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FUNCTIONAL FLEXIBILITY OF THE A350XWB HIGH LIFT SYSTEM

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Abstract

On all currently flying Airbus aircraft the functionality of the High Lift Systems was focused on providing lift augmentation for the low speed flight phases. Automatic functions were mainly introduced on classic High Lift Systems for protecting the aircraft structure from excessive loading (e.g. flaps load relief function) and for protecting the aircraft from consequences of certain erroneous pilot commands during the flight (e.g. cruise baulk functions). This article focuses on the enlarged functional flexibility and complexity of the A350XWB flap system, which provides several additional functionalities that improve the overall aircraft performance. The A350XWB flap system provides means for adjusting the center of lift in chord and in span direction and allows performing the lateral compensation for undesired roll movement. This functional enlargement is mainly based on the new feature of differential flap settings, i.e. the ability to position the inner and outer flap independently from each other, and on the comparatively simple dropped hinge kinematics. The maximum lift performance of the dropped hinge kinematics is supported by another novelty of the A350XWB High Lift System, which is the active gap control by means of drooping the spoilers according to the actual flap position. This gap control is realized by the fly-by-wire Primary and High Lift flight control systems.

1. INTRODUCTION

Each wing of the A350XWB aircraft is equipped with high lift surfaces at both, the leading edge and the trailing edge of the wing (fig. 1).

There are two different types of surfaces at the leading edge. One Droop Nose Device is installed inboard of the engine and 6 Slats are covering the full wing span outboard of the engine.

The trailing edge movable surfaces are composed of two flaps (inner and outer flap) which are complemented by 7 spoilers and a droop panel. The droop panel and the 2 most inboard spoilers are mounted as upper panel over the inner flap; the 5 outboard spoilers are mounted over the outer flap. The 2 ailerons are contributing to the high lift performance of the aircraft by a drooping function.

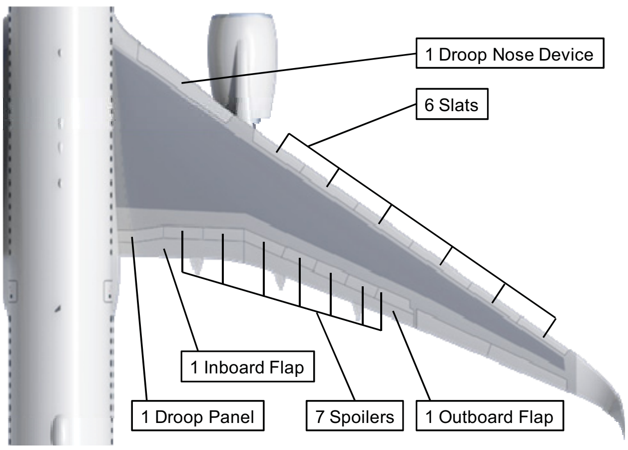

FIG 1. A350XWB High Lift Surfaces

2. LEADING EDGE SYSTEM ARCHITECTURE

2.1. Droop Nose Devices and Slats

The leading edge inboard of the engine is composed of one Droop Nose Device (DND) on each wing side. The DND is designed such that for take-off and landing the leading edge is drooped and thus contributing to the cambering of the wing (fig. 2). But contrary to other leading edge surfaces, e.g. slats, the DND does not open any gaps between itself end the fixed leading edge of the wing. This design is on one hand leading to an only slight loss of lift performance but on the other hand it significantly reduces the drag of the leading edge in this area, which is overall beneficial for the lift-to-drag ratio (L/D) and consequently improving the aircraft performance during take-off and initial climb phases.

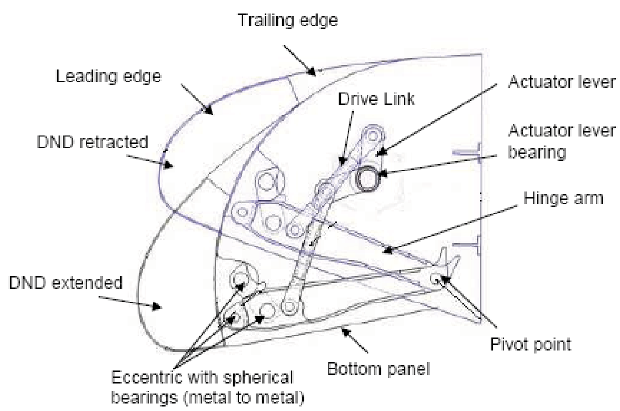

FIG 2. A350XWB Droop Nose Device

Optimization of the take-off performance was also driving the design of the A350XWB slats. The Contour Generated Sealed Slats (CGSS) kinematics and the shape of the slats in combination with the shape of the fixed leading edge of the wing are providing fully sealed take-off configurations and unsealed landing configuration (fig. 3). Like for the DNDs the CGSS design provides a maximum L/D for take-off and climb, but it also provides the required stall protection at high angles of attack during the approach and landing phases.

