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FLIGHT TEST FOR TYPE CERTIFICATION ACQUISITION OF SMALL CIVIL AIRPLANE KC-100

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Abstract

This paper is presented with the flight test program conducted to acquire the type certification (TC) for the KC-100(called as "NARAON") developed by KAI(Korea Aerospace Industries, Ltd) in South Korea. KC-100, a small civil airplane was developed and the flight test was performed to meet KAS(Korea Airworthiness Standard) Part 23 requirements(almost same with 14 CFR Part 23) for type certification. This airplane's flight test is different from the conventional military airplane development project such as KT-1, T-50 and KUH, which KAI had been already experienced in Korea. KC-100 project is the first challenge for us as a civil airplane developed with domestic technology based on all civil regulations and guidance with ROKG's certification authority involvement. KC-100 model is classified as KAS Part 23 normal category airplane having four seats, single Continental Motors, Inc (CMI) TSOIF-550K piston turbocharger engine with FADEC and a maximum take-off weight of 3,600lbs and composite structure.

On this paper, the KC-100 airplane's major characteristics and development program's overview including flight test infrastructures was briefly described, and it was introduced that the detailed flight test program was performed for acquiring TC. Especially the test results along with the lessons learned from the flight test were also described with particular attention to the success of the defined flight test and risk mitigation of airplane development flight test.

Flight test program began with the first flight of airplane No. 1 on 15th June 2011 and completed on 22nd March 2013, which was final certification flight test date conducted by ROKG's certification authority and then TC was issued 28th March 2013 from ROKG after Final TCBM's review through an intensive test program, which performed 559 flight sorties including certification flight test by using two flyable test airplanes.

1 Introduction

When the domestic airplane development cases in South Korea were looked back, there were only military aircraft developments like the KT-1, T-50 and KUH experienced by KAI but these were not the civil airplane development for type certification. For this reason, KC-100 airplane was developed firstly for the certification project of ROKG (Republic of Korea Government) for small airplane.

This airplane is classified as KAS (Korea Airworthiness Standard) Part 23 normal category having 4 seats.

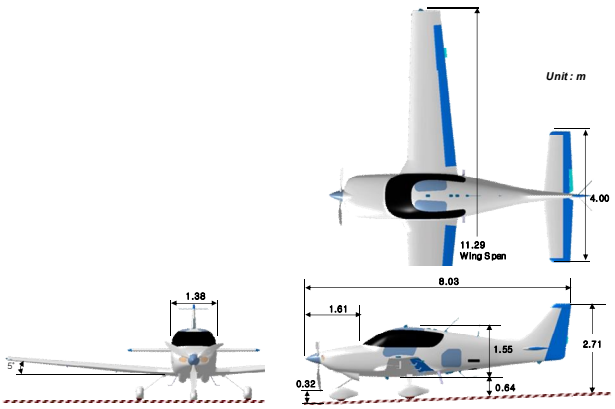

Fig. 1 KC-100 Three View Diagram

1.1 KC-100 Airplane

The goal of KC-100 airplane is to make appropriate design of normal category to show and find compliance KAS Part 23, which

applies to small airplane. The airplane belongs to general aviation and has four-seats. MTOW is 1,633kg (3,600lb) and 315hp gasoline engine is installed to the airplane. Also, state-of-the-art techniques such as all composite airframe, all electrical flight instrument system and optimized aerodynamic design are applied. By using the high intensity composite material to develop small airplane with high-tech materials according to the recent trend, it can reduce airframe weight, simplify manufacturing processes and make graceful external design. In addition, reduction of airplane weight can reduce CO_2 emissions, and meets environmental friendly factor. It enhances economic efficiency by extended fatigue life cycles and reduced maintenance costs. Configuration of the airplane was decided to apply low wing as basic configuration and conventional tail which is good at stall recovery characteristic. Actual performances of KC-100 airplane obtained by real compliance activity like analysis, ground test and flight test during development period for type certification are listed in below.

