The Turbine – better than its reputation

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The jet engine as a retrieve motor in sailplanes is rumored to have high fuel consumption, high sound intensity, and low range. But this bad name isn't justified.

Above: *The PSR T01-Turbine supplies 230 N Thrust, the competitors offer up to 400 N*

After the first reliable turbines for RC model aircraft came on to the market around twelve years ago, a new motorization concept for sailplanes was gradually developed. Of course there were experiments with small turbines a long time before that, but reasonably satisfactory results were only achieved in 2001. As the performance of the small engines improved, the Germans Roland Ritter, Horst Herrmann, and Martin Käppeler working with Bernd Schweitzer all began work on using the jet as a retrieve motor at almost exactly the same time. Martin Käppeler installed a retractable turbine in his Ventus fuselage, developed it further, and created a suitable control unit for it. Klaus Meitzner took up the idea and adapted the design enough that now after six years it's just about to be EASA certified.

Jet engine sustainer suppliers not only have to deal with actual disadvantages such as high fuel consumption, they must also compete with prestigious electric motors. These are finding more and more sympathisers. In addition they first have to win acceptance from glider pilots because as every aerospace engineer knows from university lectures, jet engines only run efficiently at high altitudes and high mach numbers. In contrast there is nothing more effective than a propeller drive for gliders.

The three existing suppliers in Europe have not been deterred however and they continue to follow varying approaches. Whilst M&D Flugzeugbau does research on their own development (and already have a motor running), Eichelsdöfer rely on the PSR T01 from Draline, who have further developed the proven 230 Newton engine from AMT. HpH Sailplanes used a modified 400 Newton thrust Titan motor in the Shark 304SJ under the designation TJ42. The electronics came from Turbinenbau Schuberth.

The Jet as an Alternative

The jet engine is smaller and lighter than a conventional Turbo and allows a higher cruise speed. This makes it particularly attractive for retrofitting to used gliders. LTB Eichelsdörfer together with Draline already have experience converting LS6 and ASW20 gliders. The PSR T01 doesn't need much room and only raises the empty mass by 16 kilograms with the kerosene tank and the battery. M&D Flugzeugbau would also like to establish themselves as retrofitters and plan to equip other models besides the LS4 with their engine. They manage that with 15 kilograms but with nearly double the thrust. HpH has no current plans to add jet engines to any models other than the Shark 304SJ. Six examples are already flying in Europe and more in the USA.

One of the characteristics of a turbine is constant thrust over the entire speed range. Where the propeller is already producing way more drag than thrust, the turbine still allows good use of speed to fly theory. For example if you are on the way home using the sustainer and you enter heavy sink, the turbine supports flying through the area

***Above:** The turbine doesn't look like much popping up out of the fuselage, but it provides a very decent forward speed*

