

STATUS OF A EUROPEAN JOINT RESEARCH
PROGRAMME INTO LIGHT AIRCRAFT NOISE

O.L.P. Masefield
Pilatus Aircraft Ltd.
Stans, Switzerland

Abstract

The status of a programme conceived and conducted by Germany and Switzerland into noise reductions for light aircraft is presented. Various propellers have been tested on a vehicle both stationary and with forward velocity. Further tests in flight were made to confirm the previous results. An engine was chosen which would give minimum interference with propeller test data.

Introduction

European countries have a high population density and a high level of industrialisation. This leads to a general awareness and annoyance with noise. Light aircraft noise has recently come under severe criticism, presumably because of the disturbance of the highly-valued leisure time, when the most light aircraft movements are conducted.

In Switzerland (1971), in Germany (1972) and in the USA (1973), regulations were introduced to limit the maximum allowable noise level of general aviation air-

craft. The limits were based on the noise measurements of light aircraft in flight primarily in Switzerland. In Switzerland the regulation not only covers new aircraft types, but also covers all aircraft registered in Switzerland on renewal of their certification of airworthiness.

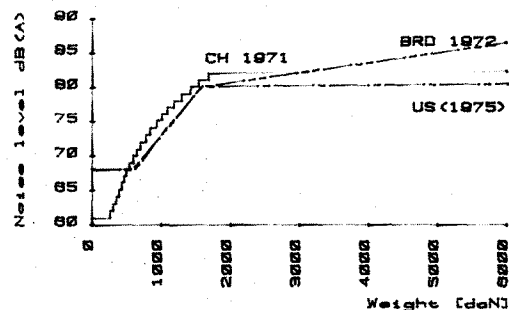


Fig. 1 Noise regulations

During these early days of light aircraft noise investigation, Pilatus Aircraft Ltd. was conducting analyses under contract from the Swiss Federal Air Office into the dominant factors contributing to light aircraft noise, and ways to predict and reduce it. Similar studies were being conducted in Germany.

In 1973 it was decided to combine

the efforts of Germany and Switzerland into a jointly financed and conducted investigation. The objective was to find the parameters which influence the emission of noise and to investigate how these must be altered to lower the noise level. The various different responsibilities of the cooperation are shown in fig. 2. It will be seen that the Dornier company is responsible for overall project management. Pilatus works in close cooperation with Dornier as sub-contractor and directly with the Swiss Air Office on the application of the techniques for noise reduction.

Problem definition

The problem was divided into two main areas:

1. Propeller noise
2. Engine noise

Previous measurements have shown that the propeller noise was in most cases the most dominant, hence the greater amount of efforts during the study placed on this

part. The procedure for the propeller noise analysis was defined as follows:

- 1 a) Analysis of most common propellers and propeller/engine combinations.
- 1 b) Measurements on a propeller test stand, stationary.
- 1 c) Measurements on a propeller test stand with forward velocity.
- 1 d) Measurements in flight
- 1 e) Analysis of parameter influences
- 1 f) Definition of programme to apply noise reducing techniques

For the engine noise analysis a different procedure was used:

- 2 a) Theoretical analysis of silencer function
- 2 b) Computer program for silencer optimisation
- 2 c) Construction of test silencers according to 2b)
- 2 d) Measurement and analysis

At the present point in time the programme has completed phases 1 d) and 2 c). More emphasis will be placed on the propeller noise study in this paper.

