MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1965-1
DAVIDSON LABORATORY

Technical Note SIT-DL-79-7-899

November 1979

FORTRAN PROGRAM OBLIQUE IN PL-FORMAT
USER'S MANUAL

by

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Prepared under
Contract N00014-77-C-0062

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INTRODUCTION

This manual accompanies the program listings and a magnetic tape containing two files, one of program OBLIQUE and one (the second) of program OBLIQO2. The theoretical procedure behind the computer programs and its limitations are described in detail in Reference 1. The programs OBLIQUE and OBLIQO2 plus the program PPEXACT are used in the procedure described herein to compute the blade bending moments of a propeller operating in an oncoming flow inclined to the propeller shaft. The theoretical analysis leading to and the operation of PPEXACT have been described by Tsakonas, et al. The purpose of this manual is to present sufficient information on the organization of the programs, descriptions of the input and output, and description of the input to the sample calculation presented in Reference 1, so that an engineer with a knowledge of FORTRAN may execute the procedure successfully.

ORGANIZATION OF PROGRAMS OBLIQUE AND OBLIQO2

The program was designed to solve an integral equation, Eq. (25) in Reference 1, namely,

$$\int_{s} \Delta P^{(0)} K^{1} ds + \int_{s} \Delta P^{(2)} K^{"} ds = \int_{s} \Delta P^{(1)} K^{0} ds$$

(1)

where $K^{0}$ is the kernel of the integral equation for the shaft-frequency harmonic loading described by Tsakonas, et al. and programmed in PPEXACT. Program OBLIQUE computes $K^{1}$, multiples by $\Delta P^{(0)}$ and performs the surface integration over all the propeller blades. Program OBLIQO2 computes $K^{"}$, multiples by $\Delta P^{(2)}$ and performs the surface integration over all the blades. Brief descriptions of the terms in (1) are given next; however, for details on the equations programmed, the reader is referred to Valentine.
The factors \(K_1\) and \(K_1''\) inside the integrals on the left-hand-side of Eq. (1) are geometric quantities related to the deviations from circular helicoidal stream surfaces of the shed helicoidal flow field behind a propeller in an inclined flow. The \(\Delta P_0^{(0)}\) and \(\Delta P_0^{(2)}\) factors are the steady and second harmonic of blade loading due to the mean and second harmonic of the circumferential spatial variation of the oncoming flow into the propeller, respectively. The subscript 0 implies that these quantities are computed by the procedure described in References 2 and 3 utilizing PPEXACT. Therefore, the propeller model used to compute \(\Delta P_0^{(0)}\) and \(\Delta P_0^{(2)}\) neglects the oncoming flow inclination. Equation (1) is of order \(\psi\), the shaft inclination angle, which is assumed to be small. The propeller is assumed to be lightly loaded.

The relatively large shaft frequency component of the measured circumferential variation of the tangential velocity into the propeller disk inclined to the oncoming flow produces a shaft frequency loading \(\Delta P_1^{(1)}\). Thus, Eq. (1) is an additional contribution to the shaft frequency loading due to the distortion on the shed helicoidal stream surfaces. Consequently, the contributions to the shaft frequency loading calculated by the present computational procedure are given by the right-hand side of the following equation

\[\Delta P^{(1)} = \Delta P_0^{(1)} + \psi \Delta P_1^{(1)}\]  

where \(\Delta P_0^{(1)}\) is determined by executing PPEXACT with the measured wake as input, and \(\Delta P_1^{(1)}\) is determined by exercising OBLIQUE and OBLIQ02. The program OBLIQ02 is required only if the measured wake has a significant second harmonic variation in the circumferential variations of the propeller inflow; therefore, for a propeller inclined in open-water OBLIQ02 is not needed.

The loading \(\Delta P_1^{(1)}\) is the solution of the integral equation (1), where \(K_0\) is the same kernel computed by PPEXACT \(^3\) for the blade frequency harmonic problem. Since the problem under consideration is linear, we may for convenience split (1) into two equations.
\[ \iint_{S} \Delta P^{(0)}_{O} K_{1} \, ds = \iint_{S} (\Delta P^{(1)}_{1})_{1} K_{O} \, ds \] (3)

\[ \iint_{S} \Delta P^{(2)}_{O} K_{1}'' \, ds = \iint_{S} (\Delta P^{(1)}_{1})_{2} K_{O} \, ds \] (4)

where \( \Delta P^{(1)}_{1} = (\Delta P^{(1)}_{1})_{1} + (\Delta P^{(1)}_{1})_{2} \). The program OBLIQUE solves (3) and OBLIQO2 solves (4).

