Business aspects of a rotor/propeller upgrade in the future – a theory

What upgrade?

Theoretically, imagine, all blades of rotors/propellers of a present day aircraft (VTOLs included) can be replaced with new blades having the variable twist feature. With all the engines, control and actuation systems - even the rotor/propeller hubs – of the aircraft left unchanged.

Effect: INCREASED POWER OUTPUT

Once the above replacement of the blades is completed, immediately, the aircraft (VTOL) will start showing increased power output:

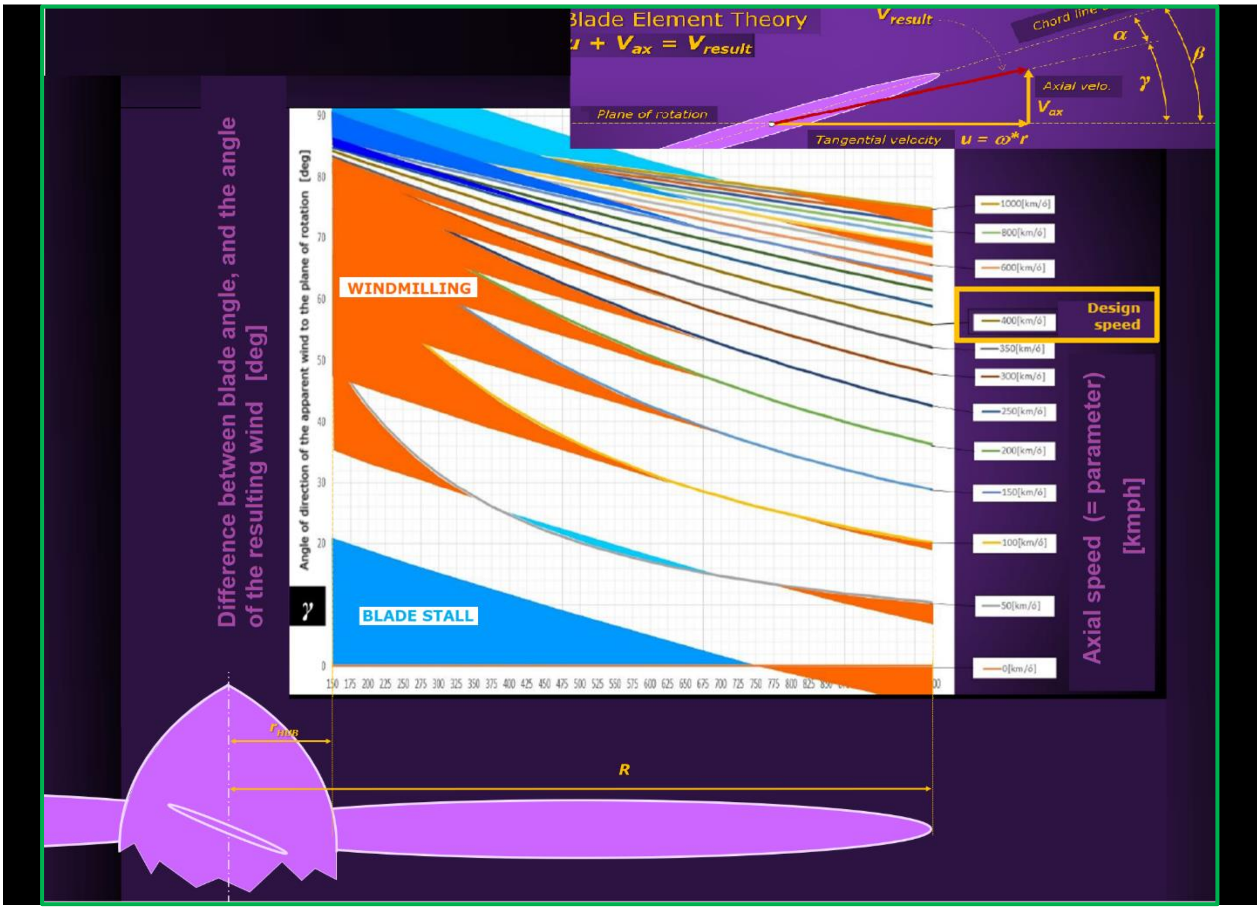
- demonstrate a sudden expansion of speed range (better takeoff/landing/hover, and a higher top speed)
- along with improved fuel efficiency;
- noise level of flight in general is reduced significantly;
- all energy requirements needed for the increased power output are covered from the reduction of former losses.

Is there a prerequisite?

Yes, there is. In order to make the theory work, first the aircraft must have some (quasy any) kind of in-flight blade pitch control system in place.

