AIRCRAFT ENGINE ENVIRONMENTAL ISSUES AND ACTIVITY PLAN OF JAXA

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Keywords: *environment, engine, emission, noise*

Abstract

The JAXA is promoting aeronautical research programs in the first four years term. The aeronautical environment technology center started "clean engine technology project", which focuses technology development applicable to the today's and tomorrow's air transportation, which will contribute to the preservation of environment and to support the development of private sectors. This paper presents the outline of the current issues and research plan.

1 Introduction

The centennial ceremonies held worldwide commemorating the Wright brothers' first success in powered flight last year declared the new century of flight vehicle. In hundred years the air transportation comes to be fundamental way of international travel which is replacing the Titanic ocean cruiser, Orient express international train service, and Zeppelin air ship. We rely on it so deeply that there are commonly two or more airports access in most world prosperous cities. Not only travelers but also computer parts, electronics, even frozen tunas from Africa or chilled lobsters from New England are imported by air freight aircrafts everyday.

On the contrast, the surrounding communities are now suffering from frequent aircraft noise and air pollution by planes and ground vehicles. Aeronautical environmental issues are urgent and never overlooked for the successive development of the world.

2 Environmental compatibilities to the 21st century aviation world

In 1944 fifty two countries signed Chicago treaty to create International Civil Aviation Organization (ICAO) to ensure safe, regular, efficient, and economical air transport. Committee on Aviation Environmental Protection (CAEP) of ICAO takes after the Committee on Aircraft Noise (CAN) and the Committee on Aircraft Engine Emissions (CAEE) to set the rules restricting aircraft noise level and engine emission pollutant concentration. Since 1986 CAEP has held six formal meetings in 1986 (CAEP/1), 1991 (CAEP/2), 1995 (CAEP/3), 1998 (CAEP/4), 2001 (CAEP/5), and 2004(CAEP/6). The regulation standard levels are revised to meet preservation of environment and airline operation.

2.1 Engine exhaust emission issue

Figure 1 shows the ICAO regulation trend on NOx emission. NOx is considered to do harm on human health and reacts by ultra-violet ray to form ozone to cause photo-chemical smog. As open cycle engine a jet engine can not avoid combustion products exhaust. Higher bypass ratio turbofan engine requires high pressure and high temperature combustion system which accelerates NOx formation. NOx is suspected as one of the material of ozone depletion in the stratosphere.

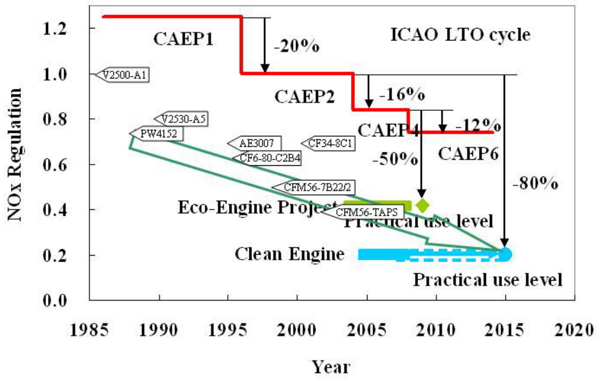

Fig. 1 ICAO trend on NOx regulation

2.2 Engine noise issue

Figure 2 shows the ICAO regulation trend on Noise level. Annoyance of aircraft noise has been alleviated by high bypass turbofan engines which exhaust jet speed is less than half of the old jet engines. Though rapid growth of civil aviation increases airline services since early morning to late at night.

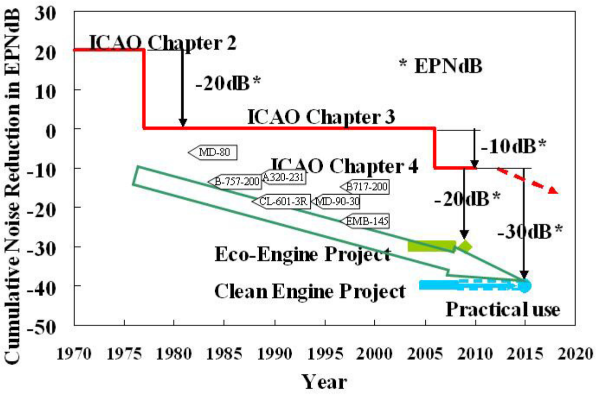

Fig. 2 ICAO trend on engine noise regulation

2.3 Green House Effect of Fossil Fuel

The world wide climatic change has been brought past 200 years since the Industrial Revolution. Coal, petroleum, and natural gas those widely consumed as energy source inevitably produce CO2. The 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change held in Kyoto 1997.12.1 - 12.10 claimed accumulated CO2 which increased 280ppm to 350 ppm in the troposphere plays green house effect gas to warm the earth 1 to 3 degrees centigrade in 2100. The aircraft fuel consumption is limited as 2 to 3 percent of total CO2