A. Computational Procedure

The procedure described is intimately tied in with the already published program PPEXACT. Therefore, it is essential to have on hand the FORTRAN program and its user's manual, the four volumes cited as Reference 3. Familiarization with the usage of PPEXACT is assumed. Since it has been adequately documented elsewhere, the list of inputs used in executing PPEXACT for the sample case will be presented in the next section without further elaboration. The input data for OBLIQUE and OBLIQO2 will be described in an appropriate subsection after the list of steps in the procedure.

The list of steps are:

Step 1. Prepare the input data deck for PPEXACT in accordance with Reference 3 for the propeller and its measured inflow appropriately analyzed into harmonic components.

Step 2. Execute PPEXACT for the harmonic frequencies up to at least the second if the shaft frequency loading in inclined flow is desired. The loadings are stored in a permanent file defined from the local file TAPE 3 in PPEXACT. This may be accomplished by the following control card

\[ \text{DEFINE (TAPE3 = SOLVECS)} \]

where SOLVECS stands for solution vectors.
Step 3. Prepare input data deck for OBLIQUE in accordance with the subsection INPUT Data Deck.

Step 4. Execute OBLIQUE for the calculation of $K_1$ followed by the calculation of $(\Delta P_1^{(1)})_1$. The steady loadings, $\Delta P_0^{(0)}$, are read from the permanent file SOLVECS onto the local file TAPE9. This may be accomplished by the control card

GETPF (TAPE9 = SOLVECS)

Step 5. Prepare output data deck for OBLIQUE in accordance with the subsection INPUT Data Deck.

Step 6. Execute OBLIQUE for the calculation of $K_2^n$ followed by the calculation of $(\Delta P_1^{(1)})_2$. The second harmonic loadings, $\Delta P_0^{(2)}$, are read from the permanent file SOLVECS onto the local file TAPE9 in the same manner as in Step 4.

Step 7. Combine results of Step 2, Step 4 and Step 6 to obtain the shaft frequency loading (or bending moments, etc.) due to the spatial distribution of inflow plus the distortion of the shed helicoidal stream surfaces behind the propeller using (2) to obtain:

$$\Delta P_1^{(1)} = \Delta P_0^{(1)} + \psi \left[ (\Delta P_1^{(1)})_1 + (\Delta P_1^{(1)})_2 \right]$$

(5)

The output of OBLIQUE is $\psi (\Delta P_1^{(1)})_1$ and the output of OBLIQUE is $\psi (\Delta P_1^{(1)})_2$. Remember that the results are printed in the output in complex form. Collecting the real and imaginary parts of (5), we may write

$$\Delta P_1^{(1)} = R + \text{i}I$$

which may be reduced to the form

$$\Delta P_1^{(1)} = A \cos(\theta - \varphi)$$

(6)

where

$$A = \sqrt{R^2 + I^2}$$

$$\varphi = \tan^{-1} \left( \frac{I}{R} \right)$$

$$\theta = \text{angular position of reference blade}$$
Equation (6) is the result of interest for the shaft frequency response of a propeller's blade in a spatially varying inflow with the mean velocity inclined to the propeller shaft.

B. Tape OBLIQUE

The tape accompanying this document is inscribed OBLIQUE. It is a 650-foot magnetic tape guaranteed for use at 800 through 6250 bpi. The tape was created with the following control cards:

- **Job Card**
- **User Card** Facility dependent controls
- **Charge Card**
  - GETPF (OBLIQUE)
  - GETPF (OBLIQ02)
  - LABEL (TAPE, VSN = TXXX*, LB = KU, D = HD, NT, P0 = W)
  - REWIND (TAPE)
  - COPYBF (OBLIQUE, TAPE)
  - COPYBF (OBLIQ02, TAPE)
  - UNLOAD (TAPE)

6/7/8/9 END-OF-FILE CARD

Therefore, the tape supplied is NOS unlabeled (LB = KU), where NOS is the operating system of the CDC 6600 computer at New York University on which the tape was made. The tape is 9-track (NT) and was used at 800 cpi (D = HD). Two files were copies (P0 = W) onto the tape. The first file is OBLIQUE and the second file is OBLIQ02.

In order to mount and read (P0 = R) the tape on another CDC 6000 series computer, the control cards required are:
Job
User Facility dependent controls
Charge
DEFINE (TAPE1 = OBLIQUE)
DEFINE (TAPE2 = OBLIQ02)
LABEL (TAPE, VSN = TXXX*, LB = KU, D - HD, NT, PO = R)
REWIND (TAPE)
COPYBF (TAPE, TAPE1)
COPYBF (TAPE, TAPE2)
UNLOAD (TAPE)
6/7/8/9 END-OF-FILE CARD

Since the programs are in PL-Format, the following sequence of control cards are required to obtain a listing of the program:

Job
User Facility dependent controls
Charge
GETPF (OLDPL = OBLIQUE)
UPDATE (F)
COPYSBF (COMPILE, OUTPUT)
7/8/9 END-OF-RECORD CARD
7/8/9 END-OF-RECORD CARD
6/7/8/9 END-OF-FILE CARD

where GETPF is equivalent to an ATTACH card. A similar sequence is required to list OBLIQ02, which is also in PL-Format.

