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THE NATO/CCMS WORKING GROUP ON HELICOPTER NOISE PREDICTION MODELLING - AN OVERVIEW

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ABSTRACT
In 1990 the NATO Committee on the Challenges of Modern Society (CCMS) agreed to establish a Follow-Up Group to the Pilot Study on "Aircraft Noise in a Modern Society". The aim of this follow-up program was to continue the exchange of information among member nations and to encourage appropriate national and multi-national research and development. One of the areas identified for research was the development of noise databases and models for helicopter noise. Following the 1991 NATO/CCMS Symposium on Noise Aspects of Rotary Wing Aircraft, the Follow-Up Group agreed to form a Working Group on Helicopter Noise Prediction Modelling. The conference concluded that the noise generated by and experienced from helicopter operations differs from fixed-wing operations, and that although much research has been directed towards the noise generation aspects of helicopters, limited knowledge was available concerning response to and exposure to helicopter noise.

1 - INTRODUCTION
The aim of the Working Group on Helicopter Noise Prediction Modelling was to collect and exchange information on helicopter noise and associated predictive noise models. It was recognized that helicopter noise as heard by a receiver on the ground could be affected by a number of independent and interdependent variables. It was therefore the objective of the working group to study and evaluate as many of these variables as possible, starting with the noise source data of each NATO member nation and going on to consider the effects of helicopter operating procedures. Attention was also given to existing models and the noise propagation algorithms. Finally, the aim was to make proposals towards a common helicopter noise modelling program.
Contributors to the Working Group on Helicopter Noise Prediction Modelling came from Canada, Denmark, the Federal Republic of Germany, The Netherlands, Norway, Switzerland, The United Kingdom and The United States of America.
One goal of the working group was to exchange information on helicopter noise modelling. This included information about helicopter noise databases, helicopter noise measurement techniques and data acquisition, noise propagation algorithms, helicopter noise directivity and helicopter noise exposure models.

2 - HELICOPTER NOISE SOURCES
The total noise signature of a helicopter consists of several characteristic sounds. Aerodynamic flow phenomena occur around the rotor blades and fuselage, resulting in a number of noise sources. Since air flow velocity and direction will vary during different kinds of operation, so will the directivity and characteristics of these sources.
Helicopters in flight emit noise which is highly directional and can vary widely depending on flight mode, airspeed and rate of climb/descent. A helicopter overflight is typically characterized by higher noise levels to the forward and right side (for counter-clockwise rotating main rotors) compared to behind and to the left. The noise associated with landing at a heliport may be quite different, both in character and in directivity, than that of a level flyover, take-off or hover. All this adds up to a very complex three dimensional directivity pattern of the total noise from a helicopter. This directivity pattern will differ from one type of helicopter to another and also will distinguish from one type of operation to another for

each helicopter type. These differences must be taken into account in order to make useful predictions of the noise associated with each flight condition at heliports or airfields.
Helicopter noise signatures will vary from operation to operation because the velocity of a helicopter relative to the surrounding air has a great influence on the noise generation mechanisms. The forward motion of the helicopter will result in a continuously varying relative airspeed over one blade as the blade rotates. Higher relative airspeeds will occur on that side of the helicopter where the blade advances on forward flight and lower on the other side. All this results in the non symmetric directivity patterns. Different forward flight speeds will produce different directivity patterns as well as different overall noise levels. It is therefore necessary that data acquisition and modelling methods must handle the directivity of the noise correctly.
The dominant noise source may vary depending on the flight operation. For example, Blade Vortex Interaction noise (BVI) is typically more dominant for a descending helicopter but usually not present during climb. Helicopter noise must therefore be measured for the following normal operations: take-off, climb, level flight, descent and landing, as well as hover and in some cases taxiing. For each flight mode data are needed for different helicopter speeds, weights and rates of climb and descent. In order to model the noise exposure of helicopter operations a very accurate description of the operational use is essential.