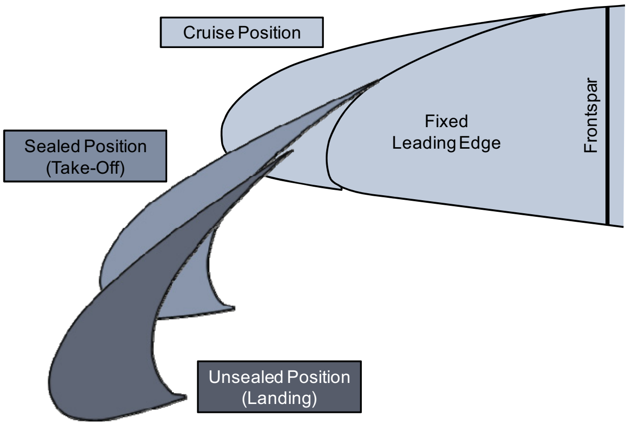

FIG 3. A350XWB Contour Generated Sealed Slats

2.2. Slat Actuation System Architecture

The architecture of the A350XWB Slat Actuation System (fig. 4) is very similar to the system architectures of previous Airbus aircraft like the A380.
The Slat Actuation System is powered by a central Power Control Unit (PCU), which is located in the center fuselage area of the aircraft. The PCU operates a transmission system, which distributes the power into the wings and which is composed of torque shafts and different types of gear boxes. At the final stage the power transfer to the leading edge surfaces is performed by Geared Rotary Actuators (GRA), which provide high gear ratios that transform the high rotational speed and moderate torques of the torque shafts into a slow, high torque movement of the Droop Nose Devices and Slats. Each of the leading edge surfaces is actuated by 2 Geared Rotary Actuators, thus there are in total 28 GRAs driving the leading edge surfaces.

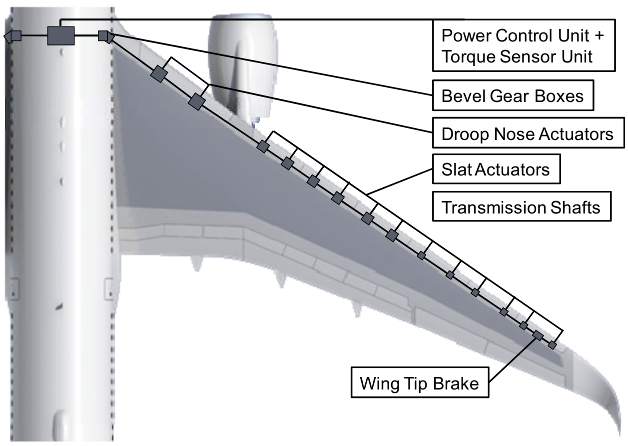

FIG 4. Architecture of the Slat Actuation System

3. TRAILING EDGE SYSTEM ARCHITECTURE

3.1. Dropped Hinge Kinematics

Each of the 2 flaps of the A350XWB aircraft is supported by 2 levers holding the flap panels. The levers are connected to the fixed supports by means of spherical bearings that act as simple hinge points for the Dropped Hinge Flap (DHF) kinematics (fig. 5).
The Fowler motion of a DHF is significantly reduced compared to more complex types of kinematics (e.g. track kinematics or 4-bar-linkages), but it enables simple solutions for the structural design of the flaps and their supports.

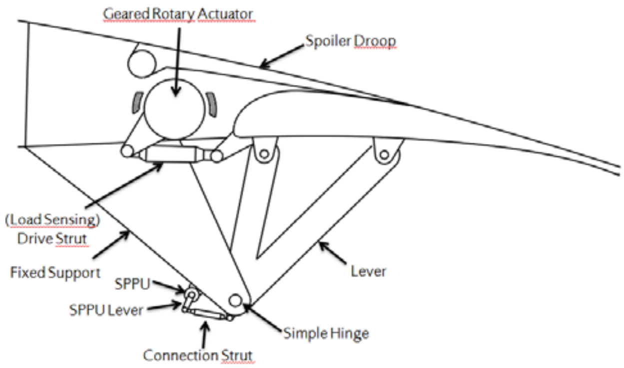

FIG 5. A350XWB Flap Kinematics

For a simple hinge kinematics like the one used for the A350XWB flaps the natural and simplest direction to deploy the flaps would be deploying the flaps parallel to the fixed trailing edge. Due to the kink in the A350 trailing edge a parallel deployment would result in a gap between the inner and outer flap, which could be partially filled by means of a flaperon.
For the A350XWB flaps a more complex design was chosen to enable a flap deployment in ‘stream-wise motion’ (fig. 6). Despite the trailing edge kink the flaps are always guided parallel to each other and do not open any unwanted gaps in-between, thus minimizing the vortex and noise generation and maximizing the aerodynamic efficiency of the flaps.