3 Technology development strategies in the “Clean Engine Technology” program

The scientific researches have unveiled the mechanism of environment atmospheric circulation, chemical reaction, and biomedical effect on human bodies. The final objective of a new technology development is application to the innovations. In this sense the aircraft engine development seems one of the difficult investments because of huge amount capital need, long time development work, established technology to be used, competitive and limited market, low gain from airline operation, which is called “sporty game” or “gamble”.
Japan, even the second largest country in GDP and in the air traffic, has only three or four times their own development experience in aircraft engine. In 2003 the Ministry of Economy, Trade and Industry (METI) started the aircraft industry policy to have the New Energy and Industrial Technology Development Organization (NEDO) fund new small passenger aircraft engine development. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) corresponds to make JAXA to assist the design work and hardware tests with compiled research technologies and necessary test facilities in addition to the original innovative technology research efforts.

3.1 Development & Technology road map

The NEDO engine development project began 2003. In the first year feasibility study on commercial engine market and development plan were conducted. High demand growth in the East Asia and down size sift to regional jet aircraft reminds and gives appropriate target to the small high-bypass turbofan engine suitable for the stringent environmental regulations.

The development plan is as follows (Fig.3): three years component development and next three years of engine system development. Then,

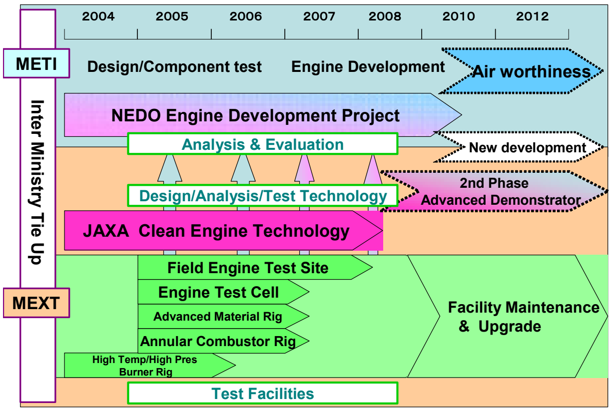

Fig. 3 Clean engine technology and NEDO engine development road map

depending on market research commercial engine development finally sets out.

Commonly it needs additional three to five years to achieve launching order and type certificate. The commercial engine market investment cycle is so long as regarded as forestry. The nursery grows to timber in more than thirty years with restless care. Once the passenger aircraft appeals in the market, its engine can be sold regularly and grasps the airlines' maintenance compatibility. And MOR service business continues to its aircrafts' life end. Engine modifications are rarely planned unless the life extension or urgent market needs are expected.
To the contrast of MOR, new technology is hardly adopted once the new engine was developed by the explanation above. So it may be believed there could be earlier chances in engine replacement or retrofit businesses to the new technology.

Civil aero engine technology has market driven nature, where high reliability and high profitability come first. Low fuel consumption is achieved by the combination of higher bypass ratio, higher component efficiency, and light weight. Fig.4 assesses the principle of causality between technologies and environmental regulation.

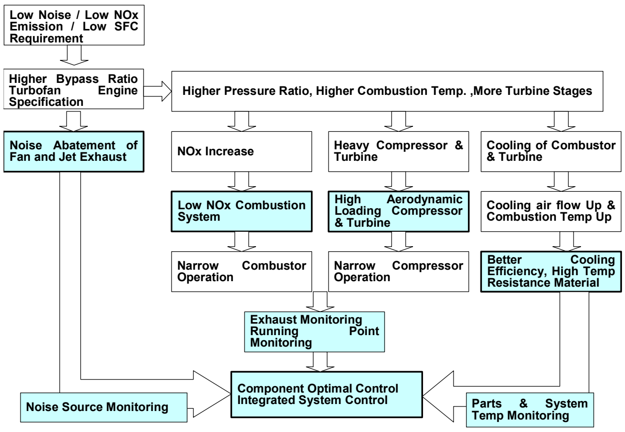

Fig. 4 Technology assessment analysis in the Clean engine technology project

3.2 Development support

For the first three years JAXA will support the engine manufacturers to design and develop engine components.

3.2.1 DOC reduction

Direct operation cost of aircraft is airlines' most concern when the new aircraft is accepted in the market. Engine SFC affects the fuel cost and rout arrangement. Higher turbine inlet temperature (TIT) is mandatory to low SFC engines. Based on the thirty years experience in turbine cooling research JAXA will help designing Simple & High performance turbine cooling method technology with computation and end experiment.

3.2.2 Environmental adaptation

The engine development needs established technology in advance. There are some low NOx combustion systems which have been researched and proposed. JAXA will help manufacturers testing Simple Low NOx burner technology impartially.

