EFFECTS OF INHERENT CHARACTERISTICS OF DRIVING SHAFT ON THE DYNAMIC BEHAVIOR OF A CAM MECHANISM

By

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ABSTRACT

The inertia, flexibility, and damping of the driving shaft, are important factors in the dynamic behavior of a cam mechanism. These factors will be studied by utilizing a two degrees of freedom dynamic model. The formulation of the model in which each of the follower and cam posses one degree of freedom is presented and the investigation is carried out by the use of the nondimensional parameters.

An algorithm for computating the positional and accelerational errors during the cam rise and dwell periods, is presented here, along with the listing of the associated computer program. The numerical results are shown in the figures and also in the tables in Appendix.

1. INTRODUCTION

In this paper the mutual effects of the inertia, flexibility and damping between the follower and cam sets on the dynamic response of cam mechanism will be investigated. The cam mechanism is represented by the two degrees of freedom model one for the follower (q_1) and one of the cam shaft (q_2) as shown in Fig. (1). In reference [1], Koster gave the effect of the flexibility of the driving shaft on the dynamic behavior of a cam mechanism, by driving a single degree of freedom model, but still many questions concerned with the effect of inertia, and damping of the cam shaft remain Bloom and Radcliffe [2] have considered the wind up of the cam shaft, assuming that the follower is infinitly stiff. In

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reference[3] EISS derived a two degrees of freedom dynamic model, taking into account the deflection of the cam shaft in the direction of movement of the follower. In contrast to the mentioned investigators Chen and Polvanicn [4] studied the damping effect on a single degree of freedom either linear or onon-linear damped simulated cam mechanism. Recently Emam [5] investigated the effect of the flexibility of the cam shaft on the dynamic behavior of a single degree of freedom linear damped model. However many questions in the dyanmic analysis such as the inertia and damping characteristics of the cam shaft are still vague.

In the present work among the several types of follower motion the cycloidal cam curve, was chosen for the present investigation. The inertia; flexibility as well as damping characteristics of the follower and cam sets are expressed as nondimensional parameters throughout the analysis of the simulated cam mechanism. Attention will be given particularly to the positional, and accelerational errors of the output member in the primary and residual regions.

In computing the mentioned errors, the computer solution Fig. (5) by applying Runge-Kutta method is derived. The numerical results and a complete listing of the computer program written in FORTANT IV language are shown in the appendix.

2. MODEL OF THE TWO-DEGREES OF FREEDOM SYSTEM

In reference [6] it is possible to draw up for the mechanism of Fig. (1) the dynamic model shown in Fig. (2). In this dynamic model it is assumed that:-

1. The input angular velocity of the cam shaft can be considered to be constant (ω = constant).
2. The damping characteristic is considered as a linear viscous damping.
3. The backlash, starting from the driving element up to the end of follower linkage can be neglected.

Here m_{q_1}, m_{q_2} represent the mass of the follower and the mass of the cam measured in the q_1 and q_2 directions respectively. The stiffness of the follower set is K_{q_1}, the stiffness of cam set is K_{q_2}. The damping of the follower is characterized by C_{q_1}. The damping of cam set is given by C_{q_2}. Refering to references[1] 1, 6 the transmission ratio is given by $i = dy/dq_2$ where y is the cam curve displacement.

3. FUNDAMENTAL EQUATIONS FOR 2 DF MODEL

Referring to the lagrange's equations, the equations of motion based on a two degrees of freedom model Fig. (2) can be derived in terms of the kinetic energy (T), potential energy (V) and dissipation function (D), Here as

$$T = \frac{1}{2} m_{q_1} \dot{q}_1^2 + \frac{1}{2} m'_{q_2} r^2 \dot{q}_2^2 \qquad \text{...........(1)}$$

$$V = \frac{1}{2} K_{q_1} (q_1 - y)^2 + \frac{1}{2} K'_{q_2} (q_2 r - \omega t r)^2 \qquad \text{...........(2)}$$

$$D = \frac{1}{2} C_{q_1} (\dot{q}_1 - \dot{y})^2 + \frac{1}{2} C'_{q_2} (\dot{q}_2 r - \omega r)^2 \qquad \text{...........(3)}$$