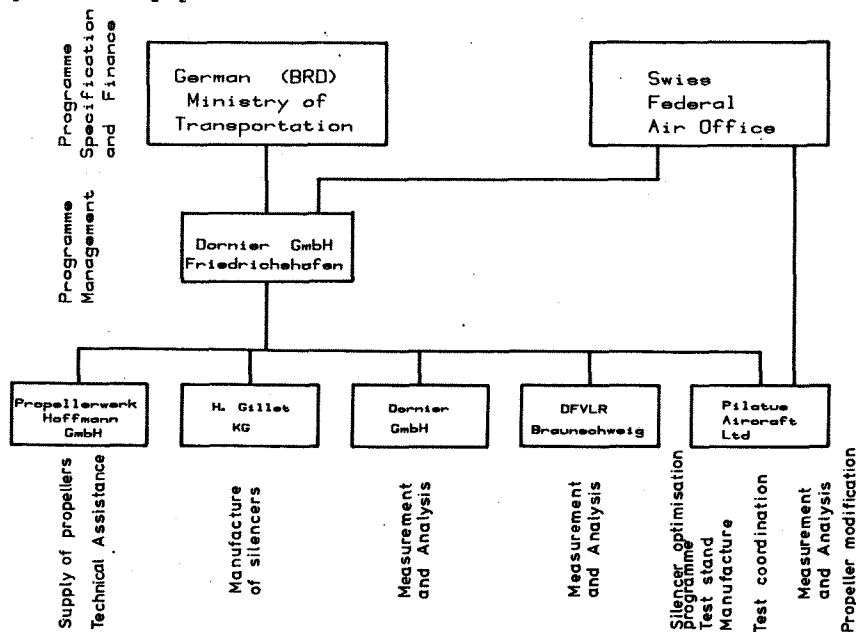


Fig. 2 Organisation

Ground Measurements

For all ground and flight measurements it was imperative to power the chosen propellers by an engine which would not interfere in the noise measurements themselves. Pilatus, who was responsible for the design and manufacture of the test stand, recommended the usage of the Pratt & Whitney of Canada PT6A-20 two shaft turbo-prop engine. This engine has three main advantages - Firstly, a low overall sound level; Secondly, the majority of the rotational parts turn at high speed (over 35'000 rpm), leading to high frequency noise which is easily distinguishable from the low frequency (≈ 100 Hz) propeller noise, and is also rapidly attenuated with distance; Thirdly, it has a maximum power output of 550 shp allowing a large variation in power application to the propellers (for constant speed propellers it is also possible to vary propeller rpm and torque independently, an important factor for parametric analysis).

It was, however, necessary to adapt the propeller governors of the engine so as to obtain propeller speeds up to 2800 rpm (normal rating of 2200 rpm). It was this fact that led to the experimental rating of engine for the period of the tests.

The low noise level of the engine is shown in fig. 3. The lower curve shows the noise level of the test vehicle moving at 80 km/hr with the PT6 engine running, and the upper curve shows the same configuration with a propeller mounted. Both noise levels are measured at a distance of 30 m.

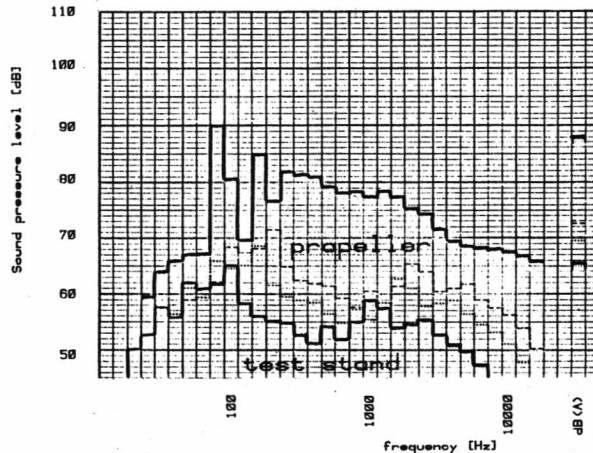


Fig.3 Test stand noise levels

The engine was mounted on a Ford Transit lorry to allow noise measurements whilst stationary and at forward speeds up to 130 km/hr. The engine was attached to the vehicle by two pylons which carried the bearing frame. Between the bearing frame and the pylons a thrust measurement pot was attached which allowed direct digital thrust indication in addition to propeller rpm, torque and other engine parameters which were indicated in the control cabin.



Fig. 4 Mobile propeller test stand

Stationary Measurements

For these measurements the vehicle was positioned on concrete, surrounded by grass. Measurements were taken around a circle with radius 30 meters from the propeller, plus near field and 100 meter distance measurement. The effect on noise of propeller speed and associated Mach number, thrust and power effects were determined at the measurements stations. This allowed directivity plots to be made such as in fig. 5.