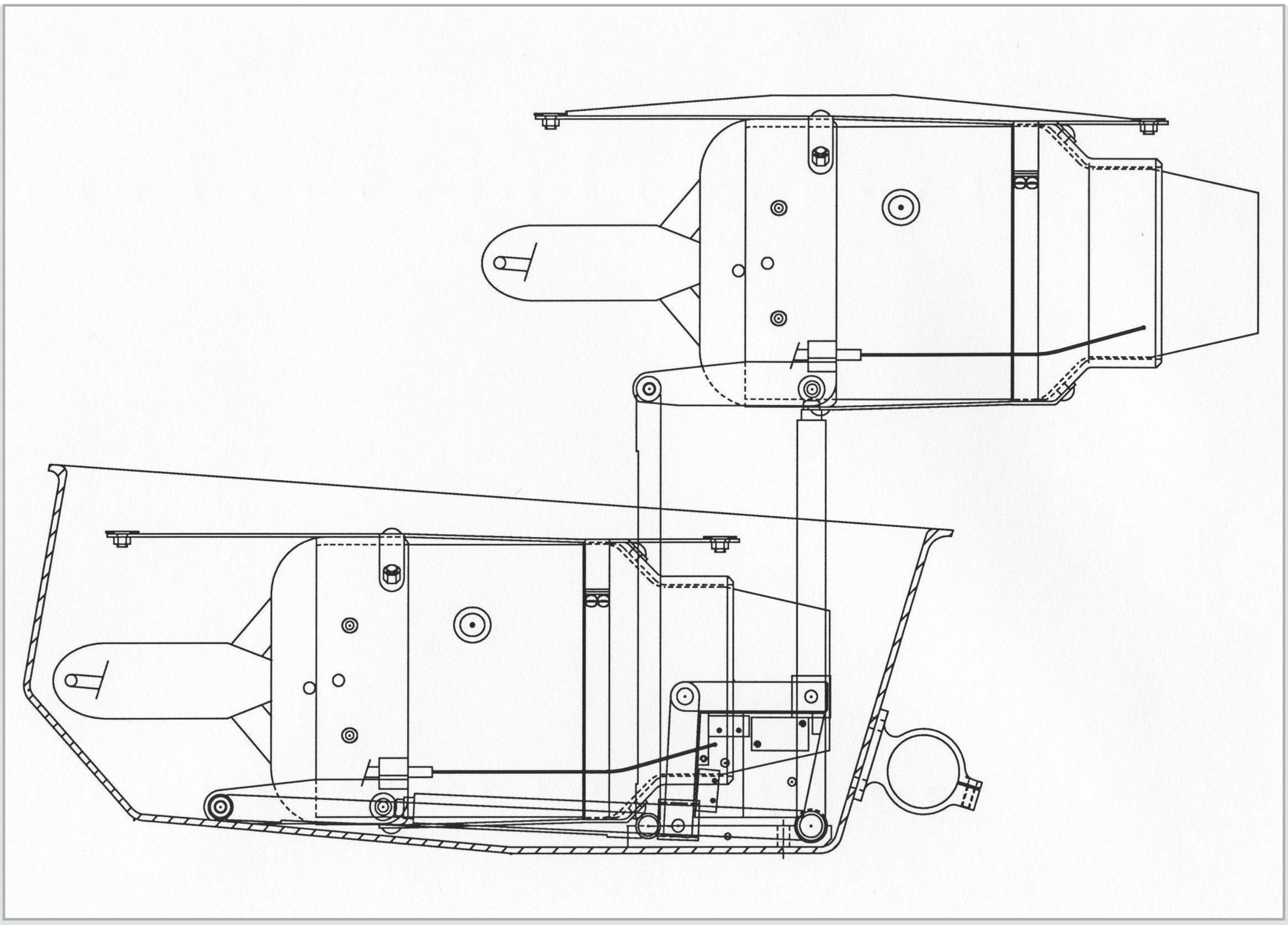
quickly. With a turbo-propeller in contrast, if the climb rate is inadequate, you have to hope that the area of sink isn't that big. If for example instead of the required 100 Knots, you can only do 60 Knots through the sink, the time spent in the unfavorable air mass is increased and you may not be able to maintain height.

