TBM 900

THE SCIENCE OF AIRFLOW MANAGEMENT

BY J. MAC MCCLELLAN

AIR MOLECULES BEHAVE in unpredictable ways when they accelerate to flow over an object such as an airplane. A shape that to us looks streamlined and sleek may turn airflow into a jumble of turbulence. It takes computer power, and lots of it, to fully understand how airflow behaves over an airplane and how to optimize the flow to minimize drag.

When the people at Daher-Socata set out to improve the very fast TBM 850 single-engine turboprop several years ago they understood that tools now exist to optimize the airplane for even better performance. There was more speed and efficiency available from the TBM airframe if they could just measure and understand how the air was flowing.

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The TBM is the fastest of the personal single-engine turboprops, climbs great, and has excellent nonstop range. But the TBM is a product of the 1980s. Socata used the aerodynamic design tools available at the time to optimize the airplane, but so much has changed and advanced in the science of computational fluid dynamics (CFD) since then that it knew more performance was there to be mined using the latest tools.

The first step was to computer model the TBM airframe and measure exactly where airflow was smooth and laminar and where it was turbulent and high drag. The CFD quickly identified areas around the cowling, particularly the engine air induction system, that showed turbulent flow and spots where the airflow accelerated very quickly over a short distance. That is the recipe for high drag.

The induction system for the Pratt & Whitney PT6 turboprop engines that power the TBM is probably the most challenging to design for any engine. The issue is that the air enters a PT6 at the rear. The engine has an annular inlet, meaning air enters the compressor from around the entire circumference of the engine instead of scooping air in by facing into the slipstream. And the incoming air must be turned 90 degrees from the slipstream inside the nacelle to enter the engine.

All engines, but particularly turbine engines, gain power and efficiency from what is called ram recovery. Since an engine is actually an air compressor, if air pressure from the slipstream can be rammed into the engine, the compressor gets a free boost. That's what turbochargers and superchargers do for a piston engine, except that boost is not free because energy from the engine powers the turbo compressor. But ram recovery is "free" in terms of adding engine power output without burning more fuel.

Socata's CFD work showed that the shape of the TBM engine air inlet was far from optimum. And the shape of the duct was causing turbulence, which has the effect of slowing and blocking air from being forced toward the engine air inlet. The CFD computer programs guided designers toward a new inlet shape and very subtle changes in the duct that tamed the turbulence and raised pressure at the end of the duct. None of these changes are intuitive. In fact, some of the CFD analysis was so complex Socata needed to allow the computers to grind away overnight to arrive at a solution.

A new secondary gear door slides down to cover nearly the entire wheel when the gear is retracted.

The other issue on engine ram recovery with a PT6 is design of the plenum that surrounds the rear of the engine. The more effectively the plenum can distribute the ram air pressure from the inlet duct around the circumference of the engine air inlet, the more engine efficiency is gained. The new TBM 900 plenum doesn't look all that different, but its performance is much improved.

The results of the CFD work on the cowling, inlet duct, and plenum is that the very same PT6 engine in the 900 produces several percent, under some conditions as much as 10 percent, more power than the engine in the TBM 850 while burning the same amount of fuel. This is not really "free" power because a big investment went into the creation of the new cowling and duct, but it is free power to new TBM 900 owners in terms of fuel burn.

CFD analysis of the TBM wingtips found another area ripe for significant improvement. The CFD data helped Socata engineers create winglets that operate in the area where the high-pressure air under the wing is es-

The engine air inlet on the 900 is larger than the 850, and is more rectangular in shape, but is much more efficient in scooping up air.

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caping around the tip. The TBM 900 winglets are not as large as on some airplanes, but help reduce overall drag at cruise speeds. The winglets also have the benefit of enhancing directional stability.

The original TBM 700 had inboard gear doors that covered the entire main landing gear wheel when retracted. Early on the doors were removed to save weight and complexity in exchange for only a small drag penalty. But Socata engineers found they could design a secondary gear door that covered the majority of the wheel well but could be attached to the main gear. The new composite material gear door adds very little weight and no meaningful complexity to the gear system but shaves drag.

The other area where CFD found possible improvement was at the TBM tail cone. The shape of the tail is crucial because the airflow that has accelerated to pass around the fuselage must slow down smoothly at the end of the airplane to minimize drag. Again, the new tail cone shape is not dramatically different and may not even be measurable without the advanced CFD programs, but it does give the TBM 900 more performance.

Early on Socata joined forces with Hartzell to create a new propeller that would optimize the thrust from the engine. Propellers care very much about the shape of the nacelle and cowling behind them. The shape behind the propeller impacts the way air flows into the prop, so how much horsepower is converted into thrust by the prop depends a great deal on the nacelle.

