which separates it from the crowd. The design proves to be nifty when it has to keep the engine above the stall speed which is an uphill task for twin engine aircraft. The asymmetric design counteracts the asymmetry when an engine fails. Pilots needs to be well versed

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when it comes to operate the plane while engine become inoperative because extreme drag is created where the engine goes dead and it is paired with the thrust on the working side. The plane persists to fly straight even when the engine fails and the pilot does not need to do much for maintaining the control of the plane. It has high fuel efficiency and the placement of the engines reduce the drag and the noise in the cabin. The design is inimitable in itself like it have a small boom to the left of the fuselage. The second engine is behind the first engine and it have a peculiarly designed horizontal stabilizer with incommensurate wings. The location of the engines is near the center of lift diminish thrust asymmetry and also the single engine controlling problems. One engine is placed relative to the fuselage and the other is mounted near the wing. The airplane furnishes better performance using two turbocharged reciprocating powerplants. Even if the engine failed, the rudder efficacy is maintained by the propeller wash down to low speeds the design is quite offbeat in itself. The left engine is moved outboard to ameliorate symmetry at low speeds and to tone down the noise generated by the engine. Left engine is reposed aft to balance the plane. Right engine is mounted near the fuselage to lessen weight. Wings are not parallel to support engines and to lessen left wing intervention. The wings are forward swept which allow higher climb without stalling and have high wing loading as well.

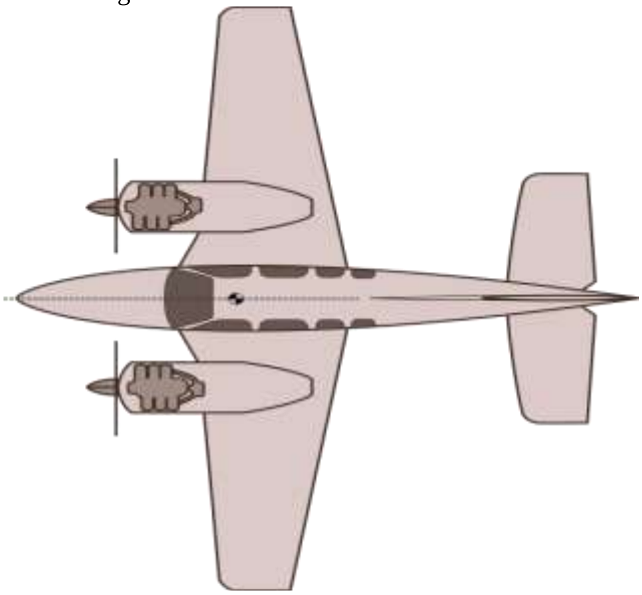

Fig. 3 Beech Baron Aircraft 58[4]

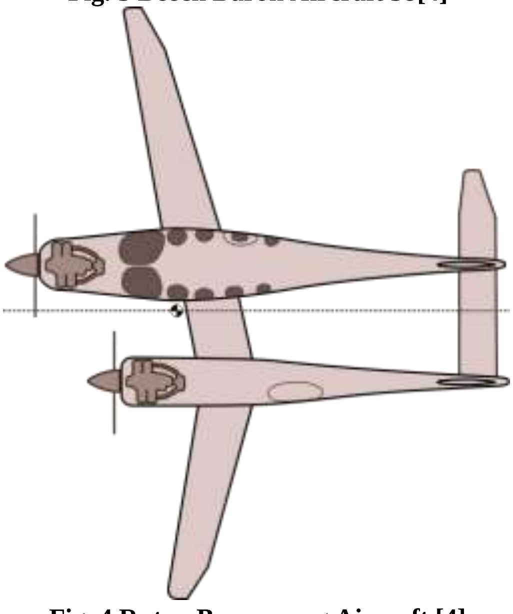

Fig. 4 Rutan Boomerang Aircraft [4]

Fig. 5. The Rutan Boomerang on the ramp of SBP [6]

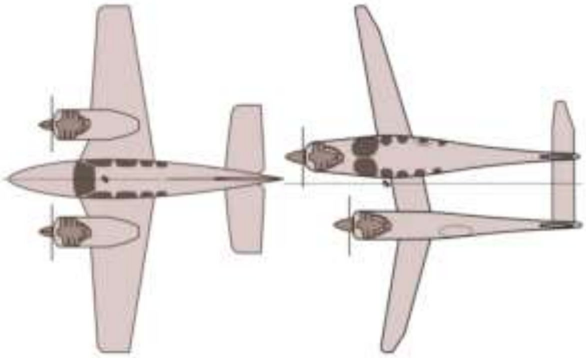

Fig. 6. Comparison Between Rutan Boomerang And Beech Baron Aircraft [6]