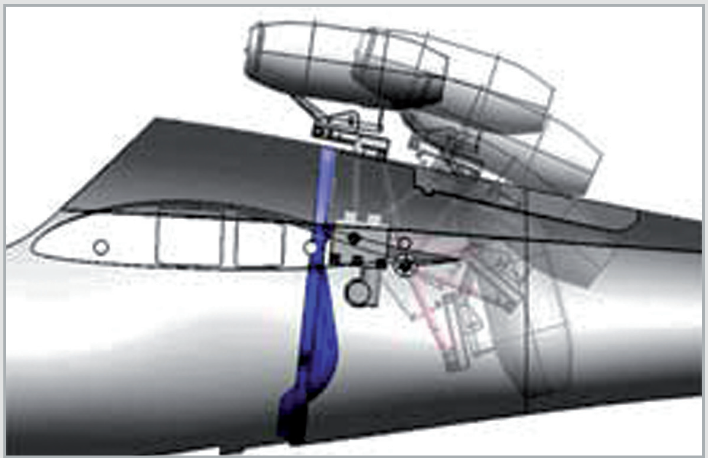
With a maximum climb rate of 140 feet/min (0,7 m/s) at 60 Knots, the PSR T01 doesn't reach the performance of a conventional Turbo however. This performance is actually only available for five minutes per turbine run. Then the turbine should be throttled back by ten percent which means the climb rate is reduced to 100 feet/min (0,5 m/s). However, comparisons purely on climb performance are not fair though, as the jet is used in a fundamentally different way. Rather than a saw tooth flight path, usually you fly straight home at around 85 Knots after the initial climb. HpH claims a climb rate of about two knots (1 m/s) for its more powerful 400 Newton engine even at 85 to 90 Knots. Up to four knots (2 m/s) should be possible, which would then be very similar to a conventional Turbo. M&D Flugzeugbau calculate a fantastic cruise speed of 119 knots for an LS4. Nevertheless, the decree to caution applies just as much with the turbine: No sustainer is powerful enough if you grope from one area of sink to the next due to lack of experience.

Installation Challenges

Thanks to its small dimensions, the jet fits behind the head rest in the luggage space including the small propane bottle. In this respect the extension/retraction mechanism is critical. The PSR Jet System has a useful solution. It looks like a parallelogram with an electrically driven lever which rotates through 270 degrees whilst sliding along the linkage arm. This serves as a lock in both the extended and retracted positions. This makes the system light. The fuselage hole is positioned between the front and rear drag pins. The luggage space must be given up.

HpH and Jonkers Sailplanes both swing the turbine through 90 Degrees into the fuse so that it is stored vertically. HpH with the TJ42 and Jonkers with the engine from M&D in their JS1-TJ. This style of storage is recommended by model turbine manufacturer AMT in their operating instructions. If, for example, a fuel valve should fail, the kerosene can run out of the combustion chamber through the turbine and so not inhibit ignition on the next start attempt. This variation of installation requires more space though, which of course was planned in to both the Shark 304SJ and the JS1-TJ from the beginning. The luggage space remains useable so there is no reduction in convenience. This mechanism is less suitable for





Above: *The PRS engine installation saves space: The engine retracts in a parallel way and fits in the luggage space of an ASW20 for example. Complicated structural reenforcement can be avoided*

Left: Die Turbine von HpH lagert senkrecht im Rumpf. Sollte beispielsweise ein Kraftsfoffventil versagen, kann das Kerosin aus der Brennkammer durch die Turbine auslaufen und so nicht beim nächsten Startversuch eine Zündung verhindern

retrofitting. Structurally this solution involves disadvantages: The fuse has to be re-enforced as the torsional stiffness is massively reduced due to the shape of the opening, over and above that, the lid can't be simply mounted to the top of the engine, but requires an elaborate door design. All this has an effect on the weight.

In all designs it's important to keep the distance between the turbine exhaust and the leading edges of the empennage as large as possible. This keeps the maximum temperature of the exhaust stream on those parts low. From roughly 600°C at the thrust nozzle, the exhaust gases should cool at least enough that the maximum temperature of the composite material is not exceeded.