Applying lagrange's equations:-

$$\frac{d}{dt} \left(\frac{\partial T}{\partial \dot{q}_j}\right) - \frac{\partial T}{\partial q_j} + \frac{\partial D}{\partial \dot{q}_j} + \frac{\partial V}{\partial q_j} = 0 \quad (j = 1,2) \qquad \text{...........(4)}$$

the equations of motion are:

$$m_{q_1} \ddot{q}_1 + C_{q_1} (\dot{q}_1 - \dot{y}) + K_{q_1} (q_1 - y) = 0 \qquad \text{...........(5)}$$

and

$$J_{q_2} \ddot{q}_2 + C_{q_2} (\dot{q}_2 - \omega) + K_{q_2} (q_2 - \omega t) + m_{q_1} \ddot{q}_1 \frac{dy}{dq_2} = 0 \qquad \text{.........(6)}$$

Introducing the parameter u as the deviation between the output and input motions

$$u = q_1 - y \qquad \text{...........(7)}$$

The equation (5) becomes

$$\ddot{u} + 2 \zeta_{q_1} \omega_{q_1} \dot{u} + \omega_{q_1}^2 u = - \ddot{y} \qquad \text{...........(8)}$$

Where $\omega_{q_1} = \sqrt{K_{q_1}/m_{q_1}}$ = the natural frequency of follower set in the uncoupled position and ζ_{q_1} is the damping factor of follower set.

The permit of arriving at an expression in dimensionless parameters, let us introduce a number of definitions: period of natural vibration of follower set:

$$T_{q_1} = 2\pi\sqrt{m_{q_1}/K_{q_1}} \qquad \text{............(9)}$$

period of natural vibration of cam set:

$$T_{q_2} = 2\pi\sqrt{m_{q_2}/K_{q_2}} \qquad \text{..........(10)}$$

The time ratio of the follower set:

$$\tau_{q_1} = T_1/T_{q_1} = T_1/2\pi\sqrt{K_{q_1}/m_{q_1}} \qquad \text{..........(11)}$$

The time ratio of the cam set:-

$$\tau_{q_2} = T_1/T_{q_2} = T_1/2\pi\sqrt{K_{q_2}/m_{q_2}} \qquad \text{..........(12)}$$

Where T_1 is the cam rise time.

Mean slope of pressure angle during cam rise Fig. (3)

$$\tan \alpha_{me} = h/r_c B \qquad \text{..........(13)}$$

Where h : stroke at cam, r_c constant pitch radius and
B : cam angle of rotation for maximum follower rise [7] .

Inertia ratio

$$F_m = m_{q_1}/m''_{q_{2\,me}} = (m_{q_1}/m'_{q_2}) \tan^2 \alpha_{me} = m_{q_1}/J_{q_2}(h/B)^2 \qquad \text{..........(14)}$$

Stiffness ratio

$$F_k = K_{q_1}/K''_{q_{2\,me}} = (K_{q_1}/K'_{q_2}) \tan^2 \alpha_{me} = K_{q_1}/K_{q_2}(h/B)^2 \qquad \text{..........(15)}$$

Therefore

$$\tau_{q_1} = \tau_{q_2}\sqrt{F_k/F_m} \qquad \text{..........(16)}$$

Damping ratio:

$$F_d = C_{q_1}/C''_{q_{2\,me}} = (C_{q_1}/C'_{q_2}) \tan^2 \alpha_{me} = C_{q_1}/C_{q_2}(h/B)^2 \qquad \text{......(17)}$$

Therefore

$$F_d = \zeta_{q_1}/\zeta_{q_2}/\sqrt{F_k F_m} \qquad \text{..........(18)}$$

Where

$$C_{q_1} = 2\,\zeta_{q_1}/\sqrt{m_{q_1} K_{q_1}}\ ;\ C_{q_2} = 2\,\zeta_{q_2}\,/\sqrt{m_{q_2} K_{q_2}} \qquad \text{..........(19)}$$

