PERFORMANCE DETERIORATION - AN AIRLINE PERSPECTIVE

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SUMMARY

Due to the drastic energy cost increases which have been with us since the 1973 oil embargo, Pan Am, along with most of the world's airlines, has become painfully aware of the impact on costs and operations caused by the steadily deteriorating fuel efficiencies that characterize the aircraft we operate.

We estimate that the fuel efficiency of our original 747 fleet is down 6 to 6 1/2% from when it was new, of which about 1 1/2 to 2% is airframe deterioration and the balance of 4 to 5% is in the engines.

Although the NASA engine diagnostics program recommends periodic refurbishment as a technique for reducing deterioration, our own experience with this approach (which we adopted for improved reliability rather than performance restoration) has been disappointing.

Pan Am has consistently held that efforts for improvement of existing engines to achieve reduced fuel consumption should be in the direction of retaining the performance already in the engines rather than developing sophisticated design changes to reduce fuel burned.

Furthermore, we have always stressed the necessity for retrofitability in a practical and cost effective sense of any fuel savings feature.

Additional on-board engine instrumentation to allow component performance analysis using data from actual flight conditions is a most desirable feature for new transport aircraft designs. This will allow us to define for our shops which parts of the engine need attention to restore excessive performance losses. Effective measurement of one very important engine parameter continues to elude us, namely thrust. We need a thrust meter.

Main engine bearing configuration (number and location), cowl load sharing, inlet reactive loading along with practically any other design and/or installation feature that will stiffen the engine will, in our view, have significant payoffs in retaining engine performance efficiencies and reducing fuel consumption.

INTRODUCTION

Like most of the world's airlines today, Pan American World Airways has become painfully aware of the impact on costs and operations caused by the steadily deteriorating fuel efficiencies that characterize the kinds of transport aircraft we all operate.

This awareness was spawned by the 1973 oil embargo, which precipitated the sharp, relentless energy cost escalations that have been with us since that time and seems destined to continue with no relief in sight.

Fuel prices have increased nine-fold since pre-embargo days. Pan Am's fuel costs for 1973 for a fleet of 142 aircraft (30 747's and 112 narrow-body aircraft) was $170 million (1.2 billion gallons) for an average price of approximately 14¢/gallon. For 1981 Pan Am's fuel budget is $1.36 billion (1.1 billion gallons) for a fleet of 112 aircraft (64 wide-body and 57 narrow-body aircraft) for an average price of $1.24/gallon. Fuel costs have risen from 25% of direct operating cost in 1973 to nearly 50% currently.

After just over 11 years of operation, we find that our 747-100 aircraft have deteriorated to the point where fuel efficiency is down 6 to 6 1/2% from when they were new. Our fleet of 747SP aircraft which entered service in the period 1976 to 1979 has deteriorated to a point where on the average fuel efficiency is down about 5 to 5 1/2% from when they were new.

Based on our own performance monitoring effort along with what has been learned from the NASA deterioration studies, we feel pretty confident that we can isolate about 1 1/2 to 2% of that deterioration to the airframe. The remaining 4 to 5% performance loss is attributable to the engines - this loss appears in spite of a number performance improvement modifications which we have incorporated in the JT9D over the years.

At current fuel prices, recovering or retaining just 1% fuel efficiency amounts to $7.6 million (6.9 million gallons of fuel) saved for the year just for our 747 fleet alone. Across the entire fleet, savings for a 1% improvement would exceed $10 million.

With this basic background information, it is not difficult to understand why we are so concerned about performance deterioration.

Pan Am's commitment to finding the causes of and cures for these punishing performance losses is reflected at least in part by its enthusiastic support for and extensive participation in the NASA Engine Component Improvement Program which commenced in 1977. We served as reviewers for both the Performance Improvement Program and for the Engine Diagnostics Program. In addition, Pan Am was under subcontract to Pratt & Whitney Aircraft to provide extensive historical engine performance data as well as making available certain JT9D engines in a program of special test cell, on-wing and in-flight tests to determine the mechanisms of deterioration in the JT9D-7A engine.

While our experience and effort to date have focused on the JT9D engine, we are closely monitoring the performance of our newly-acquired L1011-500 aircraft powered by the Rolls Royce RB211-524B engines. Furthermore, our efforts will now broaden to incorporate the CF6-6 and CF6-50 along with a sizable JT8D contingent.

As a result of our efforts and concerns, we have formed certain views and ideas about various aspects of engine performance deterioration and retention. These thoughts and ideas are set out hereunder.

NASA ENGINE DIAGNOSTICS AND PERFORMANCE IMPROVEMENT PROGRAM

At the outset of the NASA Engine Diagnostics and Performance Improvement Programs we strongly urged, in our capacity as program reviewers, that emphasis be placed on finding ways to retain performance with particular stress on retrofitability. We have consistently maintained that from the standpoint of reducing overall fuel consumption, the potential payoff is greater if we are can retain performance that is already in the engines we operate rather than to develop sophisticated design changes to reduce fuel burned.

We have always stressed the importance of retrofitability of any modification, whether for performance improvement or for performance retention. Unless the now more than 3,000 CF6 and JT9D engines in service can play a part, it is doubtful in our minds at least that significant fuel savings will be realized for these model engines.

As it has turned out so far, very few of the concepts developed in the Performance Improvement Program are retrofitable in any practical sense.

ENGINE REFURBISHMENT

One of the principal recommendations to come from the Engine Diagnostics Program - and one that was somewhat disappointing to us - was that operators should periodically refurbish the compressor section as well as the turbine section as an effective means of partially overcoming deterioration.