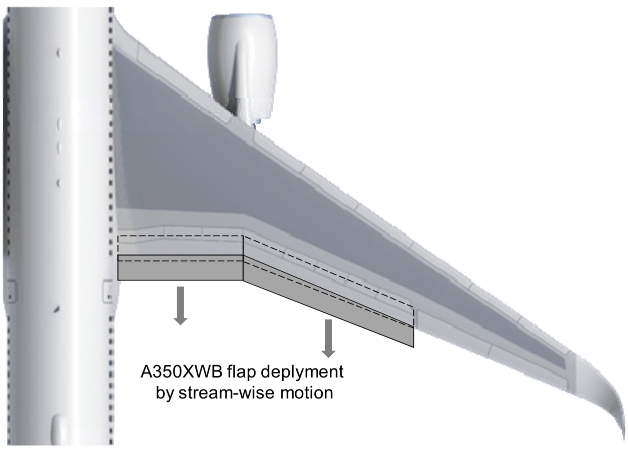

FIG 6. Stream-wise motion flap deployment

3.2. Spoiler Droop

The maximum lift performance for a given flap is limited by the maximum deployment angle for which the air stream is starting to separate from the flap. This angle can be increased significantly by drooping the spoilers when the flaps are deployed, whereby it is one of the essentials of the Adaptive Dropped Hinge Flap (ADHF) that the flaps and the upper panels are moved together without any mechanical coupling.
The spoiler droop contribution to lift performance increase is twofold. At first the spoiler droop is used for an active gap control of the gap between spoiler and flap. Since the spoiler droop is realized by using the spoiler servo control actuators, which are controlled by the Primary Flight Control System (PFCS), the gap can be set to any predefined value within a range that is limited by the kinematics of both surfaces only. Additionally the spoiler droop contributes to the cambering of the wing. The drooped spoiler does already deflect the airstream, consequently leading to a lower angle of attack to the flap surface itself. This effect allows higher flap angles without separation of the airflow on the flaps (fig. 7). This effect is to some degree comparable with the effect of a double slotted fixed vane flap.

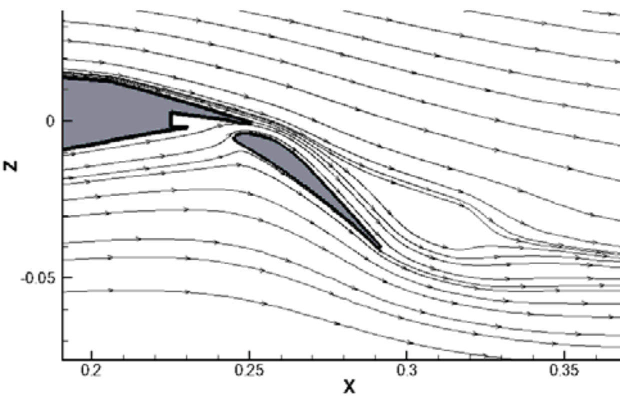

FIG 7. Air flow around drooped spoiler and flap (ADHF)

3.3. Flap Actuation System Architecture

Like the actuation system of the leading edge surfaces the basic architecture of the Flap Actuation System is mainly a central driven one. A central PCU is the main source of mechanical power, which is distributed into both trailing edges of the wing by a transmission system of torque shafts and gear boxes. GRAs with high gear ratios comprise again the final stage of the power distribution to the flap surfaces by transforming the torque shaft motion at high rotational speed and moderate torques into a low speed motion with high output torques (fig. 8).
Each of the flap surfaces is driven by 2 GRAs thus there are 8 GRAs driving the 4 trailing edge surfaces.

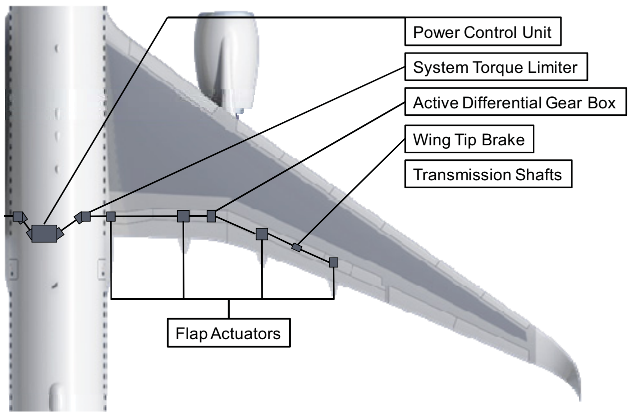

FIG 8. Architecture of the Flap Actuation System

3.3.1. Active Differential Gear Box

One novelty of the A350XWB Flap Actuation System on equipment level is the Active Differential Gear Box (ADGB). This unit allows a fully independent movement of the inner and outer flap of each wing and therefore is the enabler of Differential Flap Settings (DFS).
The basic principle of the ADGB is the one of a differential gear box with 3 in- and outputs; in any DGB the speed of the output stage is set by the sum of the speeds of the inputs. The in- and outputs of the ADGB are connected to the inner flap, the outer flap, and to an electric motor, which is physically connected to the DGB itself.
By different logics of applying the brakes of the PCU, the electric motor or the Wing Tip Brake (WTB) the ADGB allows 3 different types of motion for the flaps:

1) Unified Flap Setting (UFS)
The inner and outer flap are moved at the same time by means of the central PCU. The electric motor of the ADGB is arrested and held in position by the Power-Off Brake (POB) inside the ADGB. Thus the flaps are mechanically synchronized by the transmission system.
2) Inner Differential Flap Setting (IDFS)
Only the inner flaps are moved by means of the central PCU. The ADGB is driven in a passive mode, the POB inside the ADGB is released and the outer flaps are held in position by the WTBs. The flaps are mechanically synchronized by the transmission system.
3) Outer Differential Flap Setting (ODFS)
Only the outer flaps are moved by means of the electric motor of the ADGB. The inner flaps are held in position by the POB inside the PCU; the outer flaps are not connected to each other and thus the synchronization of the motion of both outer flaps is performed electronically by the control and monitoring system.