3 - MEASUREMENT AND DATA ACQUISITION

A large number of helicopter noise measurements have already been made. They have been used by manufacturers for design and development purposes, by government authorities for certification, and by airfield operators and local authorities for noise control procedures. Although some of the results can be used for noise modelling purposes, there is a lack of specific data and a common measurement procedure.
Noise source identification is the main tool used by manufacturers to quiet helicopters. During this kind of measurement a large amount of detailed information (for instance narrow band noise analysis) is sampled and collected. Detailed noise source identification also can be used for the calculation of noise contours from theoretical first principles. However, for helicopter noise exposure modelling there is no need to know which noise source contributes to the overall sound level.
Helicopter noise certification is carried out using a similar methodology to that introduced years ago for fixed wing aircraft. The noise metric Effective Perceived Noise Level in decibels (EPNdB) is determined at certain points for specified flying conditions. Noise certification data are not necessarily useful for the calculation of environmental noise because certification is carried out under worst case conditions.
By using noise exposure models the environmental impact of helicopter operations around airfields, helicopter landing sites and in low flying areas can be quantified. The model requires, besides noise source data, a propagation algorithm, flight profiles and the number of aircraft movements.
A noise database is required for each helicopter type and its operational procedures. The requirement for this database is to present noise data in one-third-octave-bands as well as the maximum A-weighted sound level (L_{Amax}) and sound exposure level (SEL/L_{AE}). The noise database must give the sound levels at fixed distances from the source for the following set of standard flight profiles: take-off, flyby, landing and hovering. Because of the differences in measurement procedures and the wish to create a common database, there is a requirement for a common measurement procedure.
The Working Group on Helicopter Noise Prediction Modelling evaluated various current procedures used nationally and internationally for the measurement of helicopter noise (e.g. ICAO/FAA certification measurements, and the nationally used measurement procedures in Denmark and Norway, Federal Republic of Germany, The Netherlands, Switzerland, United Kingdom and United States of America). Because of the differences in these measurement procedures and the need to create a common database, there is a requirement for a common measurement procedure. Therefore, the working group proposed a recommended test plan which is briefly described in [1].

4 - SOUND PROPAGATION

All noise prediction models must calculate the dependence (decrease or increase) of the noise level as a function of distance between the source and the receiver. Normally, the noise from helicopter operations propagates over fairly long distances. In addition to spherical spread, the effects of sound absorption by air and excess ground attenuation must be included. The algorithm which computes the noise level at the receiver site must include distance between source and receiver, air temperature, humidity, wind speed and direction, ground absorption, and shielding effects due to barriers.
Due to the lower frequencies emitted during helicopter operations, and the unique low altitude operational capabilities of helicopters in comparison to fixed-wing aircraft, there are differences in noise prediction requirements for the two types of aircraft. Firstly, in contrast to the propagation algorithms for the

noise of fixed-wing aircraft, algorithms for the propagation of helicopter noise need to cope with low frequency emissions. Secondly, due to the lower altitude flying of helicopters compared with fixed-wing aircraft most helicopter noise is propagated along the ground with grazing incidence angles and with strong contributions from excess ground attenuation. For these reasons a propagation algorithm for the prediction of helicopter noise must include the effects of helicopter operations, the low frequency content of the noise spectra and near grazing incidence angle.

There are internationally used algorithms for describing the propagation of sound emitted by aircraft. The working group looked at the following algorithms in current use: ISO Standard 3891 and SAE AIR 1751. The Helicopter Noise Prediction Modelling Working Group came to the conclusion that there is a lack of a suitable propagation algorithm especially for helicopter noise propagation. Therefore, the Helicopter Group worked towards a proposed sound propagation algorithm. SoundProp and LOOKUP programs developed by the U. S. Army CERL were evaluated by the members of the working group during a field trial in August 1993 at Ft. Bliss in southeastern New Mexico. SoundProp and LOOKUP and the results of the field trial are also described in [1].

5 - HELICOPTER NOISE EXPOSURE MODELS

Any noise exposure model is required to predict accurately the actual noise exposure at the receiver from one or more noise sources. To meet this requirement, detailed noise source spectral data, directivity and excess propagation attenuation factors are required. Since noise source data are proportional to engine power and aircraft speed, flight profile and track details also are required to perform the noise exposure calculation. Also, usually there will be a requirement to plot lines of equal noise exposure (noise contours). Exposure models for helicopters are more complicated than fixed-wing aircraft exposure models since the variables stated above sometimes cannot be clearly defined for a helicopter movement.

