PROCEEDINGS of the 4th CEAS Conference, Linköping, 2013
http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-99581

Integrated:
11th European Workshop on Aircraft Design Education
http://ewade2013.AircraftDesign.org
http://ProceedingsEWADE2013.AircraftDesign.org
http://doi.org/10.5281/zenodo.546634

Personal Jet
A student project

C. Jouannet, P. Berry, T. Melin, D. Lundström
Linköpings University, Sweden Affiliation 1, Country

Keywords: *Student project, demonstrator, aircraft design*

Abstract

The presented work considers designing, building and flight test of a demonstrator of a personal jet aircraft realized as a student project. The goal is to allow student to participate in an aircraft project from design to flight test in order to acquire aircraft design knowledge from theoretical and practical means. A first theoretical part consists of creating a sizing program for studying different concepts. Then the gathered knowledge will result in the realization of a flying demonstrator. This was realized during a student project over a 5 month period..

1 Background

Since the development of the BD5J, a kit plan, no personal jet has been available to the market. The possibilities for developing a new personal jet is studied, in order to reach a broader market an investigation on certifications regulation is performed. The project aim is to design a single seat sport jet aircraft based on a TJ100A turbine engine. To prove the design a radio controlled sub scale demonstrator will be built and flown, powered by a Funsonic FS70 jet engine.

2 Educational Challenge

Over the years there has been a dramatic reduction in ongoing aircraft projects. Today's aircraft design engineers are lucky if they will be involved in one or two complete projects during their entire careers. This is in sharp contrast to the "golden age", when an engineer was likely to be part of several projects during his career, see Table 1.

This situation creates an issue regarding the education of aircraft design engineers. When they start their professional life they will be assigned to an ongoing project and they may be involved in that for a long time before starting on a new project. The teaching approach as proposed by Linköping University is to allow future aircraft engineers to participate in a complete aircraft design project, from requirements to flight testing, as a preparation for their very first steps into industry.

The other major challenge in aerospace education is changing demands from the industry regarding the type of knowledge the yet to be engineers should be educated for. Most of university aerospace educations are focused on

Table 1 Aircraft project through an aerospace engineer's career [1]

Time Span	Aircraft projects
1950-1980	XP-5Y, A-2D, XC-120, F-4D, F-3H, B-52, A-3D, X-3, S-2F, X2, F-10F, F-2Y, F-100,B-57, F-102, R-3Y1, F-104, A-4D, B-66, F-11F, C-130, F-101, T-37, XFY, F-8U, F-6M, U-2, XY-3, F-105, X-13, C-133, F-107, B-58, F-106, F-5D, X-14, C-140, T-2, F-4, A-5, T-39, T-38, AQ-1, X-15, F-5A, X-1B...
1960-1990	A-6, SR-71, SC-4A, X-21, X-19, C-141, B-70, XC-142, F-111, A-7, OV-10, X-22, X-26B, X-5, X-24
1970-2000	F-14, S-8, YA-9, A-10, F-15, F-18, YF-17, B-1B, YC-15, YC-14, AV-8B, F/A-18
1980-2010	F-117, F-20, X-29, T-46, T-45, B-2, V-22
1990-2020	YF-22, YF-23, JSF, C-17
2000-2030	UCAV, B-3?...

developing students analytical skills and not as much to develop the synthesis capabilities nor the innovative perspective needed for aircraft design. Recent changes in educational perspective, such as the CDIO initiative[2], initiated by the Aerospace institute at MIT and tree Swedish universities, Linköping University being one among them, try to apply a more synthetical view on engineering education, by introducing small practical assignments into the regular courses. This approach is adopted in a larger scale for the aircraft design education at Linköping University, and was adopted before the creation of the CDIO initiative [2].

Nowadays team-work is increasingly important. Being able to present results and ideas in a selling manner is also an important skill, as well as to be able to convert ideas into something practical and useful. This is something which Universities seldom care much about, but that is certainly important, i.e. to bridge the cliff between the students mostly theoretical life into the more practical life in industry. One of the most important issues is to be able to gain a holistic viewpoint from the very start in working life, i.e. to possess a kind of "helicopter view" with regard to the product or project one is involved in. One way of preparing for that insight is to carry out projects like the aircraft design project at Linköping University.