4. HIGH LIFT SYSTEM FUNCTIONS

The functions of the A350XWB High Lift System can be broken down into the functions of the sub-systems at the leading and trailing edge of the wing. For both sub-systems the first level of the functional decomposition shows the basic breakdown into Manual Control Functions, Automatic Control Functions (Auto Functions), and Monitoring Functions (Monitors) (fig. 9).

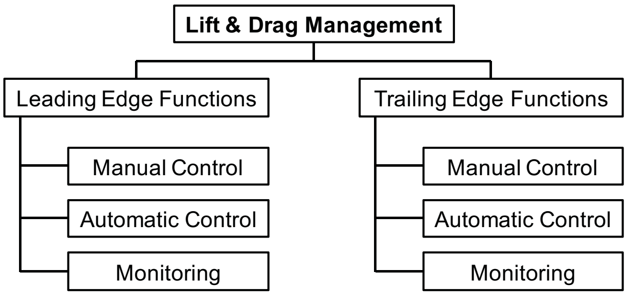

FIG 9. Functional Breakdown of the High Lift System

4.1. Leading Edge Functions

The leading edge system provides several functions that are well known from previous programs as well as some novel functions (fig. 10). The already known functions are briefly addressed below; the novel functions are described more extensive in the following chapter.

- Configuration Setting (Flaps Lever)
  Manual setting of the configuration. The Flaps Lever position '0' sets the slats to the fully retracted position ('clean wing'); positions '1', '2', and '3' set the slats to the sealed extended position; the position 'FULL' sets the slat to the fully extended, unsealed position.
- Slat α-lock
  In order to protect the aircraft against stall, the slat α-lock function prevents DND/slats retraction from extended sealed position to clean wing if the aircraft angle of attack exceeds a given threshold.
- Slat Baulk
  In order to protect the aircraft against stall, the slat baulk function prevents DND/slats retraction from extended sealed position to clean wing if the aircraft speed (calibrated air speed) falls below a given threshold.
- Slat Cruise Baulk
  The Slat Cruise Baulk Function prevents DND/slats extension during cruise when the flaps lever is (unintentionally) moved from position '0' to '1'. A selection of a lever position beyond 1 (i.e. '2', '3' or 'FULL') will enable the pilot to override the inhibition of slats extension for any abnormal situation.
- Asymmetry Monitor
  Monitoring of position asymmetry of left and right wings' leading edge surfaces, e.g. caused by a torque shaft rupture. In case that the given position asymmetry threshold is exceeded the system is stopped by applying all brakes.
- Overspeed Monitor
  Monitoring of transmission speed; a transmission shaft rupture might result in a strong transmission acceleration by the aerodynamic loads on the slats. In case that the given transmission speed threshold is exceeded the system is stopped by applying all brakes.
- Uncommanded Movement Monitor
  Monitoring of a symmetrical slats runaway that could be caused either by a runaway powered through the PCU or due to airloads in case of a freely moving PCU. In case that the given position threshold is exceeded the system is stopped by applying all brakes.
- Equipment Monitoring
  Monitoring of the status of dedicated equipment parameters to protect the equipment from damages (e.g. temperature monitoring for power electronics) or to detect damaged equipment (e.g. sensor failures or wiring defects). The system level reaction on equipment failures is depending on the gravity of the failures and their impact on system safety or operation.

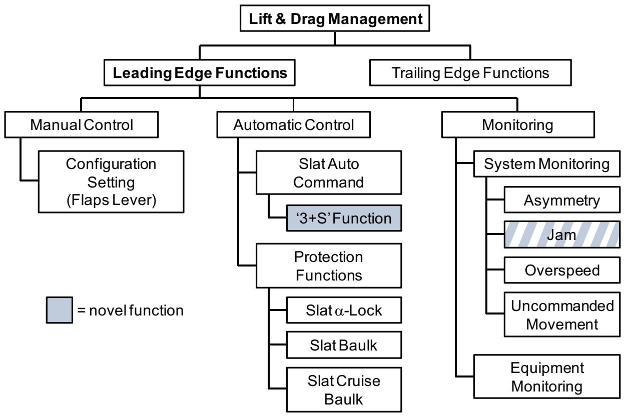

FIG 10. Functional Breakdown of the Slat System

4.1.1. Novel Slat Functionalities

4.1.1.1. '3+S' Function

As mentioned in chapter 2 the A350XWB slats are so called Contour Generated Sealed Slats (CGSS), which provide a sealed extend position for reduced drag take-off configurations. Nevertheless the slats shall be extended to their unsealed position for approach and landing.
The configuration '3' of the A350XWB High Lift System defines identical flap positions for take-off and landing, but due to the above mentioned reason the slat positions are defined differently. As the total number of configurations on the cockpit controls shall remain unchanged, the High Lift System incorporates the '3+S' function as an automatic command function. This function uses the actual flight phase, which is available through the Flight Warning System (FWS) at any time, to determine the required aircraft configuration for take-off on one hand and approach and landing on the other hand.