Most of the current models used for calculating helicopter noise exposure were originally intended for fixed-wing aircraft noise and were later adjusted to allow for calculation of helicopter noise exposure. Only one model, the Helicopter Noise Model, has been developed exclusively for helicopters. The Working Group on Helicopter Noise Prediction Modelling evaluated the following models: the Danish Airport Noise Simulation Model (DANSIM), the calculation procedure based on the German Air Traffic Noise Act, the Kostenunit-System of The Netherlands, the Swiss Noise Exposure Model, Airnoise and the UK CAA procedure, NOISEMAP developed by the U. S. Air Force, the Integrated Noise Model (INM) and the Helicopter Noise Model (HNM) developed by the FAA.

Helicopter noise models should consist of at least three modules, the Input Module, the Helicopter Database and the Computation Module. The Input Module handles the bookkeeping. It properly accounts for the numbers of operations by aircraft, runway, flight track, time of day, etc. The Helicopter Database Module contains the helicopter sound emission data as a function of various specific operational parameters for each helicopter type such as speed, engine power setting, operation (e.g. flyover, take-off, landing, descent), and directivity. This module also contains data for describing the effects of certain variables on sound propagation from the moving helicopter to points on the ground. These variables include meteorological conditions, terrain and ground surface impedance. The Computation Module contains functional relations and procedures which compute the noise level of helicopter operations at selected receiving points on the ground using inputs from the Input Module and the Helicopter Database.

Normally, there are helicopter as well as fixed-wing operations on an airfield. The noise from these two types of aircraft must be combined into one overall prediction. Therefore, a Combining Module which combines the results of separate rotary- and fixed-wing computations into a single overall result is required. The output of this module is the overall noise level in the vicinity of an airfield from both helicopter and fixed-wing operations.

In general, aircraft noise models can use three different approaches to compute the noise level:

1. Segment oriented programs.
2. Distance of closest approach oriented programs.
3. Simulation oriented programs.

Segment oriented programs compute the noise level at selected receiving points on the ground by integrating all the noise of each event on each segment of each flight track. The output is an approximation to the SEL for each aircraft on each flight track. Clearly the smaller the segment, the better the approximation. NOISEMAP uses the segment method.

Distance of closest approach oriented programs use, in principal, the maximum noise level (L_{Amax}) during each fly-by. A duration correction is added to the maximum noise level. This duration correction is a

function of the distance of closest approach from the aircraft to the receiver location on the ground and it is also a function of aircraft speed. The German Air Traffic Noise Act requires a programme which is distance of closest approach oriented.
In contrast, simulation programs calculate the true time history of the noise for every fly-by at the receiver location. Therefore, the output is L_A as a function of time. This process is repeated for every noise event which contributes to the noise at the receiver location. An integration over all noise events gives equivalent level (L_{Aeq}). Recent increases in computing power makes the simulation approach a feasible tool for helicopter noise models. In the future, simulation programs will give more flexibility by adding new versatility such as helicopter noise directivity so it seems reasonable to assume that future helicopter noise models will use the simulation approach. The ideas for helicopter noise prediction programs will be discussed in greater detail in a different report of the working group [2].

6 - CONCLUSIONS

Public annoyance about helicopter noise in the vicinity of heliports and around training areas has generated controversy and litigations which have restricted helicopter operations in densely populated areas and around highly used airfields. In planning noise abatement helicopter operations, therefore, the need for helicopter noise prediction modelling is evident.
The most important conclusions of the Working Group on Helicopter Noise Prediction Modelling are:

- The working group emphasizes the requirement for an easy to use noise exposure model.
- The working group found out that most present noise exposure models do not meet all the needs required for helicopter operations, especially with respect to directivity and propagation.
- The working group agrees on the necessity to incorporate helicopter noise directivity information into the helicopter noise database. Therefore, a procedure for helicopter noise directivity measurement and data acquisition needs to be developed.
- The working group concludes that the influence of terrain on helicopter noise propagation is important and should be taken into consideration.

During the course of the deliberations of this working group not all the objectives in the Terms of Reference have been achieved. However, all the issues have been addressed. In some cases immediate action was neither possible nor achievable within the resources and the time frame available. Therefore, recommendations on the basis of the above-mentioned conclusions have been made for future work to meet these objectives [1, 2].

REFERENCES

1. **NATO/CCMS**, *The NATO/CCMS Working Group on Helicopter Noise Prediction Modelling - A Report of the Working Group Study*, 1994
2. **NATO/CCMS**, *The NATO/CCMS Working Group on Helicopter Noise Prediction Modelling - The Final Report of the Working Group Study*