3 Project Task

The project will be divided into the following phases:

- First phase: Concept generation and design competition
  - The group will be divided in teams and will compete for the best design
  - An advisory board will select 1 or 2 designs for further studies.
- Second phase: Conceptual and preliminary design
  - Further study of the selected designs
  - Sizing and performance calculations
  - CAD design
  - The advisory board will select one design for final development
- Third Phase: Detailed design and demonstrator development
  - Detailed studies of the final configuration.
  - Demonstrator development
  - Design
  - Manufacturing
  - Flight testing

3.1 Design specifications

The main characteristics are:

- Appealing design
- Good handling qualities
- Performance level similar to BD5J

Following must be included in the design of the fullscale and demonstrator must be represented in CATIA V5 R21

- Landing gear studies
  - retractable landing gear
  - steering on nose wheel
- Brakes
- Cockpit layout
  - Instrumentation and instrument panel
  - Adjustable pedals to accommodate different pilot sizes
  - all necessary information for the cockpit¨
  - Field of view for the pilot
- Mechanism for control surfaces/Flight control system
- Fuel system designed for advanced flight
- Engine installations
  - Duct design
  - Outlet design
- Emergency escape mechanism
- Electrical system Sizing for
  - Navigation light
  - ECU/engine start
  - Avionics

4 Certification and regulations

To be allowed to fly the airplane and make it profitable for production the airplane needs to be certified by competent authorities. Different certifications categories were studied, it appeared that the categories CS-VLA (Very Light Airplanes),
CS-LSA (Light Sport Airplanes) and Experimental could not be used for this project for different reasons. The CS-VLA is for non-aerobatic aircraft and the CS-LSA does not allow turbine engines, making both of these regulation categories unavailing. In addition, the experimental category is different in every country witch is not optimal for export possibilities.
The two remaining categories were CS-23 (Normal, Utility, Aerobatic, and Commuter Airplanes) [3]and FAR, another category for experimental aircraft. It was decided to use the CS-23 as certification basis for the aircraft, mainly because this category allows aerobatic and jet aircrafts and also commercial sales. Once the aircraft regulation category was decided, it was necessary to further study the associated regulation in order to extract the information needed and ensures that the aircraft is in accordance with the regulations.

5 Concept development

The conceptual phase started as a sketch exercise to present various ideas around a personal jet, examples of those sketch are illustrated in Fig. 1.

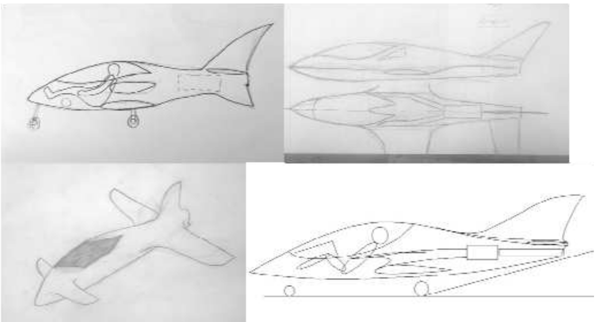
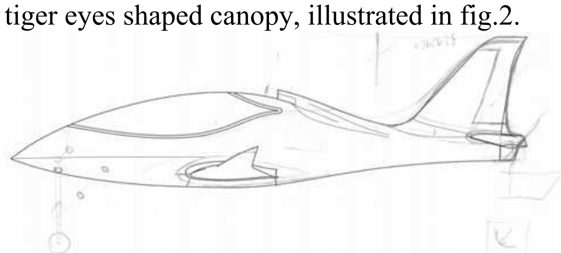


Fig. 1 Early concept sketches

Further discussion and development gave the airplanes more aggressive contours and keeping an aerodynamic shape. Inspiration from nature and animals gives a shark-shaped outlines and tiger eyes shaped canopy, illustrated in fig.2.