4.1.1.2. Novel Jam Monitoring

For protecting the transmission system from the stall torques of the PCU in case of jam failures in the slat actuation system the torque is limited by a dedicated monitor. This monitor replaces the known mechanical System Torque Limiter (STL).
The novel monitor requires a Torque Sensor Unit (TSU), which measures the PCU output torque to each wing and

provides these data to the Slat Flap Control Computer (SFCC). In the A350XWB slat actuation system this TSU is integrated into the PCU. If the PCU builds up an output torque that exceeds the given threshold the SFCC detects a system jam condition and consequently stops the motion of the PCU immediately to avoid any further increase of the output torque.
For comparable system architectures with a mechanical STL a jam condition outboard of the torque limiter leads to a lock-out of the STL, which results in an earthing of the excessive PCU output torque through the STL into the aircraft structure and finally a stop of the PCU motion after the unit's stall torque is reached.
By avoiding the PCU output torque increase up to stall torque level the novel jam monitoring helped to realize a significant weight saving in the slat actuation system and the aircraft structure.

4.2. Trailing Edge Functions

The A350XWB flap system provides a significantly larger portion of novel function than the slat system. Nevertheless the functional breakdown of the flap system functions (fig. 11) also shows a set of well known functions, which are briefly addressed below.

- Configuration Setting (Flaps Lever)
  Manual setting of the configuration. The Flaps Lever positions '0' and '1' set the flaps to the fully retracted position ('clean wing'); the positions '2', '3', and 'FULL' set the flaps to associated extended positions.
- '1+F' Function
  The Flap Auto Command Function '1+F' provides for two alternative flap settings with flaps lever in position '1'. If the aircraft speed (CAS) is greater than or equal to the defined Auto Retraction Speed then the flaps are commanded to the fully retracted position. If the aircraft speed (CAS) is less than or equal to the specific Auto Extension Speed then the flaps extend automatically to configuration '1+F', which is a flap angle between the configurations '0' and '2'.
- Flap Load Relief
  The High Lift System provides a flap load relief function for protecting the flaps from structural damage when the aircraft speed (CAS) is exceeding the maximum operating speed for flap extended (v_{FE}). The function is active with the flaps lever in gated positions '2' to 'FULL' and commands a flaps retraction to the next lower configuration if the CAS exceeds v_{FE} + 2.5 kt. The flaps return to their original position when the CAS drops below v_{FE} – 2.5 kt.
- Flap Cruise Baulk
  The Flap Cruise Baulk Function prevents flaps extension during cruise when the flaps lever is (unintentionally) moved from position '0' to '1'. A selection of a lever position beyond '1' (i.e. '2', '3' or 'FULL') will enable the pilot to override the inhibition of flaps extension for any abnormal situation.
- Asymmetry Monitor
  Monitoring of position asymmetry of left and right wings' flaps, e.g. caused by a torque shaft rupture or by asynchronous movement of the left and right wings' ADGB. In case that the given position asymmetry threshold is exceeded the system is stopped by applying all brakes.
- Overspeed Monitor
  Monitoring of transmission speed; a transmission shaft rupture or a freely moving ADGB might result in a strong transmission acceleration by the airloads on the flaps. In case that the given transmission speed threshold is exceeded the system is stopped by applying all brakes.
- Uncommanded Movement Monitor
  Monitoring of a symmetrical flaps runaway that could be caused either by a runaway powered through the PCU or due to airloads in case of a freely moving PCU. In case that the given position threshold is exceeded the system is stopped by applying all brakes.
- Equipment Monitoring
  Monitoring of the status of dedicated equipment parameters to protect the equipment from damages (e.g. temperature monitoring for power electronics) or to detect damaged equipment (e.g. sensor failures or wiring defects). The system level reaction on equipment failures is depending on the gravity of the failures and their impact on system safety or operation.

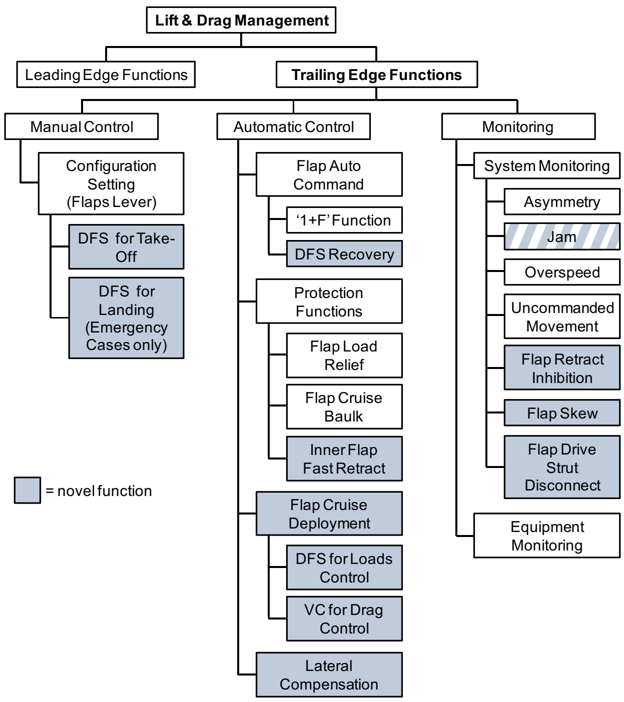

FIG 11. Functional Breakdown of the Flap System

4.2.1. Novel Flap Functionalities

4.2.1.1. Design Rationales

In general an aircraft's wing design has to be optimized for two opposing criteria. A wing that is optimized for maximum aerodynamic efficiency shall provide a span-wise lift distribution as close as possible to an elliptic load distribution, while a weight optimized wing design must lead to a load distribution that is minimizing the wing root bending moment as far as possible. The final aerodynamic wing shape and the overall wing design will always be a compromise between both criteria (fig. 12).

