Aerospace Structures & Computational Mechanics
Ph.D. Seminar Series

Jurij Sodja, PhD

Design of Flexible Propellers with Optimized Load-Distribution Characteristics

M. M. Munk already noted in his patent application back in 1949 that already relatively small elastic changes in blade pitch angle noticeably improved propeller performance. Therefore, several attempts to develop efficient and useful adaptive flexible propellers occurred in the past. Among others, an insertion of a flexible element between the hub and the root of the blade was proposed. Exposed to aerodynamic loads, the flexible insertion would undergo torsional deformations that would yield a favorable change in pitch angle at the root of the blade. Based on the results of the study it was reported that swept blades in particular could benefit in terms of improved performance from this approach.

Another interesting approach to passively adaptive propellers was proposed based on the idea somewhat different from the flexible blade approach. The blades were still treated as rigid but they were allowed to pivot freely around the radial axis at the hub of the propeller. The aerodynamic properties of the blades were then tailored in such a way that the equilibrium of the aerodynamic loads was attained at the optimum inflow angle. Alternatively, in the case of flexible blades, the blades have a fixed pitch, but they are designed in such a manner that their elastic axis and pitch deform into a more favorable configuration when the aerodynamic and/or inertial loads change. On the other hand it is well known that variable-pitch propellers effectively solve the problem of propeller efficiency at different advance ratios. However a flexible fixed-pitch propeller has a number of advantages over its variable-pitch counterpart: it reduces the complexity and weight of the propulsion system, furthermore variable pitch propellers are not allowed in certain light sports aircraft categories as for instance FAA-LSA category.

In order to investigate the potential benefits of passively adaptive flexible propeller blades a complete mathematical model taking into account both aerodynamic and structural behavior of the blades is proposed. The propeller aerodynamics model is based on an extended blade-element momentum model while the Euler-Bernoulli beam theory and Saint-Venant theory of torsion are used to account for bending and torsional deformations of the blades, respectively. The proposed blade-element momentum model extends the standard blade-element momentum theory with the aim of providing a quick and robust model of propeller action capable of treating high aspect-ratio propeller blades having a blade axis of arbitrary geometry. Based on the proposed mathematical model a static flexible propeller blade design procedure and its associated analysis algorithm are established. Dynamic aeroelastic phenomena like propeller flutter and divergence are not covered by the presented mathematical model, design and analysis algorithm. Experimental validation was carried out with an objective of evaluating the performance of the developed mathematical model and the design strategy. Both theoretical and experimental results are presented along with pertinent concluding remarks.

time:	**Tuesday, October 1st, 2013, 16:00**
location:	**Zaal H**
organization:	**Dr. Martin Ruess ‹m.ruess@tudelft.nl›**