We have always known that new parts will improve engine performance. However, this is a very costly way to gain performance, and as long as the basic design of the parts is unchanged the deterioration characteristics are fundamentally unchanged. At best this technique restores some performance for a limited period of time, but performance retention is really not improved.

Quite coincidentally, in 1978 as the Engine Diagnostics Program was well under way, Pan Am initiated a major change in its engine maintenance philosophy, changing from the long-popular on-condition maintenance concept to a periodic refurbishment program of the kind recommended by the engine diagnostics study for its JT9D engines.

This refurbishment program was adopted at Pan Am specifically to achieve improved engine reliability, with reduced fuel consumption as an anticipated secondary benefit.

The new maintenance program has been quite successful from the standpoint of improving reliability of the JT9D. In addition, TSFC of completely refurbished engines are on the average 1 to 1 1/2% lower than all other engines when measured in the test cell after repair.

However, over the 3 year period the program has been in effect, we have been unable to see any real improvement in fuel consumption attributable to refurbishment based on our routine aircraft and engine performance monitoring procedures. The most we might be able to say is that further deterioration may have been somewhat arrested. This has been an unexpected and disappointing result, for which we have no good explanation at this time.

ENGINE INSTRUMENTATION

The day is approaching, at least at Pan Am, where engines with high fuel consumption may occasionally be removed for that reason. Hitherto unscheduled removals have largely been associated with high EGT, mechanical failure or boroscope inspection revealing incipient failure.

As we approach an economic environment where high fuel consumption becomes a cause for engine removal, it is becoming increasingly apparent to us that the current variety of on-board engine instrumentation, which has changed little during the some twenty year that jet transport aircraft have been operating is inadequate.

We believe that new generations of transport aircraft should incorporate expanded on-board engine instrumentation to allow comprehensive engine component analysis using data from actual flight conditions rather than having to rely on sea level, static test cell data. When an engine is removed we must be able to specify to the shops with confidence which parts of the engine require attention to recover valuable fuel efficiency. We believe this is feasible.

Specifically, additional instrumentation should probably include at least pressure and temperature between engine stages. Where variable vanes are featured, vane angle should also be displayed in the cockpit.

Such additional engine parameters probably need not be displayed continuously. One approach would be to have one set of gages installed on the engineer's panel with a selector switch to display one engine at a time. With the advent of sophisticated performance management and flight management systems, there should be all sorts of possibilities for automatic recording of data on command from the flight engineer.

A discussion of engine instrumentation would be incomplete without mentioning thrust meters. Such an instrument has been the dream of people like us for many years. Thrust remains one of the two or three most important performance parameters for jet aircraft, yet its accurate and reliable measurement in flight continues to elude us.

Until a good thrust meter is developed, we feel that improvements can and must be made in the two most popular thrust-setting parameters: engine pressure ratio, as on the JT9D, and low-spool RPM, as on the CF6. As a reliable, accurate measure of actual thrust, especially under cruise conditions, we believe both systems have some serious flaws. In both systems there are what appear to us to be unexplained shifts in their relationships to net thrust so that we are not necessarily getting the thrust we think we are getting when we set EPR or N1. At this point common sense tells us that the integrated engine pressure ratio system used on the RB211 engine is probably superior to either of the other two systems. However, since the RB211 is quite new to us, we will have to withhold judgment for a while.

ENGINE DESIGN AND INSTALLATION FEATURES

Certain features of engine design and installation are clearly demonstrating important advantages in engine performance retention.

Bearing arrangement no doubt has an important role in performance retention. Four bearings seem to be insufficient while six are probably more than are required. A well-designed 5-bearing system would seem to be an optimum configuration.

Bearings with over-hung components such as fans, should be designed to minimize such over-hang to limit associated wobble, which in turn leads to shroud rub, or to allow closer running clearances.

We are convinced that almost any effort to improve stiffness and generally reduce flexing of the engine structure will pay off significantly in performance retention - even at a weight penalty. For this reason we favor cowl load sharing to provide additional rigidity at a relatively small cost in additional weight and complexity. Studies by the manufacturers are presently under way in this area for the JT9D-7 installation on the 747s. The approach under development is particularly attractive in that it looks very promising and cost effective for retrofit. Pan Am has indicated a strong interest in this program and we have offered to participate in any meaningful way, such as perhaps a service test program.

Along these same lines, Pan Am is planning to participate with the Boeing company this year in a service test program of a device designed to react against flight loads on the engine inlet of the 747, thereby reducing fan and low compressor shroud rub. This too is very attractive to us because of the retrofit potential, which is indeed what will be done for the service test program.

These three areas, bearing location and number, cowl load sharing, and inlet reactive loading are, in our view, key areas in the battle to retain engine performance efficiencies - particularly since the performance which is ordinarily lost when an engine flexes is lost during the first flight or two and has been largely considered unrecoverable.

CONCLUSIONS

The foregoing points up Pan Am's great concern about maintaining the fuel efficiencies of its fleet of aircraft and engines. We have actively supported past programs to determine causes of and cures for engine performance deterioration and will continue to pursue efforts to apply this valuable knowledge effectively to current as well as future engine designs.

There are over 3,000 JT9D and CF6 engines in service at this time with the number growing slowly but steadily. These engines can be expected to remain in service for a good many years to come. The challenge therefore remains to develop practical, retrofitable performance retention features that can save significant quantities of fuel on this very large body of engines in the 1980's and no doubt the 1990's.