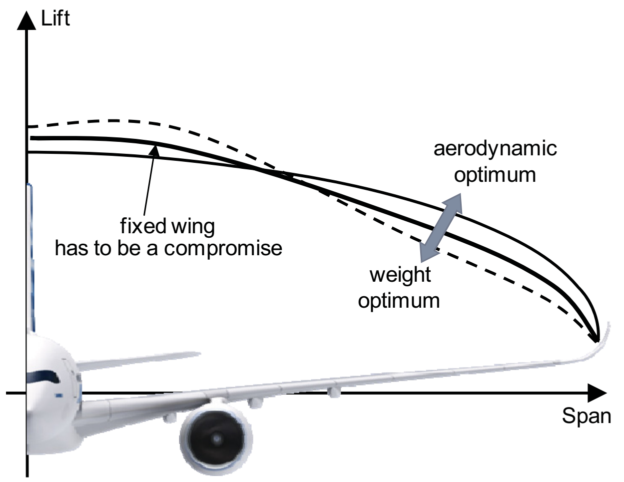

FIG 12. Span-wise lift distribution

The A350XWB wing design aims for a more weight optimized wing. Consequently the design point for the Center of Lift (CoL) is located more inboard than the elliptical CoL, thus optimizing the weight/drag balance at aircraft level but resulting in a reduced aerodynamic efficiency. For compensating this aerodynamic performance shortfall the High Lift System was designed for more flexible operation than 'just' providing lift augmentation in low speed.

4.2.1.2. Flaps Deployment in Cruise

The ADHF concept allows 2 functions in cruise with limited authority:

- Variable camber (VC):
  Trailing edge camber variation by limited, uniform flap deflection, i.e. deflection of all flaps with no gap or discontinuity enabling chord-wise CoL management.
- Differential flap setting (DFS):
  Capability for deflecting the inner & outer flaps independently allowing span-wise CoL management.

Chord-wise and span-wise CoL management in cruise requires both, DFS and VC.
During cruise at a fixed Mach number the lift coefficient (c_L) typically varies with aircraft weight and flight level. For a given flight level the lift coefficient decreases as the aircraft weight decreases; from a given flight level to a higher one, c_L increases again to compensate the loss in dynamic pressure.
The Flap Cruise Deployment Function is a purely automatic function which performs symmetrical small deflections (uniform and differential) during cruise in the limited range of -2deg (flaps up) to +4deg (flaps down) for the inner flaps and -2deg to +2deg for the outer flaps.
The control laws for flap cruise deployment reside in the Primary Flight Control System (PFCS) which receives the required input data – e.g. altitude, Mach number, dynamic pressure, aircraft and fuel mass – from other aircraft systems and calculates the flap position commands. The PFCS will send these commands to the SFCCs, which generate and execute a drive command for the flaps. Drive commands will only be executed if the flaps lever is in position '0'.
The main purpose of the flaps deployment in cruise is to adjust the centre of lift on the wing and the wing camber in cruise by UFS for optimization of aerodynamic performance (VC) and by DFS also for performance optimization and for wing load control.

4.2.1.2.1. Drag Control in Cruise

The drag control in cruise is performed by managing the CoL location in both possible directions, i.e. in chord-wise and in span-wise direction.
The span-wise CoL management is done by differential flap settings. For low lift coefficients c_L in cruise there is a benefit to move the CoL more outboard for three reasons:

- Induced drag will decrease significantly; this will overbalance the increase in trim and wave drag with still enough margin versus divergence in the critical midboard and outboard wing areas.
- Wing weight will not be increased by the CoL outboard shift as loads at a low c_L are not sizing. This is not true for the first flight level (heavy aircraft), but for the second and third flight level, i.e. for the major part of a typical flight cycle.
- The CoL outboard shift is also performed in off-design conditions (M < 0.7), climb, descent, hold and diversion when loads are not sizing.

A CoL inboard shift is performed at high lift coefficients in cruise to alleviate the wave drag of the critical midboard and outboard wing areas and the trim drag which overbalances the increase in induced drag. All this is of particular interest at a forward CG.
The CoL inboard shift is therefore contributing to meeting several challenging performance requirements, which are

- meeting the L/D_{max} target,
- meeting L/D_{max} at a required c_L for a good match with engine performance,
- limiting wave drag increase
  - when $c_L > c_L$ at L/D_{max}
  - when Mach > 0.85
  - to avoid the risk of premature buffeting or pitch-up.

An additional benefit can be drawn for reducing the emergency descent time by intentionally increasing the induced drag from shifting the CoL inboard and setting airbrakes out at M_{mo}/v_{mo}.

The chord-wise CoL management by using the same deflection for all flaps and ailerons to adjust wing camber (Variable Camber, VC) in cruise the following benefits can be achieved:

- Optimization of aircraft performance for high and low lift coefficients c_L and for high Mach numbers,
- Protection of sufficient margins towards buffet onset and pitch-up.