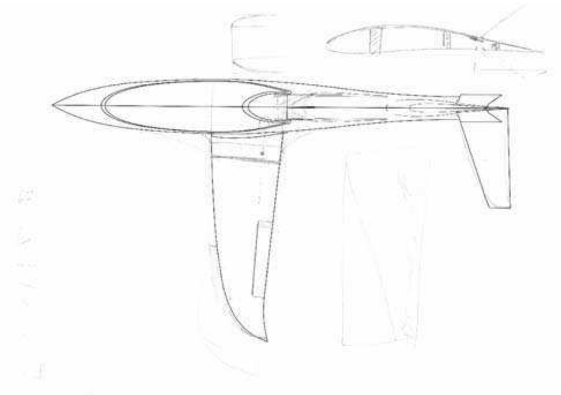


Fig. 2 Final Concept

5.1 Sizing

The sizing was performed around a given engine, the TJ100 from První brněnská strojírna Velká Bíteš. It is a single shaft, single stage radial compressor of about 20 kg's and has a static thrust of 1200N. The sizing program used is a Linköpings university in house sizing tool. The sizing tool was calibrated with the actual BD5J [4]. Weight factors were added in order to take into account composite usage instead of metal such as used in BD5J.

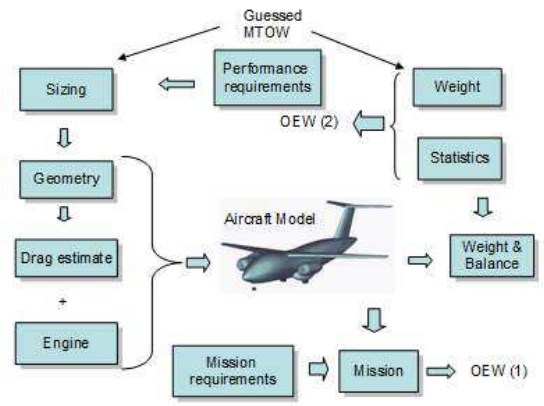
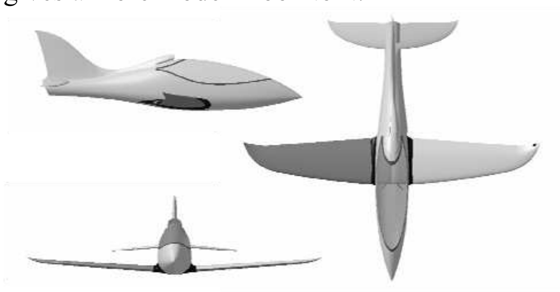


Fig. 3 sizing flow

The following characteristics were obtained from the sizing.

	MidJet	BD5J
MTOW [kg]	320	386
OEW [kg]	146	163
Vcruise [km/h]	437	386
Stall speed [km/h]	104	107
Wing loading [kg/m2]	100	137
Sref [m2]	3,2	2,8
Wing span [m]	5,2	4,36
Length [m]	4,8	3,6
Height [m]	1,46	1,68

The new design called MidJet is lighter than the original BD5J and has a lower wing loading. In order to improve handling characteristics the fuselage was stretched. The stretching of the fuselage provides a smother overall shape and gives a more modern look to it.



5.2 Engine specifications

The TJ100 is designed and manufactured by První brněnská strojírna Velká Bíteš. It is a single shaft, single stage radial compressor of about 20 kg's and has a static thrust of 1200N.

6 Preliminary design

6.1 Landing gear

A study on a retractable landing gear was performed, see Fig. 4. The landing gear has a classic nose configuration with a steerable nose wheel and hydraulic brakes on the main landing gear. The tires have a diameter of 220 mm. Retraction is performed by a mechanical system of rods and levers controlled by the force of the pilot's hand motion. The weight distribution is 92% for the main landing gear and 8% for the nose wheel.

