Shipboard Noise Prediction with LOTUS

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(LOTUS를 이용한 선박소음예측)

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1 INTRODUCTION

The use of spreadsheet packages for solving noise control problems has been cited by several authors, eg Saha[1] and Thornton[2]. The effectiveness of using spreadsheet packages compared with the traditional computer programs written in high level languages was demonstrated when applied to relatively simple problems, such as the selection of hearing protectors or the prediction of noise levels outside a plant, where one simple arithmatic equation which includes logarithmic additions at most represents the physics of the problem.

The simplicity of the governing equation together with the requirement to handle a vast amount of data are considered to be the major reasons for noise control engineers to use spreadsheet packages. Although shipboard noise prediction seems to be very complicated, the calculation procedure itself is, in essence, identical to simple noise control problems cited above. This is especially true for prediction methods based on empirical formulae[3,4], ie the procedure that consists of the three basic elements, ie source, path and receiver.

This paper discusses the application of spreadsheet package LOTUS 1-2-3 to shipboard noise prediction problems. A utility program of the package is written using macro functions and is shown to be especially useful for noise control engineers who are unfamiliar with spreadsheet packages. In addition, a new type of empirical formula, to estimate structureborne noise transmission loss, is proposed.

2 SHIPBOARD NOISE PREDICTION PROCEDURE

In principle, there are two different ways to predict shipboard noise levels, one uses analytic methods and the other semi-empirical methods. The two methods have been well summarized and discussed by Hynna.[5] Provided that the ship considered is not included in new types of vessels, semi-empirical methods are considered to be practical and give good estimates for similar ships that are planned.

From now on, the focus will be given to the semi-empirical method. A typical prediction formula for a structureborne noise contribution emanating from one specific source can be arranged as follows[3,4]:

$$Lp(cabin) = Lv(source) - TD - \sum IL + C \qquad (1)$$

where Lp(cabin) is the noise level in a cabin; Lv(source) the structureborne noise level of a source; TD the transmission loss through ship structures; $\sum IL$ additional transmission losses due to resilient mounting of a source and/or vibration level difference between deck and lining, etc; and C represents structure-sound coupling effect. The variables appeared in equation (1) are predicted by using simple arithmatic relations which either use the characteristics of the operating machinery or are given by some constants which are obtained empirically. The shipboard noise control engineer is responsible for evaluating the transmission loss of structureborne noise among others. Wave guide theory and SEA (Statistical Energy Analysis) are being applied to attack this problem. Using empirical methods, the transmission loss is approximated by the following equation[3]:

$$\begin{aligned} TD &= m \left\{ \begin{array}{ll} 1.0 & \text{for mach.} \\ 0.57 & \text{for prop.} \end{array} \right\} \\ &\quad + n \left\{ \begin{array}{ll} 5 & \text{if } n < 4 \\ 2 + 12/n & \text{if } n > 4 \end{array} \right\} \end{aligned} \qquad (2)$$

Where m represents the number of transverse frames between the source and receiver, and n represents the number of the deck on which the receiver is situated. The assumption is that TD varies according to frame and deck differences between source and receiver independently, ie TD is determined by the frame only when the deck location is fixed. This assumption may not be correct if viewed against the onboard noise measurement data explained later in the paper. Although he used different coefficients, Buiten[4] adopted the same assumption as above in connection with the simplifed dB(A) level prediction for accommodation area.