The call for more power can be heard already. Larger engines will therefore be offered by HpH, Draline, and M&D. The limit is not the higher fuel consumption, but the higher exhaust temperatures. Precautionary measures must be taken to stop the empennage overheating. The university students of Akaflieg Karlsruhe simply put their DG1000J unceremoniously in the oven to temper the empennage. This method is acceptable for experimental aircraft. Aspirations to EASA certification according to CS22 are harder to realize: As the destructive tests on GRP and GRP components are made at 54°C, the temperatures in service must not be higher than this. Klaus Meitzner reached an acceptable temperature of 48°C at the empennage with his T01 engine with 230

***Above:** So far propane gas is still needed to start the turbine; Kerosene start systems are still in development*

Newtons thrust and therefore doesn't offer any higher thrust for single seaters. Jonkers Sailplanes and HpH Sailplanes on the other hand sell 400 Newton and 430 Newton engines respectively for their single seaters. According to HpH, measurements at the empennage show 40 to 60°C so the tail unit is therefore tempered to powered aircraft standards. All the manufacturers are united in certifying the jet exclusively as a sustainer. The effort of certifying it for self launching would be disproportionately high.

Aiming for the first EASA Certification

Draline is furthest advanced towards EASA certification at the moment with the PSR T01. The stated intention is that the complete system consisting of the engine and everything necessary for its operation should be certified. All the required documents were lodged in 2011. Details like a burst protection ring were successfully tested. This should ensure that the extremely rapidly rotating components don't fly out and cause major damage in the event of a failure. It also keeps the total effort for the EASA certification process lower, as it must otherwise be shown that the turbine will not fail during its entire lifespan under normal use.

HpH is aiming for a limited version of EASA certification for the TJ42 in the form of an RTC (Restricted Type Certificate) in the coming year. So far no certification is planned for the PSR T02 from Draline which also has 400 Newtons of thrust. M&D Flugzeugbau has had EASA certification as a development organization for jet engines since 2008. The prototype is running on the company's own test bed, completing endurance and load tests. Final EASA certification for the engine is expected soon.

The Jet in Flight

An ASW20CLJ from jet pioneer Klaus Meitzner fitted with the 230 N thrust PSR T01 was made available to segelfliegen for testing. It reaches a cruise speed of up to 97 knots in still air.

Measured from the ground, the sound level of the ASW20CLJ amounts to 64.5 dB at an altitude of 300 meters. This is only true at a throttle setting of somewhat less than cruise RPM, but this fulfills the requirements for a noise abatement certificate and is quieter than normal Turbos. Ground operation, readily carried out for demonstration purposes, will not be certified. On the ground the turbine is so unbearably loud that hearing protection is essential. Astoundingly this is not needed in flight.

Operation is a great deal simpler than for a piston Turbo: Propane bottle on, throw two switches on the controller and turn the knob all the way to the right. The Engine Control Unit takes over control completely from there on. Engine extension is done electrically and takes two seconds. Another 43 seconds elapse until full thrust is available. Earmuffs are not required during the entire run time. Radio volume has to be turned up a bit, but otherwise the pilot can give their full attention back to flying and lookout. Flight continues with very little loss of height.

By comparison the actions for a piston Turbo: Fuel cock on, extend the propeller, maintain speed, ignition on, switch pitots, engage decompression and at the same time turn on the fuel pump, raise the speed, let go the decompression, take note of the sound of the motor, if successful assume best climb speed and don earmuffs, if unsuccessful do everything again. This demands full concentration and adequate height as the altitude loss comes to at least 300 feet.

A Safety Bonus

The starting procedure of the two stroke, here as an example that of a Duo Discus XT, in comparison to the PSR system not only requires more actions, but actually takes longer. There are, as demonstrated on the DG-1000T, further developments in this direction too but regardless, a stopped propeller acts like air brakes on the wing and not like a lowered undercarriage. This is a great increase in safety with the jet engine: If it fails to start, you still have more height after the third attempt than after the first attempt with a propeller drive. A start attempt, carried out automatically by the ECU, takes ten seconds.

In the process the ECU looks after spooling the turbine up to 6,500 RPM, feeding in the propane gas, ignition of the gas/air mixture, opening the kerosene valve at 88°C and calibrating the kerosene pump at 50,000 RPM according to air pressure and temperature. After that the turbine speed can be increased to 108,500 RPM within ten seconds, completing the entire start procedure after 45 seconds.

