



ENGINEERING DESIGN

Flap Actuator Design PDS

[Abstract](#)

Product Design specification for light Aircraft

58167

HND/C MECHANICAL ENGINEERING

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NAME: GERAINT WILLIAMS

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LECTURER: M LEWIS

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Design of a flap actuator

Executive summary

Conventional hydraulic aircraft actuators are more susceptible to high pressure and temperature thus reflecting high maintenance cost for such systems. These conditions translate to low efficiency in operation with escalated operating costs. With the advancement of technology in aircraft industry, the operations of aircrafts changed and larger a sophisticate planes were fabricated. With operations of these large commercial and military planes requires the use of a more reliable, safe and efficient system. The discovery of flap action systems that are centrally located in the PDU have necessitated flights and travels through plane. This report highlights the fundamental and essential design specification on the actual design of prototype model

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Introduction

When aircraft industry began, the flight control system was manually controlled through manpower. Manual control was applicable during early stages of aircraft development since aerodynamic forces were containable and the control system consisted of pulleys, pushrods and cables. With advancement in aircraft technology led to development of larger size aircrafts and thus the size of the control system equivalently increased. Increase in the size of aircraft's control unit demanded for more complex control systems to necessitate the adjustment and balancing of aerodynamic forces involved in the operation of flights systems (Pecora, 2018, p.110). The need for more efficient and effective control systems on aircraft's control unit led to the discovery of actuators for moving the aircrafts control surface units. In military and commercial aircrafts, the most commonly used actuator is the flap actuator system. Military airplane control unit consist of a shaft, power driving unit (PDU) located at the centre and a specified number of actuators.

Design of aircrafts actuation systems depends on various factors such as the specified interface, performance requirements and desired configuration of the aircraft's control unit. Power drive units can either be electromechanical or hydro mechanical and either on a dual or single motor type (Qiao et al. 2018, p.140). In the dual motor type of electromechanically power drive unit, the output motor can either be of speed summed or torque summed mode. The shafts of the flap actuators consist of torque tubes that connects the power drive unit's output with the left- and right-wing actuators. However, the configuration of the small commercial airplanes often utilizes flexible drive shafts reciprocating at considerably higher speed instead of rigid low speed shafts (Taylor, and Panella, 2017, p.131). Aircraft actuator systems are normally based on ball-screws and are linearly designed, flap actuators on the other hand utilizes irreversible ACME screws while other flap actuators are designed in rotary reversible ACME screws.

As the name suggests, the main purpose of flap actuators in aircraft power drive unit is to prevent asymmetry between right and left wings flap in the event of shaft misalignment or failure. The flap actuators are equipped with asymmetry monitoring system to detect the failure on the wings of the plan and automatically activate flap actuator systems to take control of the surface on the command position. As outlined that flap actuators can either use reversible or irreversible ACME screws. Most commonly used flap actuators utilize reversible actuators with centrally located power drive unit (PDU) and wingtip brakes systems with a dual motor type to ascertain operational reliability. This configuration is most considered since it is cost effective and more efficient while in operation (Taylor, and Panella, 2017, p.126). The configuration of either type of flap actuator depends on the dynamic behaviour of component systems. Therefore, an appropriate actuator design and simulation model is essential in evaluating the systems behaviour in terms of degree of accuracy both in normal and failure operating conditions.

Design specifications for flap Actuator

The designed flap actuator systems are for small commercial airplane with take-off mass of 180 tons. The airplane has got flaps actuators in each wing and the minimum load capacity of every flap is designed at 34 kN.m the extension time in every flap is to be a period of 30s and return time to be at 20s. This flap extension and retrace period ware obtained to be so since they are mostly deployed during landing and taking off of the plane therefore the duty cycle is at low. The arduous duty cycles in planes only occurs during flight tests or during training sessions when the absolute maximum duty cycle might register as high as 500 seconds.

The flap position during retract has be synchronized to range within 0.25 percent of the full travel while it is designed to remain at 0.5 percent throughout. This design specification is crucial since any uncontrolled flap movement can be catastrophic therefore the plane has to meet the reliability requirement of not more than 10^{-9} failure per flight hour. For the case of electrical flap actuation systems, this specification is far much beyond what can be attained therefore in the event of complete failure in electromechanical flap actuators, power-off friction brakes are used to automatically lock the actuation system in the event of failure and maintain the symmetry of the plane.

For this design, it utilizes gearbox to affect the locking of system in the event of failure without back-drive. The gearbox system is preferred since it allows electromechanical actuators to attaining the recommended 10^{-9} failure per flight hour. For the design specifications, the input speed for the input gears is at 1500 rpm and the speed of output gears at 500 rpm. From calculations of the number of teeth required to sustain the specified 1500 rpm input speed and 500 rpm output gear speeds. The inner diameter was established at 62 mm and outer diameter at 188 mm. The gear specifications are as illustrated below

Gear Design and Specifications

<i>Gear speed</i>	
Inner speed	1500 rpm
Output speed	500 rpm
Power	3000 watts or 3.0 kW

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<i>Diameter</i>	
d_{inn}	150 mm
d_{out}	150 mm
<i>Number of teeth</i>	
N_{inn}	55
N_{out}	95
<i>Torque on gears</i>	
T_{inn}	19.12 Nm.
T_{out}	33.03 Nm.

