AIRCRAFT DESIGN AE714

Quiz-01

Duration = 40 minutes **21th August 2015** **Max Marks = 40**

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1. List down the various steps followed in an Engineering Design cycle [3]

    - *Creative Synthesis*
    - *Analysis*
    - *Decision making*

2. List down the three basic needs that the end product of any engineering design exercise should definitely meet. [3]
    - *Meet the design requirements*
    - *Use efficient construction process*
    - *Make best use of resources*

3. Discuss any two advantages of a *Three-Surface* configuration in an aircraft [2]
    - *By careful design, the total area (hence weight) of Wing + Canard + Tail can be lower than that of Wing = Conventional Tail. Efficient component integration can save weight*
    - *Larger CG range, since the aircraft can be trimmed using Canard or Tail. Can trim with near minimum drag over wide CG range*
    - *Looks stylish and different from normal configurations*
    - *Enhance control and manoeuvrability, especially at very high angles of beyond the stall point of the main wing such as during takeoff and combat*

    One Mark for any two of the above

4. What is meant by "Airworthiness Requirements"? List down the three main reasons based on which are they specified. [4]
    - *Requirements that ensure that aircraft is “worthy of being in the air”, i.e., safe to fly [1]*

    Basis for their specifications are:
    - *Previous experience [1]*
    - *To ensure safety of operation [1]*
    - *Lead to uniformity & standardization in reporting data [1]*

5. What is meant by *Pylon* and *Dorsal Fin*, and explain why are they provided [2]
    - *A Pylon is the interface between an externally mounted store and the wing/fuselage, used for attaching external stores (e.g. missiles and Droptanks).*

    - *A Dorsal Fin is an extension in the vertical tail (fin) locate ahead and top of the fuselage. Its main purpose is to stabilize the aircraft against rolling and assist in sudden turns.*

6. Both SU-47 and X-29 have forward swept wings. Explain any THREE key differences between them. [3]

Parameter/Feature	***X-29***	***SU-47***

First Flight	*1984*	*1997*
Number Built	*02*	*01*
Max. Takeoff Weight	*8 Tons*	*35 Tons*
Engines	*Single*	*Twin*
Vertical Tail	*Single*	*Twin*
Range	*560 km*	*3300 km*

One mark each for any three of the above

7. List any FIVE desirable features of a well-designed transport aircraft, in your order of priority. [5]

    1. *Aerodynamically efficient, including propulsion integration (streamlining!)*
    2. *Must balance near stability level for minimum drag*
    3. *Landing gear must be located relative to cg to allow rotation at TO*
    4. *Adequate control authority must be available throughout flight envelope*
    5. *Design to build easily and have low maintenance costs*
    6. *Should be quiet, and have low emissions*

8. Describe any TWO types of Winglets, and explain their benefits. [2]

There are basically three types of Winglets

1. Wingtip Fences
They are a special variant of winglets, which extend both upward and downward from the tip of the wing. Airbus A300 was the first jet airliner to feature this type, and most of the Airbus planes (all A320 family jets and A380) feature such wingtip fences.

2. Blended Winglets
These are the most popular winglets first introduced on the McDonnel Douglas MD-11 aircraft in 1990. The Blended Winglet incorporates a large radius and a smooth chord variation in the wing-to-winglet transition area. This allows optimum aerodynamic loading and avoids vortex concentrations that produce drag. Highly Blended Winglets have demonstrated more than 60% greater effectiveness over the same conventional winglets with an angular transition.

3. Raked Wingtips
These are the most recent winglet variants, where the tip of the wing has a higher degree of sweep than the rest of the wing. They are widely referred to as winglets, but they are better described as integrated wingtip extensions as they essentially are (horizontal) additions to the existing wing. The stated purpose of this additional feature is to improve fuel economy, climb performance and to shorten takeoff field length.