Carrying out these procedures manually would not be practical for the glider pilot. For this reason a great deal of development effort has gone into the control and regulation technology behind the ECU. It guards against many eventualities including retrac-

***Left:** Engine operation is significantly simpler than with a conventional Turbo as the Engine Control Unit takes over most functions*

ting too early with an exhaust temperature over 50°C, too low or too high an exhaust temperature, and incorrect battery or pump voltage.

The Fuel has to be procured

All suppliers are currently developing a process which will do away with the requirement for additional propane gas. The Shark 304SJ already has electrical pre-warming allowing kerosene starting to be carried out which, according to HpH, works faultlessly. AMT meanwhile equip 90 percent of their turbines supplied to model builders with kerosene start systems. Proof of whether the process also functions safely and reliably in the air is yet to come.

Unlike Diesel and Mogas, kerosene is not available at every filling station, much less on the home airfield. Instead you have to drive to the nearest airport with a Jet A1 supply and convince the airport authority to supply you with a transport permit to allow you drive back to your glider with the fuel. Granted the conventional two-stroke also needs a special mixture, but only the oil can't usually be found at the home airfield bowser. Mogas, which makes up the greatest part of the mixture on the other hand, is readily available. Procuring the kerosene is clearly more effort but with a requirement of 60 liters per year, it's manageable.

The step from models to manned gliders with jet engines has been made. This is also reflected in the price. If you buy a turbine for a model aircraft, you lay out about 4,500 Euros. The same turbine for gliders, admittedly fully installed by Eichelsdörfer, costs around 20,000 Euros, but for that you also get all the relevant certification. The gap to a conventional engine is no longer large. The turbine sucks 480 grams of kerosene per minute which represents about 36 liters per hour. A two-stroke consumes barely ten liters per hour. At a price of 2.10 Euro for a liter of kerosene and 1.70 Euro for the same quantity of two-stroke mix, the turbine is about 4.4 times more expensive.

The account does look different when the consumption is compared to distance traveled. In the end, no one wants to accrue air time after a technical outlanding. Best to quickly cover the remaining distance to home. The turbine travels roughly double the distance in an hour as the conventional engine. The jet is now 2.2 times as expensive. In the course of a year you would pay about 100 Euros more if you take, for example, five retrieves of 100 kilometres each with the jet.

Conclusion

Whether with droning lawnmower motors, flying mobile phone batteries or model aircraft turbines, you can't have everything. Despite its inefficiency, the jet engine for gliders is an alternative to be taken seriously, and in many cases the only alternative for used aircraft. Retrofittable in nearly all models, light, similarly expensive to buy to a conventional Turbo, and simple to operate, but above all it makes self retrieving safer due to the lower drag of the small turbine. This makes the disadvantages like operating costs and inefficiency easier to accept. Attributes such as high consumption, high sound levels, and low range can only inadequately describe the jet engine. It need not shy away from the comparison to a conventional Turbo.

Visions of the Future

The advantages and disadvantages of the various engine systems were discussed in a small group at a glider pilot's convention in Darmstadt, Germany. The electric motor with a high static thrust is optimal for take off and climb but has the problem that 30 to 60 kilograms of batteries are required for 100 kilometers range. The turbine, with relatively low static thrust doesn't allow a self launch. However with constant thrust independent of speed, cruise speeds of up to about 100 knots are possible. For 100 kilometers range, the turbine needs 16 kilograms of kerosene with a dry weight of 15 kilograms.

"A hybrid of the two systems is possible" says turbine pioneer Klaus Meitzner. You could use batteries and electric motor performance for a launch and climb to 1600 feet with correspondingly lower battery weight. For the self retrieve you would use the jet engine. The solution with the propeller in the nose like on the LAK17A FES would be even better. Then both engine systems could be used during the start and climb, and for the retrieve only the turbine. "That would be the optimal solution for take off, climb, and retrieve from the point of view of weight, performance, and cost" says Meitzner.