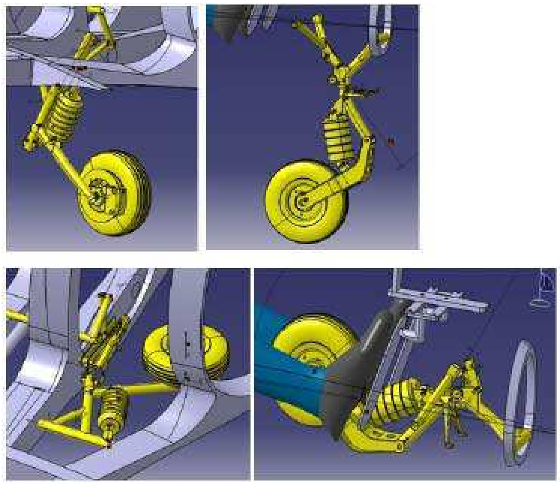


Fig. 4 Landing gear

6.2 Flight control system

In order to move the control surfaces, a linkage between the stick and pedals and the surface is required. A lot of research was done on the design of the stick. The challenge was to make a mechanism that allows the transfer a lateral and rotational movement at the same time, while being compact and robust.
The pedals are moving the rudder in the vertical tail as well as the nose wheel while it is extended.
Since the landing gear takes up a lot of space it was decided to have a lever on the stick for activating the brakes rather than toe brakes. The joint for the pedals which is usually placed underneath the pilots feet had to be repositioned to be able to fit the nose wheel.
The restrained space and rather complex routing for rods leads to a fly-by-wire system. The intention was to keep the wire as straight as possible to avoid friction between the pulleys and the wires. This was limited by the many components that had to be avoided between the stick and the control surfaces such as the fuel tank, the seat, the duct, the landing gear and the different frames.

6.3 Structure

The first thing that was considered when designing the structure was to think "composite". Then, since the fuselage and the wings are built using sandwich technique, there is neither need for stringers or longerons in the fuselage nor multiple ribs in the wings. The skin shell is stiff by itself for the fuselage but needs some reinforcements for the wings, horizontal and vertical stabilizer since they are thin parts and large bending moments are involved.

6.3.1 Fuselage design

The fuselage needed numerous frames to attach the internal components of the aircraft and this also offers more torsional stiffness (for loads that come from the vertical stabilizer), illustrated in Fig.5. The frames, regarding their location, are made with different thickness. The thin ones are used for carrying components such as engine, fuel tank or rudder pedals. Two big frames are used for the front (main) and rear spar of the wing. The main spar can then cross through the frame and therefore be very stiff. The two main frames were extended to carry the loads from the landing gear. The last spars in the rear part of the aircraft are realizing two functions: carrying the exhaust pipe and also acting as a spar for the vertical stabilizer and bring bending stiffness.

6.3.2 Wing design

Since the wing is mostly constructed from carbon fibre, there is no need for multiple ribs to support the skin. This skin links the main and rear spar and allows to form a "wing box" design and then creates something very stiff in a torsional and bending point of view. First, two ribs are needed: one at the root and one at the tip, illustrated in Fig.5. They enable to carry the hinge rod around which will swivel the flaps and ailerons. Between those two components (not on Catia) it is also required to have a hinge attached on the rear spar because of the aerodynamic forces that will tend to bend the hinge rod.
The main spar is made of two parts that are bolted together and on the frame. It was placed at the chord-wise thickest part so the web could be made as high as possible. The way of splitting the spar was to proceed with a shallow

angle (as done on some gliders) to avoid sharp corners that could generate structural problems. Therefore, the two parts bolted together that are crossing through the fuselage and allow a large bending and shear stiffness. The rear spar cannot cross the fuselage since there is the landing gear. Therefore, it is attached to a frame without going through it.

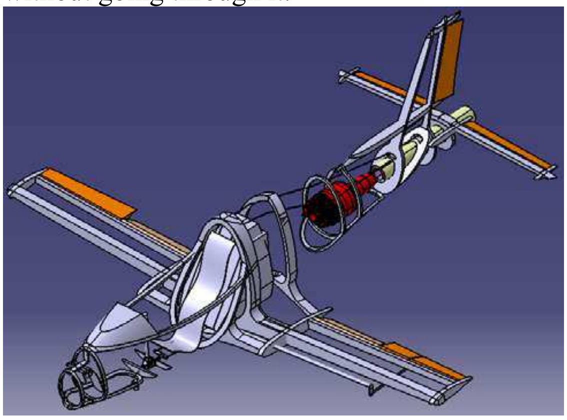


Fig. 5 Structure layout

7 Demonstrator

The scale of the demonstrator was determined by sizing down the full scaled aircraft to fit a engine (and its nozzle) that was already chosen, called FS70 made by the company Fun Sonic. The scale of the demonstrator was then set to 1:2,8. To get the center of gravity at the desired position the components had to be placed in a good way, the lightweight of the main component and the lack of "pilot" inside the demonstrator forced to use ballast in the nose in order to have a balanced aircraft.

The fuselage consists of three parts. The main and biggest part of fuselage is made out of composite sandwich with two millimeters foam core and glass fibre cloth, structure is showed in Fig.6 and molding of the fuselage is seen in Fig.7. The wings are attached wings to this part as well as the horizontal tail and the part of the inlet made out of glass fibre. On this part is glued third part of the fuselage - top part of the inlet made out of plastic on 3D-printer, see Fig.9.