4.2.1.2.2. Loads Control in Cruise

The position of the CoL in span-wise direction can be influenced by differential flap settings of the inner and outer flap. With extending the inner flap up to a flap angle of 4deg and not extending the outer flap the overall wing shape is changed to a more inboard loaded wing (fig. 13), which is significantly reducing the wing root bending moment. Due to the availability of the loads control function it was possible to reduce the wing box weight significantly.

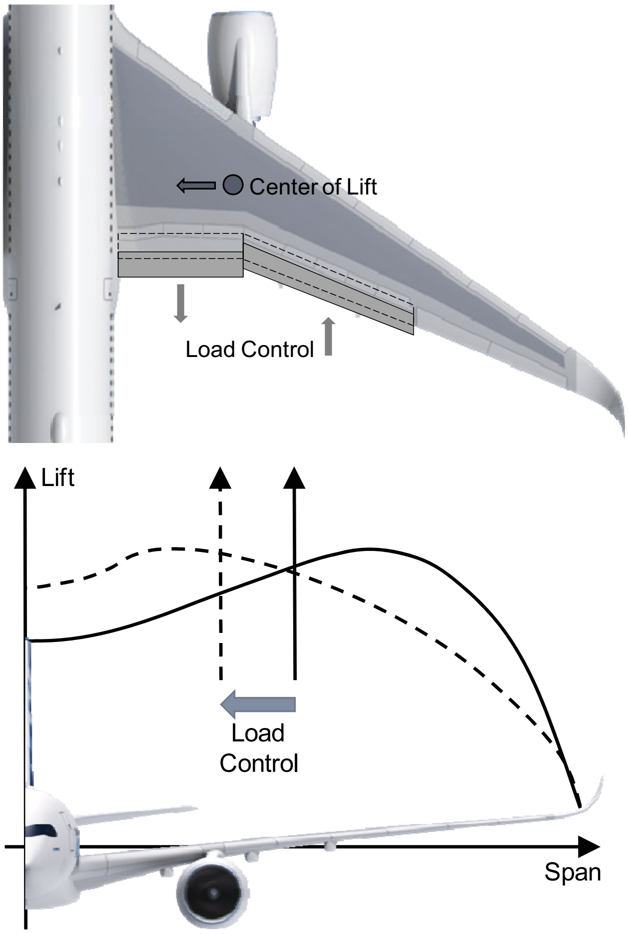

FIG 13. Loads Control in Cruise

4.2.1.2.3. Inner Flap Fast Retract

The Inner Flap Fast Retract function is a protection function that protects the flaps against high loads when the inner flap is extended for load control purpose in cruise. In case of large load factors or large angles of attack a fast retract of the inner flaps is commanded by the Flight Control and Guidance System (FCGS). In that case the inner flaps are retracted to the fully retracted position with the maximum speed that can be sustained by the ADGB as idle speed.

4.2.1.3. Differential Flap Setting in Low Speed

Low-speed aerodynamics was not the main driver for installing the DFS capability in the aircraft. The benefits of using DFS in low speed can be seen as a spin-off of high speed DFS.

4.2.1.3.1. DFS for Take-Off

Differential flap setting for take-off will be used in configuration '1+F'. The setting provides a significantly larger flap angle on the outer flap than on the inner flap (Δ=+6deg). With such setting the CoL on the wing is shifted outboard and thus the induced drag can be minimized at take-off.

Compared to a uniform flap setting the differential '1+F' setting is improving the aerodynamic performance of the wing by providing a more elliptic span-wise load distribution. This allows to meet the V_{MU} limitation with a lower total flap deflection at take-off and thus is reducing the aircraft's overall take-off drag.

4.2.1.3.2. DFS for Landing (Emergency Cases)

The standard flap settings for approach and landing are Uniform Flap Settings (UFS), i.e. inner and outer flap are commanded to identical flap deflection angles. But there are in total 3 failure conditions that will or might lead to the loss of both hydraulic power supply systems of the aircraft. These cases require the definition of non-standard flap setting for approach and landing. In these cases only the Outboard DFS (ODFS) remains available and any flaps lever selection greater than '0' will result in a dedicated DFS configuration based on the fact that in any of the mentioned failure conditions the electric power supply is still available to the High Lift System.

- Loss of both hydraulic supply systems ('Double Hydraulic Loss')
  In case of a full hydraulic loss as a result from failure combinations inside the hydraulic power supply system the hydraulic motors of the slat and flap PCUs become inoperative. The fully independent electric power supply remains available in that case. The High Lift System will operate the slats in the degraded mode at half speed with only the electric motor of the PCU driving the system. On the trailing edge the outer flaps can be operated by using the ADGB in normal mode.
- Total engine flame-out (TEFO)
  In case of a TEFO all normal operation power supplies are lost and the aircraft is powered by electrical power from the Ram Air Turbine (RAT) only. The electrical power share that is allocated to the High Lift System results in considerably reduced deployment speeds for slats and outer flaps.
- Uncontained engine rotor failure (UERF)
  In the worst case UERF all hydraulic power is lost combined with the total loss of slat operation because it is assumed that the mechanical slat transmission will be hit by rotor parts, finally leading to the engagement of all slat brakes and a 'slats locked' condition. Among all high lift surfaces only the outer flaps remain operational using the electrical power supply.