Table 1. KC-100 Performance

Airworthiness Category	KAS/14 CFR Part 23, Normal
No. of Passenger	4 Person(with 1 Pilot)
Power	315hp
MTOW	3,600lb
Service Ceiling	25,000ft
Stall Speed	58kts
Max. Range	1,090nm
Service Life	12,000flight hour

1.2 KC-100 Flight Test Process Overview

Development flight test by applicant and certification flight test by certification authority was performed to meet the requirement of airplane development specification and the technical standards of civil airplane like KAS and so on for TC. Development flight test consisted of R&D flight test and flight test for showing compliance of certification basis. Certification authority approved flight test plans for showing compliance among development flight test and witnessed for conformity of test setup and flight testing. Also after completion of showing compliance flight test, applicant submitted the flight test reports and got approval from certification authority. Certification authority reviewed the applicant's flight test reports to determine that the airplane conforms to the type design, and identified the specific flight test conditions that would be reevaluated by certification authority's test pilot. TIA(Type Inspection Authorization) for commencing official certification flight test was issued after Pre-flight TCBM, which was also reviewed if flight test risks are acceptable. During certification flight test, applicant supported flight like test airplane preparation and flight safety activities including PIC (Pilot-In-Command) role and etc. The final TCBM for issuing the TC and TCDS was held when the certification authority determined the applicant had demonstrated compliance with all applicable airworthiness standards in the certification basis.

2 Flight Test Infra Preparation

Flight test infrastructures were prepared like real-time monitoring system on ground, flight test instrumentations, safety chaser and etc. to conduct the KC-100 flight test efficiently and safely. The flight test center was constructed for civil airplane flight test, which is a unique feature of moveable shelter, space efficiency and enhanced convenience. This center was characterized by the integrated and moveable structure, centralized structure with major flight test factor-briefing and control room, mission control room, flight test instrumentation labs, post flight data processing system and toilet, extended interior space, also applying hydraulic system for operator convenience and sound-absorbing materials and waterproofing. Mission control room of flight test center can be monitored with maximum 26 engineers including test conductor, safety director and etc. Spin recovery system (SRS) was designed by Airborne System, USA and installed at No. 2 test airplane prior to stall and spin test and verified with high speed ground taxi test for deployment and jettison function of parachute in order to validate the structural integrity, reliability, and susceptibility.

Fig. 2. Taxi Test for SRS Verification

3 KC-100 Flight Test Results

3.1 KC-100 Flight Test Summary

KC-100 flight test was began with the first flight of airplane No. 1 on 15th June 2011 and completed on 22nd March 2013, which was final certification flight test date conducted by ROKG's certification authority. And then type certification was issued 28th March 2013 from ROKG based on Final TCBM's review after an intensive flight test program involving two test airplanes and 559 flight sorties.

For development flight test as applicant, KAI developed total of 21 flight test plan documentations to meet requirements of KAS Part 23 and development specification, which was categorized with 6 divisions as below.

- Structure: flutter, loads, vibration
- Aerodynamics: stability and control, performance, air data calibration, noise
- Avionics: avionics, autopilot
- Power-plant: propulsion, fuel
- Subsystem: FCS, ECS, landing gear, oxygen, deicing, lighting, electrical, EMC
- Others: pilot flight evaluation, initial airworthiness

Also these test items were allocated to two test airplane as shown below, especially some test items must be performed on the specified test airplane with special test aids and instrumentations like flutter excitation system on No. 1 test airplane for flutter test, trailing cone on No. 1 airplane for air data calibration test, spin recovery system on No 2. airplane for stall and spin test and so on.

- No. 1 test airplane: flutter, stability and control (include stall, spin without SRS), air data calibration, performance, etc
- No. 2 test airplane: load, stall and spin with SRS(part of stability and control test), avionics, etc

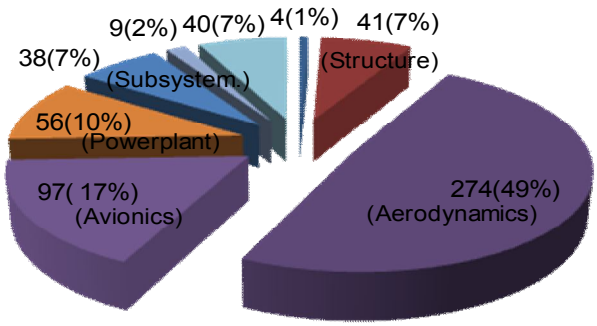

Fig. 3. KC-100 Flight Test Sorties Composition

3.2 Initial Airworthiness Test

Initial airworthiness test composed of taxi test and initial airworthiness flight test in building up to the continued envelope expansion flight test. KC-100's taxi test was performed ramp, low, medium and high speed taxi test with speed and airplane condition buildup approach, which high speed taxi also conducted with $0.8V_{s1}$, V_{s1} and V_{LOF} in thorough and cautious manner. Initial airworthiness flight test was performed two flights within flight envelope analyzed for flutter free based on ground vibration test.