9. Distinguish between *Tractor* and *Pusher* configuration of powerplant. List down any TWO relative merits and demerits of each type. [2]

Merits of Tractor over Pusher:

- *Lower drag because high velocity propwash isn't scrubbing over the fuselage or wing, creating more drag. In Pusher, Propwash is always* *creating extra drag over downstream surfaces, hence more drag than if those surfaces simply were scrubbed by the plane's airspeed*

- *More efficient Propeller efficiency, since it is facing undisturbed flow. In Pusher, the propeller is submerged in the wake of the wing and fuselage. A pusher prop is always working in a disturbed airflow, causing increased vibration and noise. If the propeller is fitted behind a wing, each propeller blade is passing through the separated boundary flow twice each rotation. These cycles create additional noise and lower the efficiency of the propeller. The vibration makes the propeller blades more susceptible to metal fatigue.*
- *Less chance of Foreign Object Damage (FOD), since it is located ahead of the Main Landing Gear (MLG). A Pusher is more prone to FOD because it is mounted behind MLG, which can throw up stones or debris even at clean airports*
- *Lesser chance of propeller strike on ground after takeoff, since the propeller moves away from the ground on rotation. The opposite is the case in Pusher type.*
- *Engine cooling is not a problem in Tractor type, since the propeller air (apart from ambient air) is blowing over the engine. This problem is most relevant in Piston engine aircraft, which are air cooled.*
- *In a single engine Pusher configuration, we have a more complex air inlet and tail design than simply letting the engine suck in air that it bites into already. Ducting and intakes are needed, adding weight and complexity.*
- *During a crash, a Tractor engine in front served as a crumple zone for the rest of the plane, particularly the cockpit and could plow through obstacles making the plane come to a halt slower. Conversely, with a Pusher, the engine was behind the pilot and not only didn't offer any protection but tended to tear loose and ram through the rest of the fuselage like a pile driver.*
- *In a Pusher configuration, the pilot can't see and therefore visually inspect the engine during flight. For e.g., if the engine starts losing oil in a Tractor configuration, you know right away. If the engine is behind you, as in Pusher, the pilot might not notice until s/he sees the gauge.*
- *A Pusher configuration stabilizes the aircraft, much like an additional horizontal tail, but without any control surfaces. Especially for a fighter aircraft, this is the opposite of what you want. This is why almost all high-powered, singe-engined aircraft have their propeller in the front. The stabilizing effect increases in proportion to the propeller surface area and the thrust, of course. Since a regular airplane needs to have basic stability with the engine running at idle, any additional stability change due to propeller placement comes on top. At full power and with the long lever arm of a single pusher prop on a central fuselage, the aircraft becomes too stable, and hence very unresponsive.*
- *For single engine aircraft at least, having a Pusher prop makes egress in flight much more dangerous (e.g., when bailing out and ejecting). Many pilots have been seriously injured or killed by their props when having to jump out of a burning aircraft. The Do-335 Pusher aircraft was fitted with a pneumatic ejection seat, and additionally the upper fin and the propeller were blown off by an explosive charge when the seat was activated.*

Merits of Pusher over Tractor:

- *With Pusher engine, one can have an unobstructed view out front, and they also are quieter since the engine is at the back. They may be safer as well, since they are difficult to stall if they have a canard configuration.*
- *The pusher design is more aerodynamically efficient, because the suction forward of the prop reduces flow separation, and the accelerated flow behind it is not streaming around the fuselage (or wing), where it would create additional friction drag. An aircraft with pusher configuration would have superior cruising speed and better wing loading because it flew through undisturbed air.*
- *A front mounted propeller in Tractor configuration limits the field of view; this is especially true in UAVs and surveillance drones like RQ-4 Global Hawk and MQ 9 Reaper. There's no pilot whose view would be obscured but there is almost certainly a great advantage for the radar, optical and other forward-looking systems, which are best mounted in the front. Surveillance missions can benefit from a relatively slow-moving, low-altitude platform. This favours the use of propellers rather than jets and the pusher arrangement can be beneficial as noted above.*

½ mark each for any two merits of Pusher over Tractor, and ½ mark each for any two merits of Tractor over Pusher

10. What is meant by an Oblique Wing Configuration, and in which type of aircraft is it provided and why? [2]

An Oblique wing is a variation of Variable Sweep Wing configuration in which the wing is mounted in an oblique fashion on the fuselage, resulting in one wing having sweep forward, while the other has sweepback [1].

This configuration is mostly provided in supersonic or transonic aircraft, in which reduction in the wave drag due to lift during transonic phase is a key design driver. The Oblique wing results in fore-and aft symmetry in lift distribution, i.e., distributing the lifting load longitudinally along its length, and this has been shown (by R. T. Jones of NASA) to mathematically result in the lowest possible wave drag [1].