2.1 Structureborne Noise Transmission

Fig. 1 shows the variation of noise levels measured onboard ships as a function of the frame difference between an auxiliary diesel engine and an ordinary cabin. The measurement data has been collected from 505 cab-

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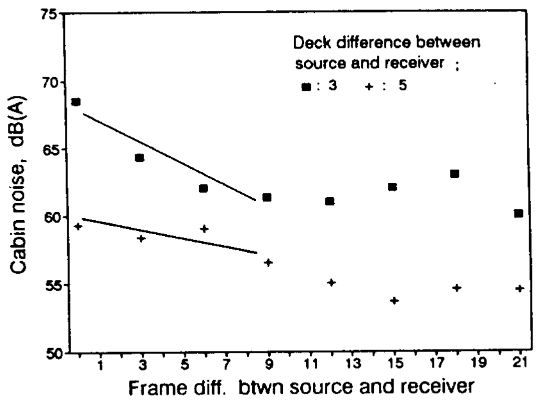

Fig 1:Noise level of ordinary cabins as a function of frame difference

ins on 26 different vessels recently built.[6] The ships include bulk carriers, tankers, and container ships with all cabins located on the same deck level. The data imply that the longitudinal transmission is not constant for all deck levels as assumed in equation(2) but dependent on the deck location of a cabin. This is because the other acoustical input data, which influence the noise level in a cabin, can be considered to be almost the same for all cabins investigated. The transmission loss from the source arising from the frame differences, is greater for lower deck than higher deck. This tendency is clearly represented by two straight lines in Fig. 1 where the frame differences decrease.

In order to use this idea to evaluate transmission loss, a new parameter K, which represents the distance from source to receiver, is introduced, as shown in equation (3):

$$K = \sqrt{(4D)^2 + (0.8F)^2} \qquad (3)$$

where D and F represent deck level and frame difference between source and receiver respectively. The total transmission loss TD is calculated by :

$$TD = TD_v(D) + TD_h(K) \qquad (4)$$

where TD_v is the contribution from the deck levels and TD_h the contribution from the longitudinal locations combined with the effect of deck levels.

Fig. 2, which shows the relationships between the average noise levels of ordinary cabins and the parameter K, gives a good correlation between the two parameters. The distance parameter K is defined in various ways based on conceivable structureborne noise sources, ie main engine, auxiliary diesel engine and propeller. Unlike the propeller, the other two noise sources show similar trends even when the two distance parameter K's differ from one another. With this in mind, it could be assumed that the measured noise levels of the cabins were dominated by diesel engines.

The longitudinal transmission loss of diesel engines can be deduced from the curves shown in Fig. 2. To derive the empirical formula, it was further assumed that the contribution from each sources to the final noise level was nearly the same. With this in mind, the two curves in Fig. 2 were redrawn and are illustrated in Fig. 3. The equivalent distance Ke is the arithmatic average value of the two distance parameters which appeared in Fig. 2, ie the average distance from the cabin considered to main and auxiliary diesel engines. Fig. 3 also shows curve fitting on the measurement data. The longitudinal transmission loss can be expressed as follows within an error of 3 dB, which is compared the two curves in Fig. 3.

$$TD_h(K) = 0.0005K^3 - 0.0106K^2 - 0.6255K \qquad (5)$$

The vertical transmission loss can be estimated from Table 1 which has been calculated from the measurement data.