Table 2. KC-100 Taxi Test Conditions for Initial Airworthiness Test

Taxi Type	Airspeed(kts)	Remark
Ramp	5~10	
Low	35	3 Point Roll
Medium	45	
High	$0.8V_{s1}$, V_{s1}	2 Point Roll
	V_{LOF}	Lift and Settle Down

3.3 Flutter Test

This test was to show that development airplane is free from flutter, control reversal and divergence within the speed range up to V_D. Flutter excitation system was installed on airplane with each wing tip's aerodynamic shaker vanes and operated at selected speed points over a frequency range up to 50Hz to excite vibration with symmetric and anti-

symmetric mode with sine sweep and sine dwell (or burst) excitation.

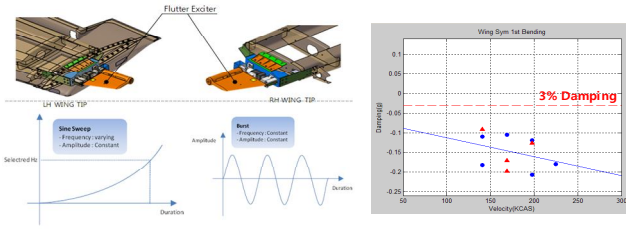

Fig. 4. Flutter Excitation & Results

3.3 Stability & Control Test

This test has the very big portion of the flight test program including static and dynamic stability, maneuvering stability, stall, and spin and so on.

During S&C test, minor modifications were occurred based on flight test results to meet requirements for wing level stall characteristics (§ 23.201) and static lateral stability (§ 23.177(b), which did not meet fully the roll off requirement (within 15deg) for wing level stall maneuvering at landing configuration and wing pick up tendency requirement at low speed ($1.2V_{s1}$) in take-off configuration. The improvement activities were implemented with lots R&D flights to meet requirement fully without questions from anyone. One was installing a small stall strip at some area close wing root for stall characteristic and the other was implementing a light weighing control stick and ARI (Aileron Rudder Interconnection) for static lateral stability.

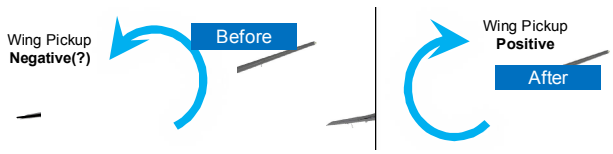

Fig. 5. Improvement Concepts for Lateral Stability

3.4 Air Data Calibration Test

The pitot-static system of development airplane should be calibrated by finding of the pitot-static system's position error using tower fly-by, pacer, tracking radar, trailing cone method and etc. and if not meet the requirement, modified the static source and calibration results shall be implemented on flight manual. Calibration test for KC-100 was conducted at whole airspeed region with each flap locations using trailing cone. Especially minimum weight condition also was performed at low speed region having the big difference for AOA.

Test results were met within the tolerance value of requirement for airspeed error and altitude error. Also spot check result for weight effect was negligible level.

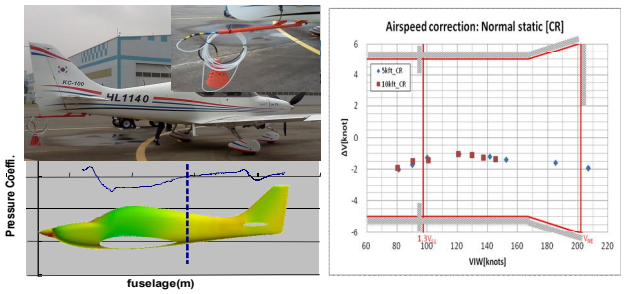

Fig. 6. Trailing Cone and Test Result for ADC

4 Conclusion

KC-100 project was a first challenge for us as a civil airplane developed with domestic technology in accordance with all civil regulations and guidance with ROKG's certification authority involvement. KC-100 model is classified as KAS Part 23 normal category airplane having four seats, single piston turbocharger engine with FADEC and a maximum take-off weight of 3,600lbs.

The certification for the KC-100 was required a very comprehensive flight test program to evaluate the structure, flying qualities, performance and systems operation. Flight test program performed 559 flight sorties including certification flight test using two flyable test airplanes. After flight test program type certification was issued from ROKG based on final TCBM.

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