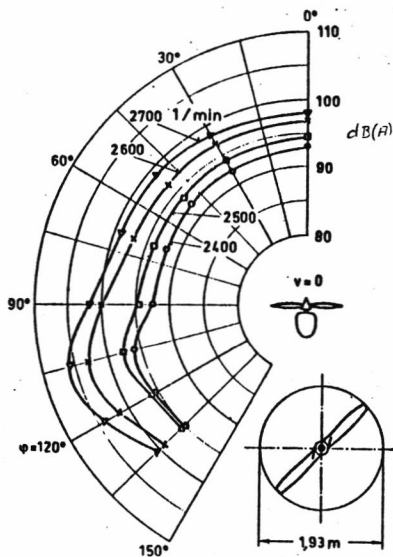


Fig. 5 Typical directivity plot

Further detailed analysis is to be found in Refs 2 and 3.

Measurements with forward speed

For these tests an airfield was used with a runway length of approx. 1800 meters. The vehicle was accelerated using both its normal engine and propeller thrust, the former was then switched off before entering the measurements area. The time at which the vehicle passed the measuring point was established and a directivity pattern could be determined once more, although on a smaller scale. The same parameters were investigated as in the stationary measurements. Further data can be found in Refs. 2 and 3.

Fly-over measurements

For the fly-over measurements the same PT6A-20 engine was used as for the ground tests, to provide a comparable set of data with the previous tests. A Pilatus PC-6 "Porter" aircraft was chosen as the test vehicle as it is normally equipped with a PT6 turboprop engine, allowing a rapid installation of the experimental test engine. In addition, the low wing-loading and high lift devices of the Porter allows this relatively large aircraft to be flown at very low speeds and therefore with a low power requirement.

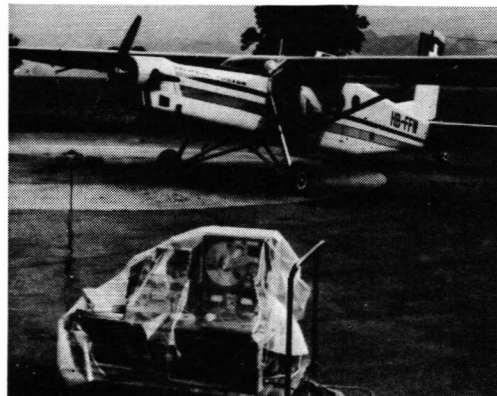


Fig. 6 Pilatus Turbo Porter with test propeller

Fly-over measurements were made at 1000 feet altitude above ground, with some checks at 500 and 2000 feet. The microphone arrangement was in a cruciform for the noise measurements on the ground with spacings of 50 to 90 meters, along and perpendicular to flight path respectively.

The same parameters were measured as for the ground tests except that the thrust measurement could no longer be made without endangering the flight safety. For further test details see Refs. 3 and 5. Measurements were conducted by a team from the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR).

Results

The figures shown in the following pages are based on results from references 1, 2 and 3 and include static, moving and flight test results.

In fig. 7 the noise produced whilst stationary, with forward speed and in flight is plotted against propeller rpm. The data are reduced to a common baseline of 1000 ft distance. Noticeable is the small difference between the measurements with forward velocity and the fly-over measurements. On the other hand a relatively large difference is visible between these values and the stationary measurements. If the associated power required is examined it will be observed that with increasing forward speed less power is required however the difference is far less than the difference in noise level. It can be assumed that additional power is very efficiently converted into sound energy due to the interaction of the shed vortices from one propeller blade by the following blade.

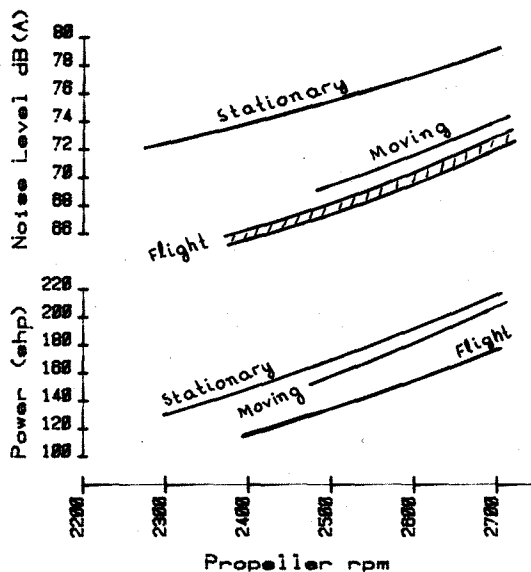


Fig. 7 Power/rpm effects (Prop# 5)

Fig. 8 shows that if noise level is plotted against helical tip Mach number again the results agree very well between flight and ground measurements with forwards speed, but stationary values are