In order to execute the created permanent files, the following sequence of cards are required.

*XXX is any integer from 1 to 999 which uniquely identifies the tape.
Job
User
Charge
GETPF (TAPE9 = SOLVECS)
REWIND (TAPE9)
GETPF (OLDPL = OBLIQUE)
UPDATE (F)
FTN (I, ER)
RFL, 200000.
LGO.
7/8/9 END-OF-RECORD CARD
7/8/9 END-OF-RECORD CARD
INPUT DATA DECK
6/7/8/9 END-OF-FILE CARD

A similar sequence of cards is required to execute OBLIQQ2 (the only card to be changed is the card with OLDPL = OBLIQUE which is changed to OLDPL = OBLIQQ2). Both programs require the permanent file created by the DEFINE (TAPE3 = SOLVECS) control card during the execution of PPEXACT.

C. INPUT Data Deck

The first data card required by OBLIQUE and OBLIQQ2 is described as follows:

1. Control for OBLIQUE or OBLIQQ2

<table>
<thead>
<tr>
<th>Columns</th>
<th>Format</th>
<th>Variable Name</th>
<th>Entry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>I</td>
<td>NPS1</td>
<td>= 0 Noninclined inflow = 1 Inclined inflow</td>
</tr>
<tr>
<td>6-15</td>
<td>F</td>
<td>ANGLE</td>
<td>Angle of shaft inclination with inflow, $\psi$</td>
</tr>
<tr>
<td>16-20</td>
<td>I</td>
<td>NIY</td>
<td>position of desired loadings in the queue of solution vectors on TAPE9; 1 for $\Delta P_0^1$ or 3 for $\Delta P_0^2$</td>
</tr>
<tr>
<td>21-25</td>
<td>I</td>
<td>NIY</td>
<td>position of blade loadings in the queue of solution vectors on TAPE9; 2 for $\Delta P_0^1$</td>
</tr>
</tbody>
</table>
The next 22 cards are identical with the input to PPEXACT for the determination of the shaft frequency loading as described in Reference 3. The input may be extracted from the input data deck used to execute PPEXACT, which is a prerequisite to this calculation.

D. OUTPUT

The output format of OBLIQUE and OBLIQO2 is identical with that of PPEXACT. The only important piece of information to keep in mind is that the output of OBLIQUE is due to the left-hand-side of (3) and the output of OBLIQO2 is due to the left-hand-side of (4) both of which are not results of the measured wake data. The latter effect was already computed by PPEXACT. Again, the reader is referred to the theoretical considerations described in Reference 1 for details of this analysis.

SAMPLE CASE

The sample case as described in Reference 1 demonstrates that the distortion of the shed helicoidal stream surfaces in the wake of the propeller are 180 degrees out of phase with the primary contributor to the shaft frequency loading, viz, the across-the-disk component of the oncoming flow.

In order to execute the programs for this calculation the input data decks are presented in Tables 1 through 3. Table 1 lists the input data used to execute PPEXACT. Table 2 was used to execute OBLIQUE and Table 3 was used to execute OBLIQO2. The results are presented in Table 4 illustrating the effects of each component. See Reference 1 for an elaboration of these results.

The execution time of PPEXACT for six frequencies of loading is approximately 10 systems minutes on the CDC 6600 computer. The program OBLIQUE and OBLIQO2 take approximately 12 systems minutes each on the same computer. Therefore, the total execution time for the
problem of computing blade bending moments including the contribution of inflow inclination on the shaft frequency loading is approximately 34 systems resource minutes on the CDC6600.

REFERENCES


### TABLE 1
**INPUT INFORMATION TO PPXACT AS PRINTED IN OUTPUT**
(See Reference 3 for Description)

a. Propeller data and options selection

<table>
<thead>
<tr>
<th>FF-1 inh PROPELLER</th>
<th>FAR= 0.330</th>
<th>P/D= 1.061</th>
<th>DESIG: J= 0.767</th>
<th>RPM=240,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHIP SPEED= 47.250</td>
<td>10 OF BLADES= 5</td>
<td>PROP NIAN=15.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PROPPELLER PARAMETERS**