11. Distinguish between the two main types of Canards, and the circumstances in which each type is used. [2]

- *Lifting Canard: Its purpose is to generate extra lift to support the wing of an aircraft. In the lifting-canard configuration, the weight of the aircraft is shared between the wing and the canard. It has been described as an extremely conventional configuration but with a small highly loaded wing and an enormous lifting tail which enables the centre of mass to be very far aft relative to the front surface*

- *Control canard: Its purpose is to generate pitching moment for control, rather than support the wing in generating lift. In a control-canard design, most of the weight of the aircraft is carried by the wing and the canard is used primarily for pitch control during maneuvering. A pure control-canard operates only as a control surface and is nominally at zero and carrying no load in normal flight. Modern combat aircraft of canard configuration typically have a control-canard driven by a computerized Flight control system.*

- *Close Coupled Canard: In this configuration, the Canard is located just above and forward of the wing. At high angles of attack (and therefore typically at low speeds) the canard surface directs airflow downward over the wing, reducing turbulence which results in reduced drag and increased lift. Typically the foreplane creates a vortex which attaches to the upper surface of the wing, stabilizing and re-energizing the airflow over the wing and delaying or preventing the stall.*

1 mark each for description of any two types of Canard

12. Why is a Step provided in the bottom fuselage of a seaplane? [2]
A seaplane float or hull must be designed to permit rotation or pitch-up, to increase the wing's angle of attack and gain the most lift for takeoffs and landings. Thus, the underside of the float or hull has a sudden break in its longitudinal lines at the approximate point around which the seaplane rotates into the lift off attitude. This break, called a "step," also provides a means of interrupting the capillary or adhesive properties of the water. The water can then flow freely behind the step, resulting in minimum surface friction so the seaplane can lift out of the water.

13. List down the key benefits of Over the Wing engine layout in the *Hondajet* (Honda HA-420) business jet aircraft [2]
    - *The over-the-wing engine mount configuration was designed to maximize cabin space, and for achieving lowering wave drag at a high speeds. This configuration decreases drag on the plane, making it 10 percent faster and 12 to 17 percent more fuel-efficient than other light jets in its size class. It also reduces engine noise and increases space in the cabin*
    - *The engines are mounted relatively high so that they can still gulp clean air at high angle-of-attack and the wings don't block the airflow.*
    - *Mounting the engines on the wings puts them forward, closer to the aircraft center of gravity, which is usually a good thing.*
    - *Mounting the engines on the wing eliminated the need for reinforcing the rear fuselage area to handle the engines' weight and thrust (airload on the airframe). This meant one could eliminate the carry-through beam for the engine mounts, saving weight and increasing cabin space.*
    - *Keeping the fuselage clean is good, because the engine pylons won't block airflow to the tail at high angle-of-attack (needed for control).*
    - *Supporting the engines from the wings passes their weight directly to the wings, rather than through the fuselage. This spreads out the wing loading, allowing the fuselage and the wing itself to be a little lighter. It also helps that the engines are mounted on top of where the wing is already beefy around the landing gear.*

    ½ mark each for any four of the benefits listed above

14. List down any FOUR factors that drive the selection of Configuration and Layout in an aircraft, giving an example for each. [4]

- *Functional Requirements*
- *Safety & Reliability*
- *Type of Propulsion*
- *Flight Envelope*
- *Economy & Production capabilities*

- *Technology, History*
- *Style & Passenger appeal*
- *Any four of the above [½ marks each], with examples [½ mark each]*

15. List down any FOUR configuration related features of the Beechcraft *Starship-I* aircraft, and explain why they were provided. [2]

- *First civil aircraft with extensive use of CFRP airframe resulted in durability, high strength-to-weight ratio, dampening of vibrations, and no structural fatigue.*
- *Heavily loaded Canard design for a Stall Free wing*
- *Two Engines located near each other, lesser imbalance in yaw in OEI case*
- *Pusher engine/propeller configuration results in a Quieter cabin*
- *No centrally mounted vertical tail, to avoid generation of noise from the propellers of pusher configuration. Directional stability and control is provided by rudders mounted in the winglets (called tipsails)*

½ mark each for any four of the features listed above