Introducing the following dimensionless parameters

$$Y = y/h;\ q_1 = q_1/h\ ,\ q_2 = q_2/B\ ,\ U = u/h\ ,\ T = t/T_1,\ Y' = T_1\dot{y}/h$$

$$,\ Y'' = T_1^2\ddot{y}/h\ ,\ q_1'' = T_1^2\,\ddot{q}_1/h\ ,\ U'' = T_1^2\,\ddot{u}/h$$

Equation (8) can be recast as

$$U'' + (4\pi\tau_{q_1}\zeta_{q_1})\,U' + (2\pi\tau_{q_1})^2\ \ U = -\,Y'' \qquad \text{..........(20)}$$

In the case of cycloidal cam curve [7] as shown in Fig. (4) we have

$$Y'' = 2\pi\sin\ 2\pi T \qquad 0\leqslant T\leqslant 1 \qquad \text{(rise period)}$$

$$Y'' = 0 \quad 1\leqslant T\leqslant 1 + T_2/T_1 \text{(dwell period)} \qquad \text{......(21)}$$

Where T_2 is the time of dwell period.

Therefore the equation (20) can be recast as

$$U'' + (4\pi\tau_{q_2}\ F_d\ \zeta_{q_2}/F_m)\ U' + (2\pi\tau_{q_2}/\sqrt{F_k/F_m}\ )^2\ \ U = -\,Y'' \text{.......(22)}$$

4 - METHOD OF SOLUTION

a. Solution Within The Rise Period

In the rise period the nonhemogenuous Eq. (22) is solved numerically by using the Runge-Kutta method (taking $\Delta T = 0.01$), since this method may be most reliable one for dealing with various types of cams [8].

The numerical results for various values of the nondimensional parameters F_m, F_k and F_d are shown in Figures, (6-23) and also in Tables (I ....III) (See Appendix).

b. Solution Within Dwell Period

In this period the hemogenuous Eq. (22) can be solved exactly, and the solution is given by:

$$U_2 = e^{-AT}\left[U_1 \cos(BT) + C/B \sin(BT)\right] \quad \ldots\ldots\ldots\ldots(23)$$

$$\grave{U}_2 = e^{-AT}\left[-(U_1 B + AC/B) \sin(BT) + (C - AU_1)\cos(BT)\right] \quad \ldots\ldots(24)$$

and

$$\grave{\grave{U}}_2 = e^{-AT}\left[-(BC - 2\, U_1 AB - A^2 C/B) \sin(BT) - (2\, AC - A^2 U_1 + U_1 B^2)\cos(BT)\right] \quad \ldots\ldots\ldots\ldots(25)$$

Where,

$$A = 2\pi \tau_{q_2} \xi_{q_2} F_d/F_m$$

$$B = 2\pi \tau_{q_2} \sqrt{F_k/F_m}\, (1 - \xi_{q_2} F_d / \sqrt{F_k F_m})^{\frac{1}{2}}$$

$$C = \grave{U}_1 + U_1 A$$

and

U_1, $\grave{U}_1$ are final conditions at the end of rise period. The numerical results for various values of nondimensional parameters F_m, F_k and F_d are shown in Figure (6-23) and also in Tables (I..III) (See Appendix).

5. DISCUSSION

In studying the sample curves of the positional and accelerational errors in primary and residual regions, for the two degrees of freedom simulated model of cam mechanisms, several characteristics have been observed.

1. Effect of Inertia Ratio F_m:

With regard to the primary postional error (U_1), the effect of τ_{q_2} on U_1, for different values of F_m is represented in Fig.(6,7). The increasing of τ_{q_2} caused a considerable decrease in the value U_1. This is expected, for a low speed (ω) a low mass of cam set, and a high torsional rigidity of the cam set. For the same F_m, the rate of decrease of U_1 is relatively high for values of $1 \leqslant \tau_{q_2} \leqslant 5$.

It can be noted also that the increase of the mass ratio causes an increase of the positional error U_1. This is expected for a light weight of cam set and heavy weight of follower set. For small values of the mass ratio ($F_m \leqslant 1$); the values of U_1 are sensitive to the variations of ζ_{q_2} and F_m.