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<th>0</th>
<th>0</th>
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<th>0</th>
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<td>8</td>
<td>9</td>
<td>11</td>
<td>2</td>
<td>17</td>
<td></td>
</tr>
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<td>4.00320</td>
<td>0.33300</td>
<td>0.38720</td>
<td>1.99380</td>
<td>47.25960</td>
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<td>0.33300</td>
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<td>0.14250</td>
<td>0.02560</td>
<td>0.02924</td>
<td>0.02357</td>
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<td>0.005203</td>
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<td>0.48596</td>
<td>0.51753</td>
<td>0.64275</td>
<td>0.56077</td>
<td>0.55651</td>
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<td>0.77121</td>
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<td>0.45670</td>
<td>0.46134</td>
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</tr>
</tbody>
</table>

**COMPUTATION FOR OTHER THAN NACA AVERAGE LINES**
b. Mean Wake taken to be zero in sample case - uniform inflow

```
WAKE 10 1
ORDER OF BLADE HARMONIC OF KERNEL= 0   ORDER OF BLADE HARMONIC OF LEFT HAND SIDE= 0
```

<table>
<thead>
<tr>
<th>SPAN-LOCATION</th>
<th>REAL</th>
<th>IMAGINARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>.333</td>
<td>0.01070</td>
<td>0.00001</td>
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<tr>
<td>.422</td>
<td>0.01070</td>
<td>0.00001</td>
</tr>
<tr>
<td>.511</td>
<td>0.01000</td>
<td>0.02000</td>
</tr>
<tr>
<td>.600</td>
<td>0.00000</td>
<td>0.08000</td>
</tr>
<tr>
<td>.699</td>
<td>0.00000</td>
<td>0.09000</td>
</tr>
<tr>
<td>.773</td>
<td>0.00000</td>
<td>0.09000</td>
</tr>
<tr>
<td>.867</td>
<td>0.00000</td>
<td>0.09000</td>
</tr>
<tr>
<td>.956</td>
<td>0.00000</td>
<td>0.09000</td>
</tr>
</tbody>
</table>

c. Flow angle contribution was computed in sample case
d. Camber is approximated by sine squared distribution

**CODE OF BLADE HARMONIC OF KERNEL= 0**

**KERNEL MATRIX BY BIRKBAUM APPROACH**

LEADING-EDGE-RADIUS/CHORD

<table>
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<tr>
<th>SIDE SQUARED</th>
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<tr>
<td>0.0120</td>
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<td>0.0050</td>
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<td>0.0050</td>
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<tr>
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<tr>
<td>0.0027</td>
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</table>
e. Wake data for the first and second harmonic of loading

**WAKE 10 2**

<table>
<thead>
<tr>
<th>ORDER OF BLADE HARMONIC OF KERNEL = 1</th>
<th>ORDER OF BLADE HARMONIC OF LEFT HAND SIDE = 1</th>
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<tbody>
<tr>
<td>SPAN-LOCATION</td>
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<tr>
<td>.333</td>
<td>-.03210</td>
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<td>.422</td>
<td>-.03290</td>
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<tr>
<td>.511</td>
<td>-.01640</td>
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<td>.600</td>
<td>-.01480</td>
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<tr>
<td>.698</td>
<td>.00330</td>
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<td>.778</td>
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<td>.867</td>
<td>.00830</td>
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<tr>
<td>.956</td>
<td>.00270</td>
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**WAKE 10 3**

<table>
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<tr>
<th>ORDER OF BLADE HARMONIC OF KERNEL = 2</th>
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<td>.867</td>
<td>-.01910</td>
</tr>
<tr>
<td>.956</td>
<td>-.01670</td>
</tr>
</tbody>
</table>
### TABLE 2

**SAMPLE INPUT DATA DECK FOR PROGRAM OBLIQUE**

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<thead>
<tr>
<th></th>
<th>1</th>
<th>10.4</th>
<th>1</th>
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<td>1,061</td>
<td>0.767</td>
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TABLE 3

SAMPLE INPUT FOR PROGRAM OULIQ02
TABLE 4
RESULTS OF SAMPLE CALCULATION
Shaft Frequency Blade Bending Moment

Coefficients, \( \tilde{K}_b^{(1)} = \tilde{K}_b^{(1)}/(\rho n^2 D^5) \)

Components of Calculated Blade Bending Moments

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<th>Non-dimensional Propeller Radius ((r/r_o))</th>
<th>(\tilde{K}_{b_0}^{(1)})</th>
<th>(\varphi_0^{(1)}) (deg)</th>
<th>(\tilde{K}_{b_1}^{(1)})</th>
<th>(\varphi_1^{(1)}) (deg)</th>
<th>(\tilde{K}_{b_2}^{(1)})</th>
<th>(\varphi_2^{(1)}) (deg)</th>
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</table>

*Contribution due to shaft frequency harmonic of hull wake.

**Contribution due to \( \Delta P_0^0 \) and \( K_1^1 \).

***Contribution due to \( \Delta P_0^2 \) and \( K_1^2 \).