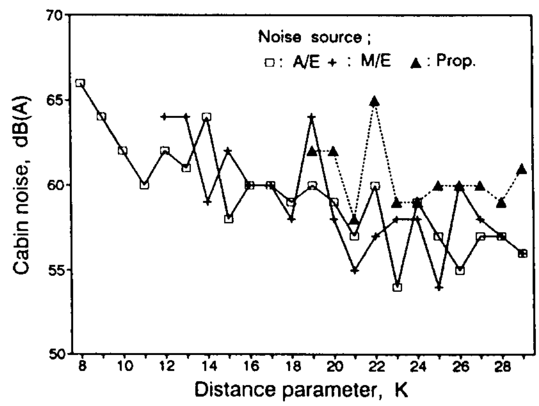

Fig 2:Cabin noise levels by K

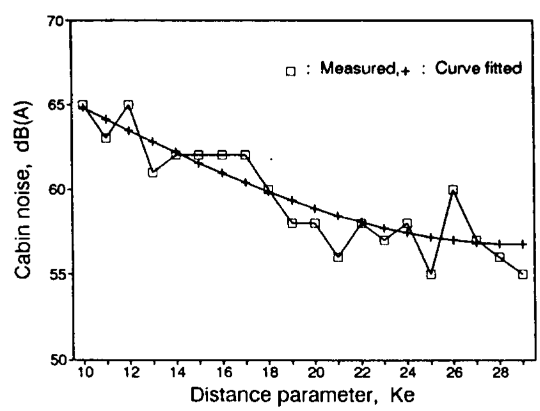

Fig 3:Cabin noise levels by Ke

Table 1 Vertical transmission loss, TDv(D)

Deck differ.,D	1	2	3	4	5	6	7
TDv(D)	10	16	20	23	22	22	20

2.2 Simplified dB(A) Level Prediction[4]

Buiten proposed a simplified method for predicting dB(A) levels in accomodation spaces as follows:

$$Lp(cabin) = Ls(1m, ff) + Ce - TD(hor) - TD(ver) - \sum IL \quad \text{dB(A)} \qquad (6)$$

where TD(hor) is the transfer level difference in fore and aft direction between the source and the cabin; TD (vert) is the same as TD (hor)-but for the vertical distance; Ls(1m,ff) is the sound level A at 1 m distance from the source under free field condition; Ce a constant relating Ls(1m,ff) to the sound level A inside the cabin and $\sum IL$ the total effect of acoustic measures. Buiten also gave the specific values or formulas for the variables listed above. Equation (6), with the exception of the transmission losses TD(hor) and TD(Vert), was used during the implementation of shipboard noise prediction procedure on spreadsheet.

3 IMPLEMENTATION OF EMPIRICAL FORMULA ON SPREADSHEET

For technical computer programs to be attractive to field engineers who may not possess in-depth knowledge on the specific technical fields, they must be be accessed with ease and must produce a well-documented output. This is why so many pre- and post-processors for general purpose computer codes, which are very popular, are being developed. With this in mind, a user interactive pre-processor has been developed and integrated with the main calculation scheme embedded in the spreadsheet LOTUS 1-2-3.

3.1 Pre-processor

Noise control engineers are not usually familiar with the usage of spreadsheet packages, which have emerged from business world and do not consider them suitable for their purposes. This is true for most of engineering problems which involve many scientific calculations; but for simple calculations, eg equation (6), the spreadsheet can be used very efficiently to produce a variety of further documentation to aid reporting.

Familiarising oneself with spreadsheet manuals can, however, be time-consuming and therefore a pre-processor was prepared to overcome this problem. It is written with C language which is widely used because of its flexibility with the computing system environment and because it dose not sacrifice most of the features high level languages. As shown in Fig. 4, the pre-processor adopted a menu-driven system so that field engineers are feel free to use the program. In particular, any doubts about input variables are for the most part answered by pressing HELP key at the appropriate cursor position.

Two important functions of the pre-processor are to prepare an input data file for the shipboard noise predicton and to make a smooth connection with spreadsheet packages. The latter of these two functions is considered the most important in this specific case.

Spreadsheet program is automatically loaded in the memory via a selection key and control is handed over to the spreadsheet program. The user is not required to invoke the spreadsheet.

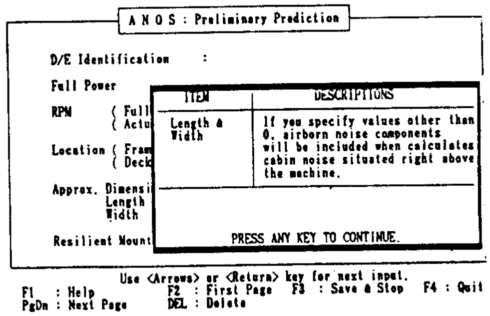

Fig. 4 An example display of pre-processor

3.2 Spreadsheet Package

Although it is not the purpose of this paper to detail a manual for a spreadsheet package, it is necessary to mention about some basic concepts relating to the spreadsheet. They are not intended to explain the package, but rather to identify personal experiences gained whilst working on shipboard noise predicton using the spreadsheet LOTUS 1-2-3.