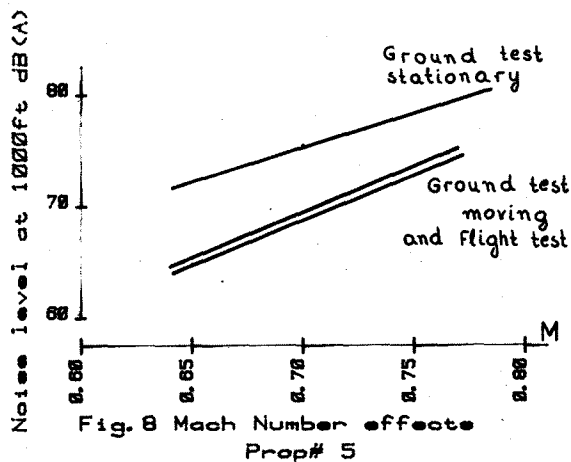


Fig. 8 Mach Number effects (Prop# 5)

again somewhat higher.

The very good agreement of all test values, in spite of considerable parameter variation, when plotted against Mach number shows the powerfulness of this parameter in noise production.

The previous two diagrams showed the results of one particular propeller. However to get an understanding of the general problem it is necessary to measure several propellers and to determine why any one particular propeller is better than another. Fig. 9 shows, for the ground tests with forward velocity between 100 and 130 kilometers per hour, how the power required, propeller speed, thrust and noise levels (at 30 meters) are interre-

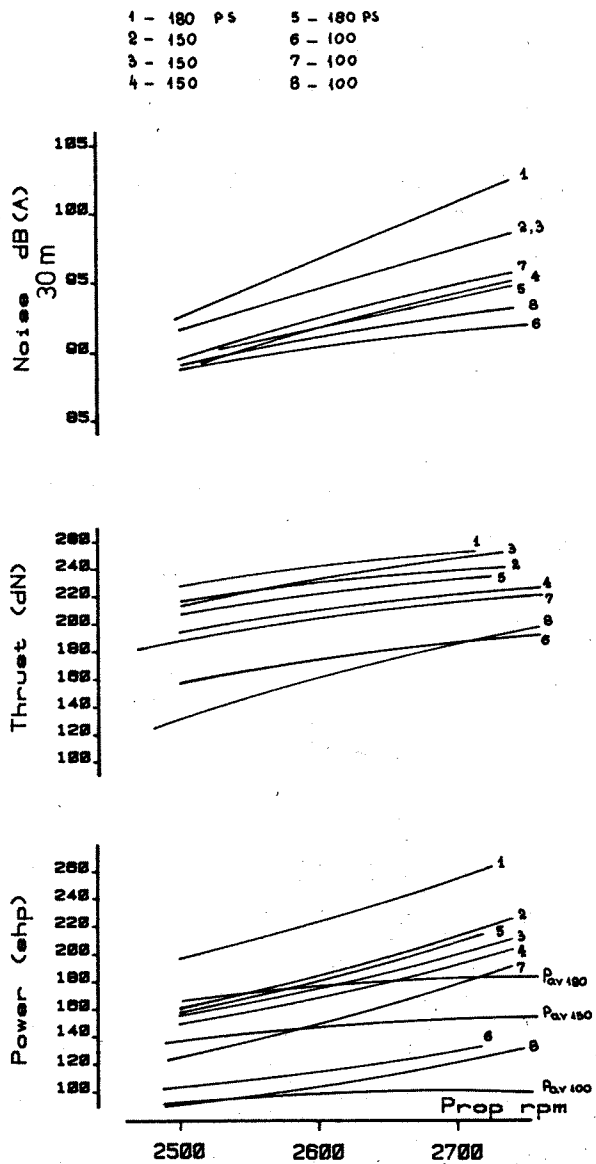


Fig. 9 Propeller variables
Ground test V=100-130 Km/h

lated for the eight propellers tested. It must be remembered during analysis that the PT6 engine has the possibility to overpower these propellers. Although in general terms it is correct to say that the higher the rpm, the higher the power required and the thrust and noise levels this is not always true. For instance propeller number 5 has a relatively low sound level in spite of high power requirement and relatively high thrust, the reverse being true for propeller 7.

If the noise level is plotted against the ratio of thrust to power input (representing the aerodynamic efficiency of the propeller) there is surprisingly no trend apparent.

