PROPS AREN'T AIRSCREWS

By Joe Wagner

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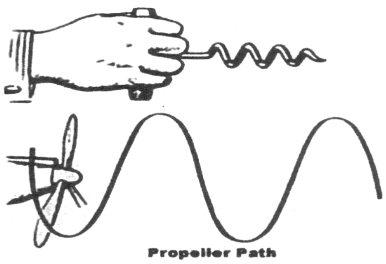
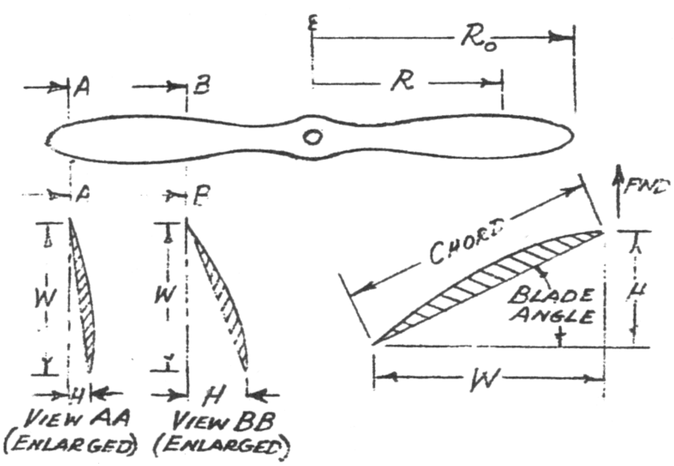
Except for gliders, we model flyers have to depend mainly on upon propellers for the impetus to get our miniature planes airborne (Ducted fans are really just small diameter, multlbladed props.) Yet too few modelers truly understand propellers, exactly how they work, and why. The Brits call propellers "airscrews." This name suggests that they thread themselves along through the air In the same way that a spinning nut runs down a bolt. That concept is false. A propeller is a rotating airfoil, not a screw**.** It pulls itself through the air in just the same way a wing produces lift, by deflecting the gas molecules in the air it strikes. A prop pushes these behind it, and obtains forward propulsive force as an opposite reaction.



True, the "pitch" of a propeller is determined as if the prop was intended to screw into something solid. A "9-6" prop has its blade undersurfaces twisted so they'd move forward six inches if rotated once through, say, a block of clay (The underside angle is smaller toward the tips than at the hub, because the tips travel farther circumferentially. The slower-moving inner portions of the blades thus need to be more steeply inclined, so they will "advance" the same distance per revolution as the fast-travelling tips do.) In actuality, the propeller's slanted undersurface is merely what provides the angle of attack its airfoil requires to generate "lift". The way a wing airfoil produces lift, however, differs markedly from the way a prop develops its thrust. In flight, a wing moves forward into an atmosphere that is essentially motionless. But a propeller pulls the air it works in towards itself.



If a model wing's angle of attack exceeds about 10 degrees, it "stalls" and the model stops flying. But rubber model props can work just fine with blade undersurfaces tipped 50 degrees and more! Such steeply angled surfaces surely are "stalled" when they start revolving. However, the reason an airfoil stalls isn't that its lifting ability vanishes at high angles. Its "drag" shoots way up first. The excessive drag of a stalled wing begins by slowing the aircraft, then lift drops in consequence. The airplane quits flying and becomes a falling object.

When a high-pitch propeller begins spinning its airfoil is definitely "stalled", but power from the rubber motor keeps the prop rotating despite the excessive drag its blades are developing. This is what causes most of the "torque surge" we notice when we release the propeller of a fully wound rubber model. Hold the airplane a second or two before launching, to let the prop airflow stabilize, and the savage left-twisting effect largely disappears. As we stated earlier, the "lift" that the prop airfoil produces pushes its working air backwards (the "slipstream'); then more air gets sucked in from the front to take its place. The blade's effective attack angle is lessened by this incoming airflow because the air is already moving in the desired direction when the blade strikes it. Thus, drag goes down and thrust goes up; incoming and outgoing slipstream velocities both increase. Within a second or so, the whirling propeller establishes its own optimum working environment. The incoming airflow automatically adjusts the angle at which It meets the blades, until optimum effectiveness occurs for that particular prop diameter, blade shape, pitch and available power.

The working effectiveness of any reactive propulsion system (propeller, jet or rocket) is found by comparing the velocity of the powered vehicle to the relative velocity of its "backflow". If these were the same for an airplane (an impossible condition), its propulsion would be 100% efficient, and there would be no slipstream behind the aircraft. The air it had moved through would stay motionless. However, the closer we can approach this ideal with a propeller-driven aircraft, the higher its efficiency. The thrust that keeps our airplanes flying comes from the reaction that results from accelerating a mass of air rearward. If this mass is low, like that behind a small-dlameter propeller, it has to be accelerated quite a lot to provide appreciable thrust. On the other hand, the larger mass acted upon by a large prop needs much less acceleration to achieve high thrust output. That's why a single-bladed propeller can outperform multi-bladers. For the same shaft power it's significantly bigger in diameter.

Another important factor in propeller performance is blade stiffness. If a prop has flexible blades, they will bend and twist under the forces generated by torqµe, flywheel action and other aerodynamic effects. There's little likelihood that such bending and twisting could improve efficiency. That is, if a propeller is optimally designed and made for a specific purpose, any distortion to its shape in operation has to be detrimental to its performance. When a propeller alters its pitch by flexing under power, the angular change increases the further out from the hub it occurs. That's exactly the opposite of what's needed for efficiency. Even controllable pitch propellers, those whose blades pivot axially, lose efficiency in doing so. The angular change is identical from root to tip, instead of becoming smaller the further it gets from the hub.

I've performed many experiments with identically shaped model airplane props made from materials with different flexibilities. In every test, with gas motors, carbon dioxide, rubber and electric, the stiffer the blade, the higher the thrust output. Stiffness is the main reason today's reinforced plastic props for gas motors work so much better than the more flexible plain nylon props commom in earlier years. Tissue covering the thin bladed wooden props we use in our outdoor rubber-powered models improves their efficiency in just the same way.

One more method of improving model propeller efficiency is to sand the forward half of the front surface with medium sandpaper to produce a region of parallel hub-to-tip scratches (leave the back surface as smooth as possible). This provides the same sort of "turbulation" efficiency improving effect as multispars do on a model wing.