- Basic functions

  Spreadsheet can be considered as a large blank paper used for calculation purposes. The whole calculation sheet is divided into small basic areas called "cell". A cell can hold literals, numbers, formulae and program statements called macros. Each formula references the current contents of other cells and shows the result immediately, ie the formula written in one cell always keeps track of the cells it has referenced and therefore changes as soon as input data varies

  Once the blank sheet is systematically organised with cells containting templates, input data and formulas, this method of basic calculation enables spread sheets to be utilised in a variety of ways for engineering as well as business purposes.

- Macro functions

  A macro is an elementary tool used to develop utility programs within a package. It is a kind of programable languages such as Fortran which is widely used in engineering society. Its usage is very restrictive and primitive compared with high level languages. Previous studies[1,2] have recommended that macros should not be used in spreadsheet packages which relate to the noise control problems. This argument applies when attempts are made to write programs based on the traditional concept. Macros can, however, prevent new users from having to spend a lot of times learning commands and instructions etc, inherent in the package.

Furthermore, the operating environment of the spreadsheet, unfamiliar to most engineers, can, by utilising macros, be applied to engineering. The interactive processes within the system then can become trivial and the calculation itself, acommodated in the spreadsheet package, is irrelevant to the program which serves as an interpreter between users and the package.

- Other functions

  There are many other attractive functions within the spreadsheet package, eg graphic capabilities, file handling functions, database management and word processing capabilities. Furthermore, speadsheets themselves are being refined and new features are being continually added by various vendors. This is why spreadsheet packages are so popular in the business world . Of course, all of these functions can be applied to engineering problems.

3.3 Spreadsheet Applied to Shipboard Noise Prediction

It has already been mentioned that the pre-processor invokes the spreadsheet automatically. Once it is loaded, the operating environment of the spreadsheet can be arranged adequately for shipboard noise prediction by an auto execution macro function called "\0". This is especially useful for beginners. Advanced users can choose the original operating environment of LOTUS. An example of start-up screens after accessed by the pre-prosessor is shown in Fig. 5.

For this specific shipboard noise application, the spreadsheet were divided into 5 sub-areas based on the basic functions assigned to them. They were a user interactive input field; a storage area of input data file prepared by pre-processor; calculation tables; a storage area of informations related to database; and a programing area. The paragraphs below give a detailed summary of each sub-areas.

- User interactive input area

  When a user selects the manual option in the main menu shown in Fig. 5, he can input data in the appropriate cells directly. The data in this area are referenced by the formulas permanently embedded in the calculation table. The manual input option is convenient for experienced users to perform a "what-if" study, ie the results are instantly recalculated as soon as the input of data are changed for an area. Templates and organization of input data are considered to be important in view of the appearance of the read sheet itself and they are convenient for the input process. The area can also be filled with input data imported from external files, prepared by a preprocessor, via an option command.

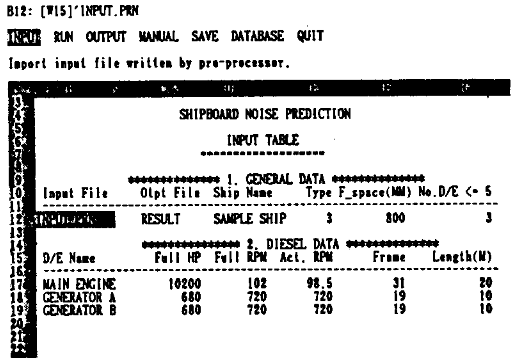

Fig. 5 The start-up screen

- Imported file storage area

  This space is used to store an imported data file. Informations written in this area is automatically copied to appropriate cells on an input table, mentioned earlier, by choosing input option on the main menu. The option is usally selected when a new job is started or data currently in the spreadsheet needs to be changed. The imported file should comprise one item of data per line, otherwise the importing and transfering processes of input data may prove difficult.