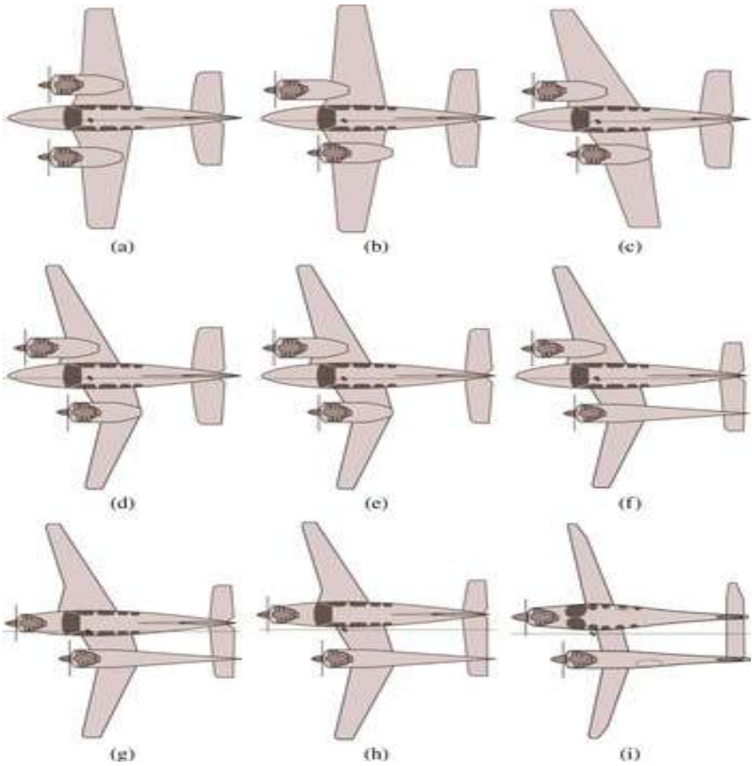

Fig 5. Evolution of the Boomerang configuration adapted from Rutan Boomerang (2015) [9]

4. Performance Parameters

- **Maximum speed :** 530 km/h
- **Cruise speed :** 402 km/h
- **Stall speed :** 130 km/h
- **Range :** 3801 km
- **Rate of climb :** 9.7 m/s
- **Max climb :** 34.7472 km/h
- **Gear :** Electric retract
- **Engine type:** Lycoming O-360 (200 hp) RHS, Lycoming O-360 (210 hp)

5. Design Parameters

- **Length :** 30.6 feet
- **Weight:** 2370 lbs.
- **Capacity :** 1 pilot, 4 passengers
- **Wing span :** 36.7 feet
- **Wing Area :** 101.7 ft^2
- **Aspect Ratio :**13.2
- **Fuel Weight:** 1026 lbs.
- **Max Cabin Payload:** 1000 lbs.

II. RESULT AND DISCUSSION

The design of Boomerang sets it apart from the custom designs of other aircrafts.It was built to provide safety through asymmetry and is extremely useful in the case of multi engine failure.The pilot confronts lot of issues associated with single engine failure and this aircraft is perfectly a good panacea to that issue.It has an inimitable twin boom layout which places two engines close to the centre of lift reducing the thrust asymmetry.This aircraft is designed in a very astute way which enable it to fly faster owing to its asymmetrical design incorporated in the aircraft.The plane is little disparate as compared to the other twin engine aircrafts as the pilot needs to make less use of the rudder pedals which is certainly little strange in the case of twin engine aircrafts.Rutan built Boomerang as his personal aircraft but that aircraft proved to be one of the best aircrafts he ever built.

III. CONCLUSION

The Boomerang twin-engine, asymmetric airplane formulated and constructed by Burt Rutan is now lately rigged up with an Electronic Flight Instrument System ("EFIS") from UAV Navigation. The EFIS runs on the installed AP04OEM2 Attitude and Heading Reference System ("AHRS"). Rutan's plane was designed for safety and good efficacy in which lightweight materials were used to construct the twin engine aircraft. Its innovative, asymmetrical design provides unique safety advantages in the event of an engine failure. This aircraft is noted for its asymmetrical design. The design helps in tackling with the asymmetrical thrust generated during one engine failure. It was an uphill task for a pilot to control the twin aircraft with one single engine. But the design of Boomerang revolutionized the way the pilot used to fly the plane. It made flying that sort of aircraft cozy for the pilot. Because Boomerang enabled the pilot to control it before the outset of stall. The cardinal advantage of this aircraft is its controllability even in the case of stall. The pilot is able to control it as a single engine aircraft. Its performance is akin to turboprop engine aircraft. The main specialty of this aircraft is that it renders safety through asymmetry. It surpassed the other twin-engine aircrafts of its ilk. Rutan deem Boomerang as the greatest accomplishment of all the airplanes he designed and forged in his career.

REFERENCES

[1]. By Dan Linehan (2011) Burt Rutan's Race to Space: The Magician of Mojave and His Flying Innovations.
[2]. E. Torenbeek and H, Wittenberg. (2009), Flight Physics: Essentials of Aeronautical Disciplines and Technology, with Historical Notes
[3]. Leonard J, (2001), Twin-engine propeller-driven aircraft configurations.
[4]. Raymer DP, (1992) Aircraft Design: a conceptual approach
[5]. Lange RH (1988) Review of unconventional aircraft design concepts.
[6]. Paur J (2011) Burt Rutan's boomerang: safety through asymmetry.
[7]. John S Gero, (2015), Computational design synthesis of aircraft configurations.
[8]. Kroll E, Condoor SS and Tansson DG. Innovative conceptual design: theory and application of parameter analysis. Cambridge University Press, 2001.
[9]. Pahl G, Beitz W Feldhunsen J and Grote KH. Engineering design: a systematic approach. 3rd edition,Springer,2007.
[10]. Roskam J. Airplane design: parts I to VIII. 2nd edition, 2003.
[11]. https://www.flightglobal.com/
[12]. www.airspacemag.com/
[13]. https://www.wired.com/2011/07/burt-rutans-boomerang-safety-through-asymmetry/
[14]. https://www.historynet.com/burt-rutan-reaches-outer-space.htm
[15]. Rutan Boomerang's Smart Aircraft Design | Airways Magazine(images)
[16]. Burt Rutan's Favorite Ride | Flight Today | Air & Space Magazine
[17]. https://www.cambridge.org/core/journals/design-science/article/casting-innovative-aerospace-design-case-studies-in-the-

parameter-analysis-framework-to-uncover-the-design-process-of-experts/240398C389F54E6887AC3511B02AD

[18]. https://www.cambridge.org/core/journals/design-science/article/casting-innovative-aerospace-design-case-studies-in-the-parameter-analysis-framework-to-uncover-the-design-process-of-experts/240398C389F54E6887AC3511B02AD87D(images)