Fig. 6 Structure layout of demonstrator

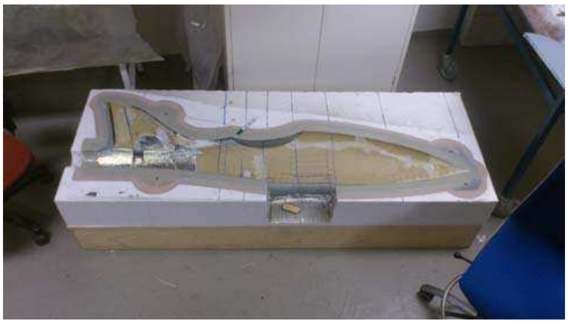


Fig. 7 Molding of the fuselage

Further stiffening of the fuselage is not required, so the structure inside is focused mainly on holding components. The front part of the structure is the frame and floor for attaching nose landing gear, batteries and extra weight for keeping center of gravity at the right place. Behind the nose landing gear there is space where regulators and remote control receiver will be attached. The wing will be attached on floor which is held by two frames from each side. The wing itself is attached to the floor by four screws. This part of the fuselage also holds the fuel tank, hopper tank and floor where the engine is attached. After the engine follows exhaust pipe that is held by four frames, where second frame is reinforced and used also as a vertical tail beam. The third frame is used to hold rudder hinges.

Fig. 8 Molding of the wing

The wing is made from composite structure and is undivided, see Fig.8. The wing attachment is done via 4 bolts, going into the fuselage wing attachment floor, made as a plywood sandwich. The bending moment is transferred by the main spar, specially by flanges of the main spar. Shear stress is transferred in the web of the main spar and finally the torsion moment is taken by the skin.

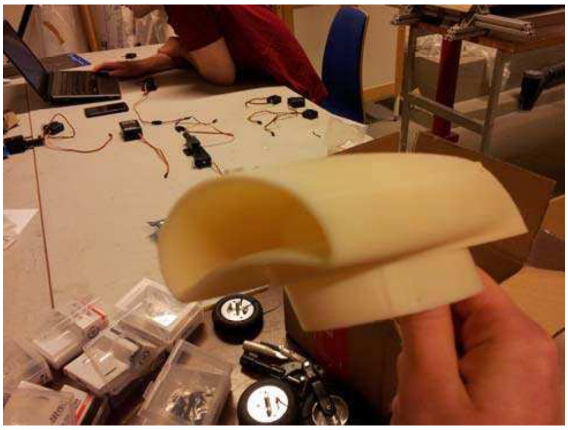
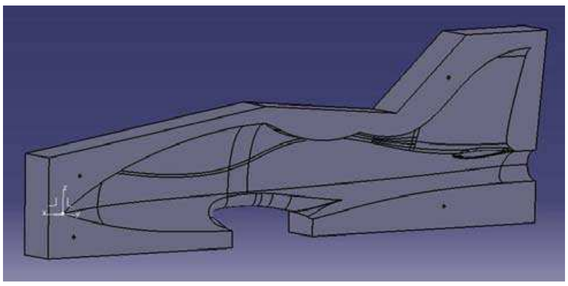


Fig. 9 3D printed inlet



8 Conclusion

Realization of a student project is a dual challenge. Education and the success of the project. The goal in this case is to give the student a broad understanding of the aeronautical challenges and the interaction between disciplines. The usage of a flight demonstrator, an advanced RC model is sufficient to allow students to acquires a sense for the challenges while applying there theoretical skills. The manufacturing phase remind the students that manufacturing is time consuming and that system installation is a large part of the finalization of aircraft project prior to flight testing. This makes this kind of project very suitable for education of broad aeronautical engineers.

Fig. 10 Artistic illustration of the MidJet

References.

[1] Scott, W. B., "Industry's Loss Expertise Spurs Counterattack - Aerospace in Crisis" Aviation Week & Space Technology, March 13, 2000, pp. 60-61

[2] http://www.cdio.org

[3] EASA Certification CS-23: http://www.easa.europa.eu/agency-measures/certificationspecifications.php#CS-23 (retrieved 2013-04-1)

[4] BD-5 info: http://www.bd5.com/bd5info13.htm