- Calculation table area

  Cells in this area contain templates and formulas permanently embedded in the spreadsheet. The formulas are stored internally so that they are not seen literally. Calculated results from the input data ie, the original feature of the spreadsheet, are shown instead

  The organization of the area is important and should look presentable so that users can interprete and examine the result easily. Unlike the output from ordinary programs, the output, ie the calculation table, resides in the spreadsheet program and is renewed at any time as the calculation proceeds. This means that as many calculation tables as cabins can be calculated. The individual calculation table is compared to a formatted sheet of paper for shipoard noise prediction. Therefore, each calculation tables in the spreadsheet is considered as a part of documented final report of the prediction. The report can either be printed out literally or graphically, using options listed in the main menu.

- Area for database

  Database handling capacity is beneficial to the empirical evaluation of shipboard noise level. It is not only necessary to store inside the spreadsheet the source level of a specific equipment measured onboard, but also noise levels emanating from within cabins. All such data can be used to increase the accuracy of the prediction. For instance, the measured source level is directly inserted in the empirical formula as in equation (1), as soon as the source level of the same machinery can be accessed from the database. Previous measurements of cabin noise levels are used to evaluate empirical parameters shown in equation (5). This improves the programs and the area on the spreadsheet should be large enough to hold any future data.

- Program area

  Several unit programs were written in the spreadsheet in order to aid users. The main purpose of them is to change the operating environment simply and adequately for shipboard noise prediction.

  Through the auto execution macro program "\0", the spreadsheet is arranged for shipboard noise prediction as soon as the spreadsheed is loaded in the memory for the first time. The auto execution program is called; "\r", thereby enabling the program to be called at any time from the original LOTUS environment by pressing ALT and R keys simultaneously. The choice of the operating enviroment depends on the individual preference of users. Experienced users prefer the origininal environment as it exploits flexibilities of the spreadsheet. The other programs are invoked from the auto execution program according to the selection in the main menu. Fig. 5 shows examples of the main menu of the shipboard noise prediction problem.

  Besides the auto execution program, progrms related to final documentation and database are worth mentioning. The output document takes the form of report filled with letters only or with some graphs. Usually if no graphs are required, the output is a hard copy of the output table area . Documentation programs use PRINT and GRAPH system functions of the spreadsheet extensively. Fig. 6 is an example of graphic output from the program. A database program must be capable of adding new data, updating old data, extracting required data and regression analysis. Functions listed above are handled well by DATA function of the spreadsheet. Database programs serve only to use the DATA function in different ways, ie the database program is nothing but a re-organization of DATA function for a specific application.

4 EXAMPLE OF APPLICATION

Following the outline explained, a utility program of the spreadsheet package LOTUS 1-2-3 was prepared for shipboard noise prediction. The main calculation scheme was based on the equation (6) with transmission losses from equation (5). Fig. 7 is an example of documented output. The examples of graphic outputs in Fig.6 show the comparison between measured and predicited noise levels inside cabins. For ship A, the agreement of the two values is quite satisfactory and shows that the new empirical transmission loss model shown in equation (5) is a promising one. The accuracy for ship B is not good. This is due to the limit inherent in empirical formulas. Ship B was much larger than ship A in size, and ship A was as the same size as the past vessels which the empirical coefficients were derived. The appropriate coefficients for ship B can be obtained and applied in the calculation process by use of a database program if enough data are stored in the database of the spreadsheet.