4.2.1.4. Lateral Compensation

A Lateral Compensation Function performed by the outer trailing edge flaps is implemented in the High Lift System for lateral compensation of an 'asymmetric' aircraft or in certain aircraft failure cases.

The asymmetric deployment of the outer flaps using the DFS capability of the High Lift System generates a long-term roll effect to compensate an unacceptable asymmetrical behavior of a new aircraft (i.e. the tendency to turn left or right in straight and level flight although all flight control surfaces are in neutral position: neutral asymmetry). Lateral compensation avoids asymmetric

rigging in the final assembly line to balance the asymmetric aircraft through wedges on the flaps plus controlling the effect by test flights. The benefits are a shortened lead time in the final assembly line and a simpler flaps design without wedges, i.e. no structural reinforcement required to account for increased loads due to wedges.
An asymmetric deployment of the outer flaps can also be used to balance the aircraft in failure cases such as lateral fuel imbalance, one engine inoperative (OEI), or the loss of both actuator links to a single aileron. Since the roll moment on the aircraft is compensated by the flaps rather than by the primary flight control surfaces, the lateral compensation helps preserving the full roll authority of primary flight control surfaces and saving performance (no spoiler deflection necessary) in low and high speed flight.

4.2.1.5. New Monitoring Functions

4.2.1.5.1. Flap Retract Inhibition

The ADHF provides improved high lift performance by drooping the spoilers and thus using the spoilers as a high lift device. Due to the spoiler droop the surfaces of spoilers and flaps are acting in the same space; the movement of both types of devices is coordinated by the PFCS (for spoilers) and the High Lift System's SFCC (for flaps).
Some spoiler actuator failure cases can lead to the effect that the spoilers are jammed in the drooped position or they are drooped unintentionally until the mechanical end stops of the actuators are hit. If one of these failure cases occurs while the flaps are extended to a position where the spoiler surface is able to pass the leading edge of the flap it shall be avoided to retract the flaps into the space where the spoilers might be actually positioned as this might result in severe structural damage to one or even both surfaces. Therefore a 'Flap Retract Inhibition' signal is generated by the PFCS and sent to the SFCCs. The High Lift System is immediately stopped and cannot be retracted.

4.2.1.5.2. Flap Skew Monitor

The Dropped Hinge type kinematics requires a new way of monitoring any disconnections of drive stations on the flaps. Since the flaps are rotated around a fixed hinge line that is located quite close to the flaps there will be no solid body motion of the flaps (contrary to real Fowler kinematics with hinge points in infinite distance). In case of a drive station disconnect the flaps are twisted by the aerodynamic loads. The torque in the flap shall not exceed the structural limit of the flap, thus the torsion needs to be monitored. This is done by measuring the rotation angle of each flap station by means of Station Position Pick-off Units (SPPU); the differences of the angles measured at adjacent drive stations of the same flap shall not exceed a given threshold, otherwise the High Lift System is stopped and cannot be operated until maintenance actions have proven the structural integrity of the High Lift System and structure.

4.2.1.5.3. Flap Drive Strut Disconnect Monitor

Two very special case of drive station disconnects are the disconnect failures of the flap drive struts at the inboard drive station of the inner flap (station 1) and the outboard drive station of the outer flap (station 4). If one of these failure cases occurs while the aircraft is operated at low weight and speed it is assumed that the aerodynamic loads are not sufficiently high to trigger the above mentioned flap skew monitor.
Therefore the forces on the drive struts at these stations are measured and monitored when the aircraft is known to be in flight and the flaps are in extended positions. Any force below a given threshold is interpreted as zero load, which can only result from a disconnected drive strut. Subsequently the High Lift System is stopped and cannot be operated until maintenance actions have proven the structural integrity of the High Lift System and structure.

5. CONCLUSION

The A350XWB High Lift System provides a significant increase of functionality compared to high lift systems on any previous Airbus aircraft. The novel functions enable a more weight optimized wing design on one hand and provide performance improvements for the aircraft on the other hand.
The Adaptive Dropped Hinge Flap kinematics allows changing the wing camber by using small flap deflections (Variable Camber) and therefore a flexible management of the chord-wise position of the Center of Lift during cruise.
The Active Differential Gear Boxes that are located between inner and outer flap on each wing are the enabler of Differential Flap Settings. DFS is the key novelty of the A350XWB High Lift System, since many of the novel functions are using this ability of deflecting inner and outer flap independently from each other and with that enabling the management of the span-wise position of the Center of Lift during all flight phases. During cruise the loads distribution on the wing is influenced by small differential flap settings, for minimizing the wing drag in cruise DFS and VC are used simultaneously.
Despite the low speed aerodynamics draw less benefit from the additional flexibility of the high lift system, the novelties are used to optimize the low speed performance under certain conditions, e.g. for take-offs in the '1+F' configuration or for special failure cases.
The last new function that is using the DFS is the lateral compensation of an asymmetric aircraft. Such asymmetries might occur for new aircraft due to manufacturing tolerances, but they might also be generated by certain failure conditions during the flight.

LITERATURE

[1] T. Teubner, H. Rechter; A350XWB High Lift System SDD (System Description Document), issue 4 (ref. V2750SP0707081_v04); Airbus confidential

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