Why then is there a difference between the propellers? If one reverts to a plots of sound level against Mach number as in Fig. 10, two facts will be observed.

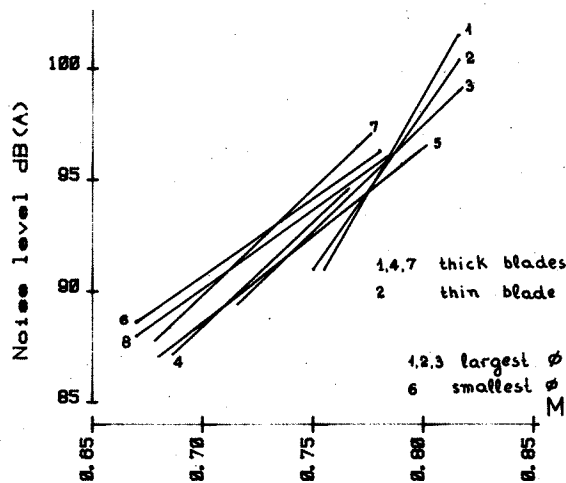


Fig. 10 Mach Number effects

Propellers 5, 6 and 8 have approximately identical gradients but are displaced from one another, the same applies for numbers 4 and 7 but with a different gradient and for 1 and 2 again with a different gradient. The parameters for the propellers are as follows:

Prop. No.	Diameter (m)	pitch (m)	width* (mm)	thickness* (mm)	angle* (o)
1	1.93	1.52	129	11.3	18.5
2	1.93	1.32	114	9.5	16.2
3	1.88	1.48	117	10.2	18.5
4	1.80	1.40	114	18.3	18.0
5	1.80	1.38	130	17	18.2
6	1.70	1.23	107	15.5	17.3
7	1.78	1.20	117	18	15.8
8	1.75	1.22	96.5	10.2	16.5

* at 75% radius

Mach number alone is obviously not quite sufficient to describe the noise level gradient as the larger diameter propellers have nevertheless for a particular Mach number a lower sound level. Noticeable is that the larger the diameter, the steeper the Noise/Mach number gradient. However not much can be said about the other parameters individually, given in the above table, but certainly worthwhile would be to investigate the pressure distribution over the blade diameter as a parameter, a work which has not at this point in time been undertaken.

Conclusions

The results of the tests leave several questions:

1. Why do the tested blades differ in noise production
2. What has to be done to bring the study to a conclusion
3. How can these parameters be used to effectively reduce the light aircraft noise problem
4. When can we expect results

The answer is that certainly more studies are required both more detailed analysis of the present work and also with the information gained, further detailed measurements.

Already a large step has been made and from the results that have been analysed it is very important for future work to know that measurements on a moving test stand are representative for noise analysis. This makes it possible to control the parameters during testing much more accurately.

In Switzerland for over five years modifications to aircraft have been made in the form of propeller tip shape changes to reduce the tip loading and local tip Mach number. The modifications have been successful on over thirty aircraft types with effective noise decreases of about 3 dB(A) on average, without measurable thrust losses, in some cases even gains!

However this solution is sufficient for only the short term, what is needed is a significant improvement for the long term. In Germany a new law has already been imposed to greatly restrict aircraft movements at weekends which have noise levels above 8 dB(A) below the present limit.

For the long term therefore it should be investigated to manufacture a completely new generation of propellers possibly using supercritical profile techniques. The governmental pressure is apparent in Europe, but by far the greatest manufactures of propellers are in the United States and as yet there are no products on the market with advanced designs for low noise.

References

1. Untersuchung zur Lärmreduzierung von Propellerflugzeug Antrieben Status report May 1974, P. Bartels et al., Dornier.
2. Untersuchung zur Lärmreduzierung von Propellerflugzeug Antrieben Status report May 1975, P. Bartels et al., Dornier.

3. Untersuchung zur Lärmreduzierung
von Propellerflugzeug Antrieben
Status report March 1977, P. Bartels
et al. , Dornier
4. Propeller Prüfstand Broschüre,
Pilatus Report No. 01.61.20.01569,
O. Huber, Pilatus
5. Propeller noise research flying
using the Pilatus Turbo Porter
Pilatus report No. PFE-TR-06-57,
O. Masefield, Pilatus