DESIGNING A LOW-NOISE PROPELLER FOR AN UNMANNED AERIAL VEHICLE

by H Peter Visser

Unmanned aerial vehicles (UAVs) are becoming increasingly popular in commercial and military applications where they are used for various purposes, from surveillance and border patrol to crime prevention and wildlife management.

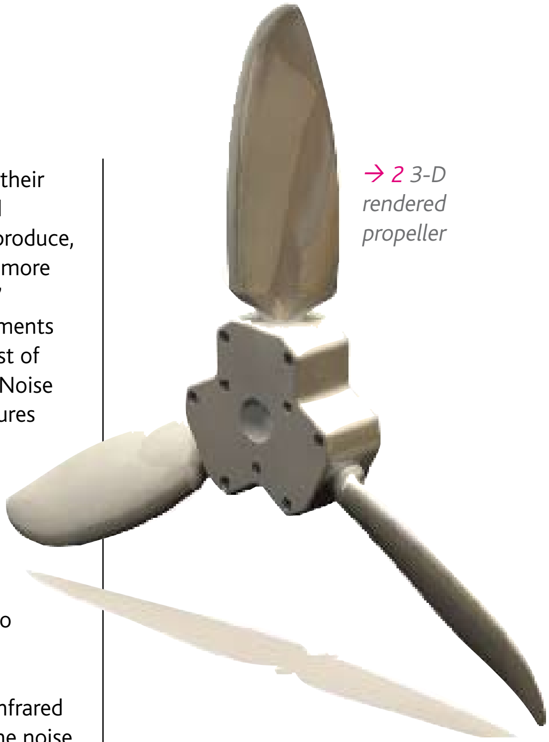
Their popularity can be ascribed to their numerous advantages over manned aircraft. They are cheaper to mass-produce, eliminate human risk, are generally more accurate, and will fly into a 'no-win' situation. One of the major requirements for UAVs in the performance of most of these missions is low detectability. Noise levels and infrared and radar signatures are the key parameters to signify detectability.

South African company Denel Aerospace Systems contributes to this innovative technology by marketing its own successful UAV to the international market. While the Denel Aerospace UAV has a low detectability footprint in terms of infrared and radar, it generates high drive-line noise levels from the engine and the propeller. As a result, an undergraduate project was launched to design a propeller with low drive-line noise levels.

Designing a lower-noise propeller

Literature proved that propeller noise is created by blade thickness, blade loading and energy loss at the blade tips. Things that were considered in the design included reduced blade thickness, reduced blade loading noise by distributing the thrust over more blades, a helical tip Mach number below 0.65 for a noiseless propeller, swept-back blades to reduce energy losses at the tips, propeller weight, inertia, balance and efficiency.

A smaller, three-bladed aluminium propeller was designed. The blades incorporate tip-sweep and the profile is the Clark-Y airfoil. The propeller's performance characteristics should match the aircraft.

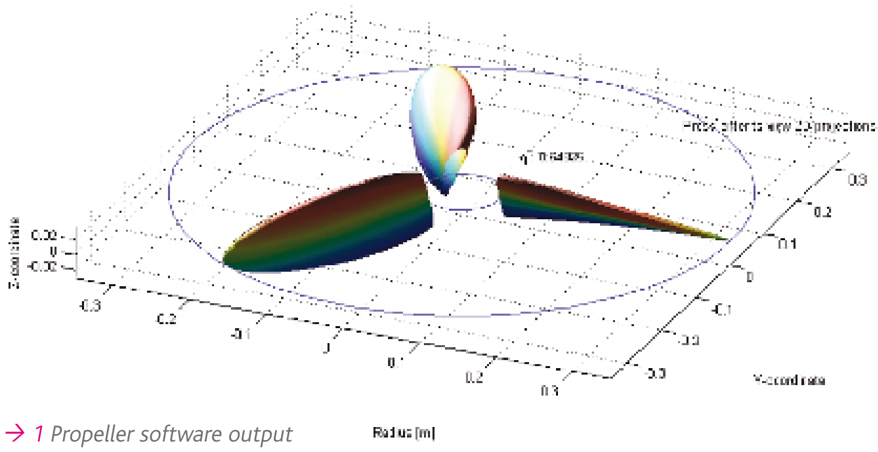


→ 2 3-D rendered propeller

Computer script generated to aid designer

A computer script was generated as an aid for the designer in the design of any two- or three-bladed propellers. General inputs, such as the flight conditions, engine parameters and certain propeller characteristics, are used to provide a three-dimensional graphic of the propeller, along with important propeller parameters, such as the activity factor, advance ratio and, as an output, efficiency.

Another useful output is text files that describe the propeller geometry. These text files allow an experienced SolidWorks® user to design and model a propeller in under 10 minutes.



→ 1 Propeller software output

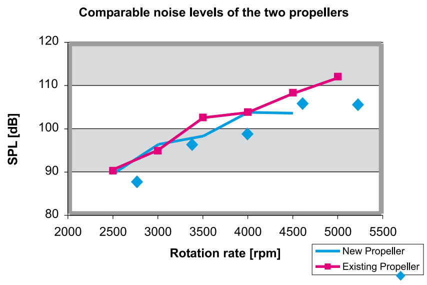
Mission accomplished
The propeller was successfully manufactured, balanced and chromic-acid anodised to be ready for testing. Noise tests on the aircraft were abandoned due to the excessive noise contribution from the engine exhaust system. Comparative noise tests between the existing and the new propeller were performed on an electric motor.

Several bystanders noted that the new propeller sounded less noisy, but the results of Figure 4 proved inconclusive. Static thrust tests on the aircraft provided good results and this has laid the foundation for possible future work. The new propeller provided 30% to 50% more thrust than the existing propeller at comparable engine speeds. The existing propeller's maximum thrust could not be met, since a higher pitch setting is needed for efficient cruise conditions.

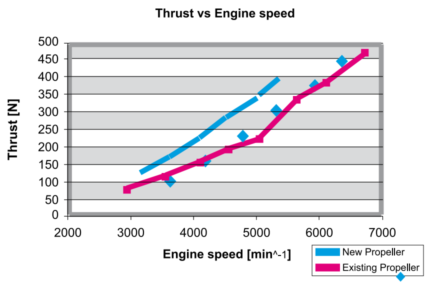
Future developments
Several areas have been indicated for further research and development, such as determining the induced flow angle caused by secondary flow over the blade; a comparative study of the different design methods available; the implementation of aero-elastic noise prediction theory in the computer software; and increasing the capabilities of the software to design a propeller with up to eight blades, using any arbitrary airfoil.

It is further recommended that noise level testing should be conducted in an anechoic facility, where all external noise is eliminated.

→ 3 *Peter Visser with the propeller after completion of manufacturing processes*



→ 4 *Comparative noise levels of the two propellers*



→ 5 *Comparative propeller thrust response*

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