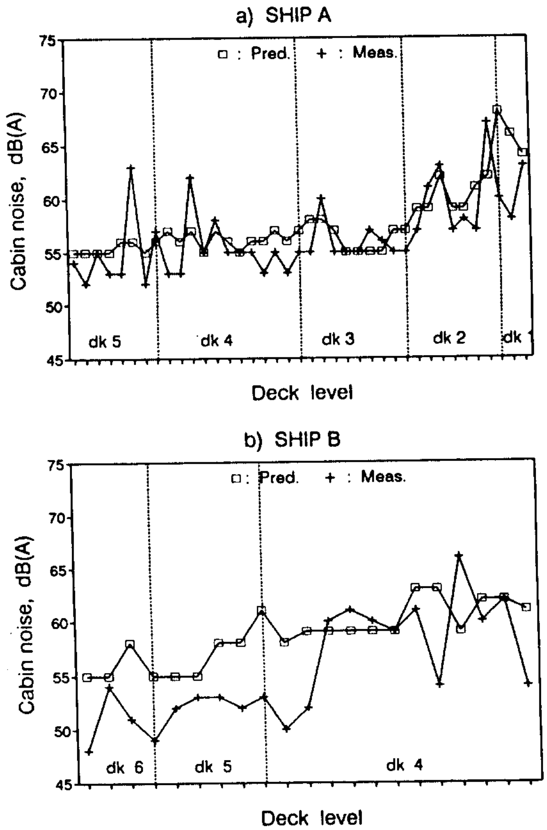

Fig 6:Noise levels predicted and measured

5 CONCLUSION

A method of applying spreadsheet packages into shipboard noise prediction have been presented. The introduction of macro programs inherent in the package has been effectively incorperated by using a spreadsheet, so that engineers without prior knowledge about the spreadsheet can use the program with ease, a matter over looked in previous research studies. To make the utility programs of the spreadsheet attractive to

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                 ***********************************
                 *                                 *
                 *   ANOS : Preliminary Prediction *
                 *                                 *
                 ***********************************

          **********  INPUT DATA SUMMARY  ************

1. General Data

  1.1  Ship Name            : SAMPLE SHIP
  1.2  Ship Type            :  3
         :
         :
2. Source Data

  2.1  Diesel Engines

 D/E Source   Full Power    RPM       Location    Dimension(M) Resilient
    Name        (HP)     Full  Actu. Frame# Deck#  Leng.  Width   (Y/N)
--------------------------------------------------------------------------
MAIN ENGINE    10500      103    96     33    0     7.0   3.0      N
A/E1             820     1200  1200     20    1     5.0   3.0      N
A/E2             820     1200  1200     20    1     5.0   3.0      N
          :
          :

3. Cabin Data

   Cabin          Location     Noise treat.  Right above E/R
   Name        Frame# Deck#     (0/1/2/3)        (Y/N)
---------------------------------------------------------------
ECR              31     2          1               Y
C501             36     7          0               N
  :

          **********  PREDICTION RESULTS  ************

  1.  ECR               :    Overall Noise Level   68 dB(A)
            MAIN ENGINE    :  58 dB(A)    A/E1           :  64 dB(A)
            A/E2           :  64 dB(A)    PROP           :  42 dB(A)
            Airborne       :  60 dB(A)

  2.  C501              :    Overall Noise Level   59 dB(A)
            MAIN ENGINE    :  52 dB(A)    A/E1           :  55 dB(A)
            A/E2           :  55 dB(A)    PROP           :  33 dB(A)
               :
               :
```

Fig. 7 Example of documented output

engineers, it is believed that well organised templates and formulas are essential. The spreadsheet can be a powerful tool especially when used for systematic calculation based on relativiely simple formulas. It should be remembered, however, that the calculation of the spreadsheet are not of a scientific nature although they are geared to engineering. With the advancement of spreadsheet program itself and with the integration capability with external programs such as a pre-processor explained in this paper, the spreadsheet is expected to increase its applications into field of engineering problems

Finally, the dependency of longitudinal transmission losses on deck levels, as expressed in equation (5), is considered to be a better model than the traditional ones.

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