Socata was able to exchange its advanced CFD analysis of the new TBM 900 cowling with Hartzell, which applied its own advanced computer analysis programs to the propeller design. The result is a very effective matching of prop to airplane. It's uncommon for an airframe and propeller maker to work so closely together in the fundamental design stage, but the cooperation paid nice dividends. The five-blade advanced composite propeller from Hartzell with its very wide chord blades with dramatically swept leading edges makes the most effective thrust of engine power available. And the lightweight blades help reduce vibration and sound to fanjet levels.

A flat glass backup PFD is standard. The cabin pressurization controller is gone and the system is fully automated.

A new single lever controls power, prop rpm, feathering, beta, reverse, and fuel cutoff.

Socata retained the Garmin G1000 flat-glass avionics system in the new 900 because TBM owners like it, and it's hard to think of what the system can't do. But the TBM 900 has a new power lever quadrant with a single lever. Gone are the propeller rpm control and the fuel "condition" lever. On the first engine start I needed a bit of advice on how to move the single lever from idle cutoff, and then over into normal flight mode, but after that it becomes a natural operation. And so is the engine starter. Gone is the need to switch off the starter. The starter-generator output has increased to 300 amps, and the standby generator is rated for 100 amps.

The other system change in the TBM 900 is that pressurization control is now automated. The pressurization controller automati-

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cally looks in the flight management system to find the field elevation for the departure and destination airports and controls the cabin pressure for the complete flight with no pilot input.

As you would expect, the TBM 900 handles like an 850 for taxi, but when you line up for takeoff things change. Gone is the "850 mode" that limits engine power output in the TBM 850 to 700 shp when flaps are extended. The 850 mode is there because the TBM 850 didn't always stall straight-ahead power-on with flaps extended. In the 900 with its many aerodynamic improvements the airplane now passes the power-on stall test with flaps down so you have 850 shp available from the engine at all times.

The extra power on takeoff and the performance of the new Hartzell prop are a real kick. Socata has measured a 20 percent decrease in takeoff run for the 900. I also noticed that the new engine-prop combination comes up to speed smoothly with little of the rpm "hunting" that is typical in other PT6 powered airplanes.

We couldn't get an unrestricted climb clearance from controllers so I couldn't measure time to climb to 28,000 feet. But when leaving FL 270 for FL 280 we were going up at 900 fpm even though the air temperature was 10°C above standard. With the enhanced engine-prop the maximum speed cruise altitude for the 900 is FL 280, up from FL 260 for the 850.

The aircraft manual showed that under our 10°C warmer than standard conditions the 900 would cruise at 320 knots burning 61 gallons per hour. The true airspeed settled on 320 to 321 knots, but fuel flow was 60, not 61 gph. I have every reason to believe the book number of 330 knots at 61 gph on a standard temperature day is exactly right.

The new prop is very smooth, and the drag from its huge blades helps you get down. I pulled power back to idle out of 28,000 feet, descent rate was more than 5,000 fpm, and the new pressure system held cabin altitude perfectly. On landing approach the big prop helps you slow down quickly with a power reduction. I carried 100 knots or so on final because of strong winds and turbulence but still turned off at the 3,000-foot point with prop reverse but almost no braking.

Bottom line is the TBM 900 is 20 to 30 knots faster than the 850, climbs to altitude faster, cruises several hundred miles farther at either long-range or high-speed cruise, and does it all for the same fuel burn. And it's all possible because Socata has the technology to understand how those pesky air molecules behave. It could be said the 900 gets its extra performance out of thin air. And air, but not fuel, is still free. EAA

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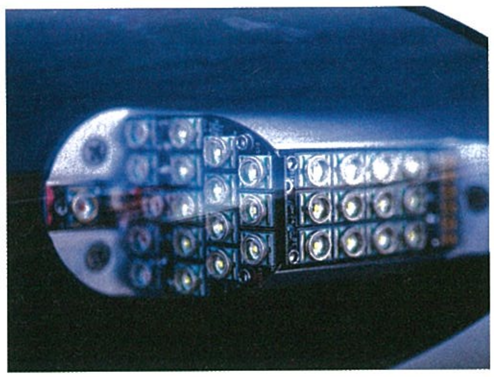
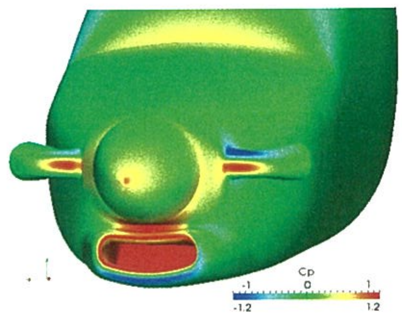


The 900 uses low-draw very-long-life LED lighting.



The CFD analysis showed areas of drag on the previous cowling and air inlet and how airflow was smooth to favorable "green" in the 900.

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