3.2.3 Engine system

With all other members JAXA will participate in the target engine design with computer aided engineering (CAE) capability especially in mixture of internal and external flow.

3.3 Advanced component studies

Parallel to the development support JAXA will keep pursuing advanced engine technologies, which shall be widely utilized in any application chances.

3.3.1 Noise reduction

JAXA has been raising practical and analytical approach in noise related technology. In measurement and analysis we have developed sound source location sensing technology with a microphone array system. This technology evaluates the intensity distribution of sound source of an aircraft or a moving object. The sound generation and propagation mechanisms are searched by computational fluid dynamics (CFD) analysis to point out the direction of improvement. Some noise reduction (passive and active) and attenuation techniques are under study.

3.3.2 Low emissions technology

The combustion system is a special component which treats chemical reaction. NOx is mainly produced in high temperature combustion process. Optical diagnostics and computational analysis is believed to be a powerful tool in analyzing precise flow condition where NOx is locally produced. As a combustor component, combustor liner cooling air should be reduced in high temperature conditions. An advanced fuel control system enables fuel staging or zoning in conjunction with FADEC system.

3.3.3 High Temp/High Loading Turbo machinery

High thermal efficiency gas turbine cycle needs higher temperature combustion and higher pressure compression. Advanced turbo machinery has to be designed based on aerodynamics, heat transfer, mechanical vibration, and distortion. Advanced turbine cooling or CFD prediction can only be applicable when they are experimentally validated.
Static and rotational component rig test should be necessary in this area.

3.4 System technology studies

In accordance with the progress of component technologies several technologies should be developed to integrate into the total system.

3.4.1 Advanced computational simulation technology

High performance components can be designed by computers. CFD has made progress to be necessity of compressor and turbine airfoil design. The domain of computational model comes to be so much refined as treating three dimensions, viscosity, unsteady. JAXA will seek further challenge in acoustics, mechanical coupling, heat transfer coupling, and multi-stage interaction. These computational frontiers need experimental verification to clarify the limitation.

3.4.2 Engine material adaptation and evaluation

Every design effort of hardware depends on the material to be used. Jet engine should be light weight and strong enough to resist high temperature and centrifugal forces. Special metal alloys and advanced material such as composite or ceramics are commonly used. Other than at normal condition, the mechanical data at elevated temperatures, high pressures, and high loading conditions can hardly obtained from the material supplier. We will equip the material test systems to evaluate their properties and will adapt the material to the hardware.

3.4.3 Advanced Engine concept & system control

The requirement to the engine cleanliness seems somewhat limitless. Advanced component technologies are available if the components are operated properly, thus the engine system should be precisely controlled within the harmony of components. Thanks to the IT technology, it will be realized by the integrated control system development with distributed optimal control. The fragility of complex system will be made good compensation by redundancy and software. The component and system hardware technology will be demonstrated with small jet engines.

3.5 Engine and component test facilities refurbishment

JAXA is taking after the NAL prospectus as the national center of aeronautical research facilities. Though there has been long given the engine development chance since 1970's, most of the engine and component test facilities are in operational conditions. Some modification and renovation is partially needed to satisfy the current research standard level.

3.5.1 High Temperature/High Pressure Combustion Test Facility

Originally facilitated to develop high pressure combustion system of industrial gas turbine, its 5MPa and 1000K test capability was a brilliant challenge in 1980's. Airflow capacity increase enables accurate NOx evaluation for sector combustor models.

3.5.2 Simulated Condition Material Evaluation Test Facility

Utilizing the existing air heater of the high temperature/high pressure combustion test facility, this facility equips an additional burner to simulate actual temperature, pressure, and combustion products conditions of advanced high-pressure turbines.

3.5.3 Annular Combustor Test Facility

In 1975 this facility was built to test the full scale annular combustor of the FJR710 turbofan engine. Replacing the air source compressor to feed higher pressure air will be suitable for NEDO engine class.

3.5.4 Field Engine Test Site

The test field of the Kakuda branch which was used in FJR710 engine tests is no longer operational due to the facility expansion relating space propulsion research. Somewhere else we must find an engine test field necessary to demonstrate air worthiness and noise test.

3.5.5 Engine Test Cell

Built in 1975 this engine test cell was used in FJR710 engine development. Engine operation console will be enlarged and renewed to fully electronics type.

4 Summaries

For nearly fifty years NAL or JAXA now has lead aircraft engine researches in JAPAN. In 2003 JAXA started the "Clean Engine Technology" project, which focuses technology development of noise, NOx and CO2 emission reduction. These research outputs will contribute in cooperation with engine research and development organizations to help engine manufacturers to develop new civil aero engine by the sponsorship of NEDO.

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