Key factors of implementing the variable blade twist

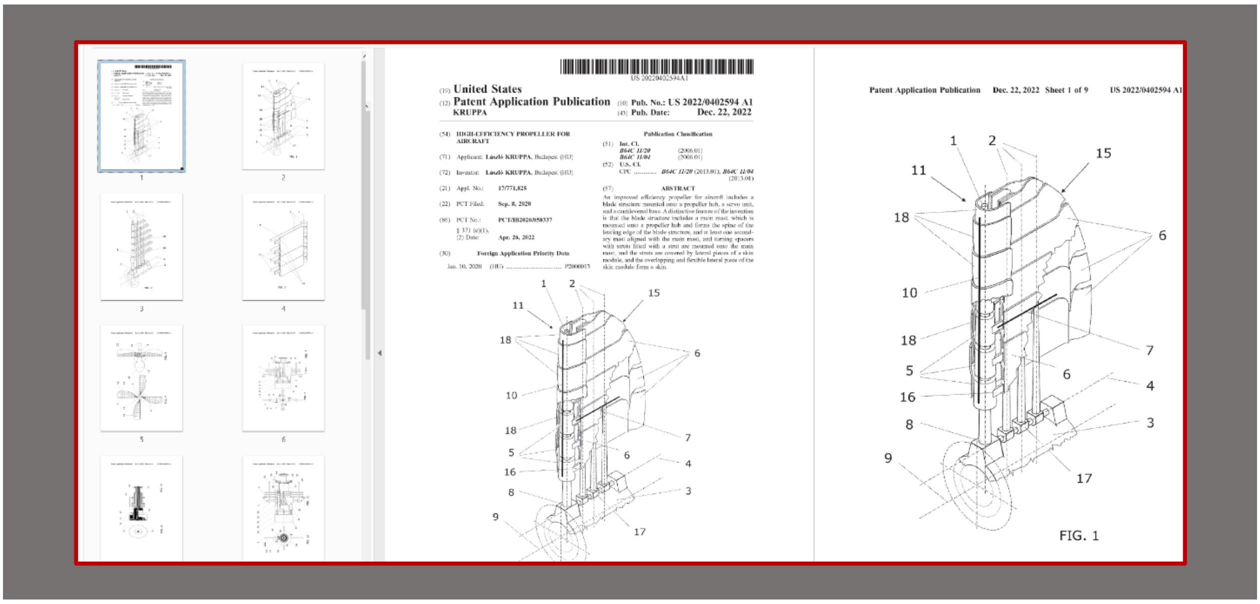
The above positive effects of the upgrade take place in case the variable blade twist feature is implemented as a higher quality pitch control. Increased power output-phenomena can happen due to the elimination of losses characteristic for the traditional blade pitch control. (See picture below. Greatness of the shaded areas is proportional to the greatness of the losses of a traditional blade pitch control system. More description and details of the chart are given in the eBook.)



To build the above graph the **simplified Blade Element Theory (BET)** was used in 3D. (Here, small legend in the upper right corner shows the basic, 2D vector triangle used by the BET.)

In order to deliver as stated, implementation of the new blade shall meet the following requirements (also see Pic. below) :

- blade body must have a morphing structure (i.e., cannot be either monolithic or stiff);
- to perform the controlled 3D morphing motion the blade actuation system shall take one single control parameter only; (Which must be the same that the substituted traditional variable pitch blade used to take: the blade angle calculated for the section at the 0.75R.)
- given the single input parameter, the blade structure must be able to perform a re-shaping motion, in 3D, which will perfectly copy the 3D motion of speed vectors of a changing resulting wind around the propeller radius. By doing so the new blade will eliminate any possible local stall, along the whole working radius.



The blade body. Presently, the corresponding patent application has the final "Publications/Issue Fee Payment Verified 03/20/2024" status.

"Get a stronger plane for the price of a set of propeller blades!" (business opportunities)

I believe, in the coming years it is going to be a routine mechanical engineering task to design replacement blades based on the new (morphing) concept, practically for any existing propeller system that uses blade pitch control. As the future morphing blades for sure will have their technological nuances, the latter option may slightly change the business model the aviation industry has been built on.

For the sake of comparison, just for a moment, let us consider that – energetically and by importance – for a car, tires are the same than propeller blades are for a plane. (E.g., by mounting new, high quality tires you can make your car work better: consume less fuel, have higher maximum speed, roll more smoothly and silently etc.) To have a feeling of the real importance of the issue, take a look at the list of the top ten companies within the global car-tire industry:

Michelin, Goodyear,
Continental, Pirelli,
Bridgestone, Dunlop,
Yokohama, Toyo,
Hankook, Cooper.

I wonder if we can speak of the "propeller blade industry" today. Not sure. But in the future (with special regard to the present green priorities of the market) this latter may quite well become absolutely sure.

Last but not least: VTOL (Tiltrotor!) flight safety

Few words from an earlier post with chart (https://hover.vtol.org/discussion/recent-osprey-crash-again#bm28dfe1c1-f5b6-4f12-9ac8-c06f97d00ff2): "It is quite remarkable that vertical flight is how much more sensitive to blade stall than forward flight is. Planes flying with heavily stalled props are just burning more fuel, but otherwise fly happily. However in vertical flight, when blade stall is driven to the extreme during operation, a bubble of turbulent air is produced. Then it gets bigger, and finally too big. Envelopes the rotor and suddenly VRS happens."

Getting rid of blade stall for tiltrotors is more than "just" a business issue. It is an efficiency issue coupled extremely tightly with flight safety. This post has been written with tiltrotors in the main focus.

Takeaway

Variable blade twist is nothing but a high quality version of the traditional blade pitch control. That also means it is only (almost only) the blades which make the difference. E.g., for any kind of in-flight pitch control application (even for a fully sealed constant speed propeller system) you will be able to buy replacement blades, with a 100% plug-and-play capability. By installing the new blades your plane or VTOL will experience a sudden expansion of speed range (better takeoff/landing/hover, and a higher top speed) along with an improved fuel efficiency.

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