The fowler motion flap mechanism has been used to minimize gaps in the support fairing and to maintain the desired flap sealing with the rear surface of the aircraft's wings. In the design of shafts that connects the flanges and the bearings of the flap actuator and enables the transmission of power from motor to into gearbox where speed regulation is affected according to specific operation of the flight, the following are specifications for the design of shafts for the system.

Design Specification for shafts

Tangential forces	695.37 N
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Bending Moment of input gears

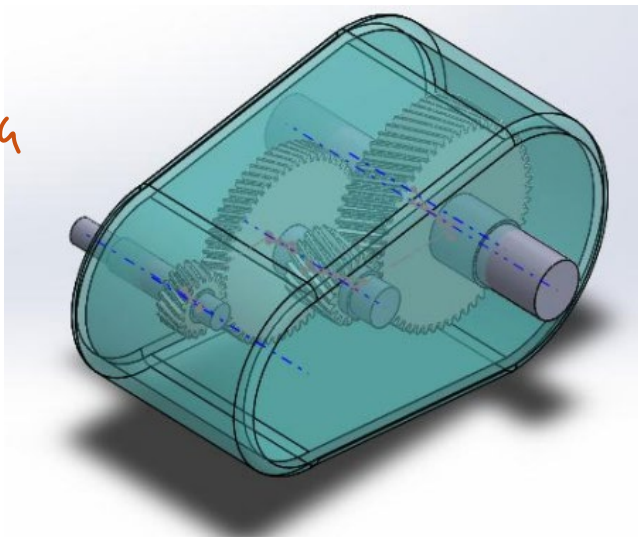
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RA	250.05 N	
RB	250.05 N	
Shaft Diameter	19 mm	
Deflection and slope		
Slope	6.534 rads	
Deflection	3.05 mm	
Critical speed of shafts	3334 rpm.	
Grade Material for Gearbox		
Input Parameters		
Parameters	Gear 1	Gear 2 - More
Transmitted Power (kW)	1.88	1.88
Speed (rpm)	1248.3	469.9
Torque (N-m)	19.12	33.03
Overload factor	2.0	2.0
Expected service life (h)	3500	3500
Reduction Parameters		
Centre Distance to tolerance	ISO 286-2010; Measure js7	ISO 286-2010; Measure js7
Normal diametrical pitch	9.432	9.432
Transverse pitch	8.45	8.45

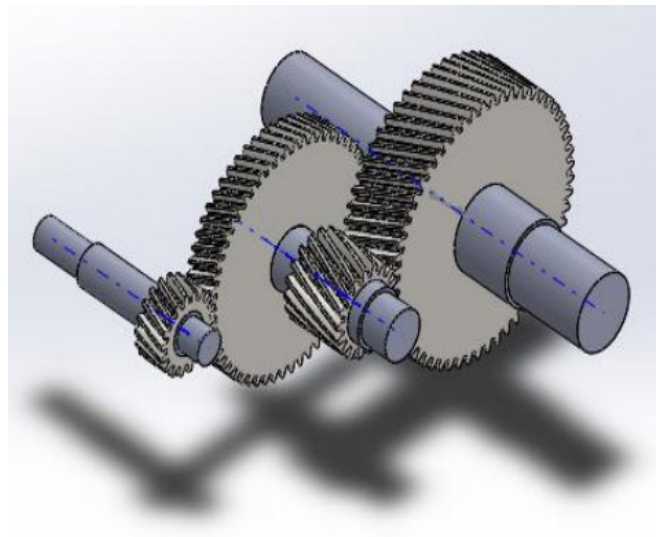
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Normal module	2.00	2.00
Pressure angle	20	20
Helix angle	17.3	17.3
No. of teeth	19	32
Face width	55	95
Hand Gear	Right	Left
Accuracy Grade	A8	A8

Gearbox Design



Gearbox with Housing



Gearbox without Housing

Grade of Material Used in Gearbox

<i>Material Grade List</i>		
No.	Part	Material
1.	Driving shaft	Composite of IPN resin and enforced by E-glass fibre
2.	Counter shaft	Forged C1045 medium carbon,
3.	Main shaft	medium tensile steel
4.	Bearings	Advanced Polymer (brass)
5.	Gears	Hardened steel
6.	Gear lever	Cast iron

Since a fault tolerant motor drive system are capable to attain level of 10^{-7} per hour, therefore it is recommended that electromechanical flap actuators be designed with speed ranging between 20% to 70% to provide for operational safety allowance.

References

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