With regard to the primary accelerational error ($\ddot{U}_1$), the effect of ζ_{q_2} on $\ddot{U}_1$ for various values of F_m is represented in Fig. (8). For small values of ($F_m < 1$) the increase of ζ_{q_2} is followed by a decreasing of $\ddot{U}_1$. It can be seen also that the increase of the mass ratio causes an increase of $\ddot{U}_1$. For large values of F_m, it is noticed that the increase of ζ_{q_2} causes higher accelerational error, whatever the values of damping ratios.

With the regard to the residual postional error U_2, it shown in Fig. (9) that the increase of the mass ratio F_m is followed by an increasing of the residual positional error (U_2). Also it can be seen that the increasing of ζ_{q_2} causes a decrease of U_2 for ($F_m < 1$) and an increase high values of mass ratio increasing (ζ_{q_2}) causes increase U_2.

With the regard to the residual accelerational error $\ddot{U}_2$, as shown in Fig. (10) generally increasing F_m is followed by increasing of the $\ddot{U}_2$. It can be seen also the increase of ζ_{q_1} is followed by decreasing of the $\ddot{U}_2$ for ($F_m < 1$). For larger values of the mass ratio, it seen that the $\ddot{U}_2$ is propotional with ζ_{q_2}. This expected for heavy weight of follower set and light weight of cam set.

II. <u>Effect of Flexibility Ratio (F_k):</u>

With the regard to the primary positional error (U_1), the curves of U_1 against ζ_{q_2} for various values of stiffness ratio F_k are plotted in Fig. (11). Noting that the increase of F_k is followed by a decreasing of positional error U_1.

With the regard to the primary accelerational error ($\ddot{U}_1$), it can be noticed from Fig. (12) that the increase of F_k may be caused a decreasing in the values of $\ddot{U}_1$.

With the regard to the residual positional error (U_2), the effect of F_k on U_2 is represented in Figure (13). It can be seen that the residual positional error (U_2) is influenced by the variation of the stiffness ratio F_k.

With the regard to the residual accelerational error ($\ddot{U}_2$), the effect of the stiffness ratio F_k on the $\ddot{U}_2$ is presented in Fig. (14). It can be noticed that the increasing of the F_k decreases the values of $\ddot{U}_2$ for relative large value of τ_{q_2}.

III. Effect of Damping Ratio (F_d):

With the regard to the primary positional error U_1, the effect of F_d on U_1 is represented in figures (15, 16). It can be seen, that the influences of F_d on U_1 are considerably small particularly at τ_{q_2} equal unity, whilst the influence F_d on the value U_1 is significant for $\tau_{q_2} > 1$. It can be noted that the inertia effect on the U_1 is very significant in particularly for large F_m, whatever the values of damping ratio F_d Fig. (17).

With the regard to the primary accelerational error $\ddot{U}_1$, it can be noticed from Fig. (18) that the increase of F_d may be decreased the value of $\ddot{U}_1$ particularly for the higher values of τ_{q_2}. For the heavy follower set it is noticed that the effect of damping ratio F_d is considerably small Fig. (19).

With the regard to the residual positional error U_2, the effect of F_d on U_2 is represented in Fig. (20). It can be seen that the increase of F_d causes a decreasing in U_2 within the region of intermediate values of τ_{q_2}. For high values of F_m the effect of damping ratio F_d on U_2 is considerably small as shown in Fig.(21), while the effect of F_d is considerably small at $\tau_{q_2} = 1$.

With the regard to the residual accelerational error $\ddot{U}_2$: Figure (22) indicated the relationship $\ddot{U}_2$ and τ_{q_2} for various values of F_d. It can be seen that the increasing of F_d cause a decreasing of $\ddot{U}_2$. Noting that, the effect of F_d may be ignored for high values of mass ratio as shown in Fig. (23).

CONCLUSION

It is evident that the nondimensional parameters, of inertia, of flexibility and of damping have significant effects in the dynamic behavior of the cam mechanisms. In the analysis of primary and residual nondimensional errors of output motion of the two degree of f eedom simulated cam mechanism, one deduces from the computed results, the following conclusions:

1. The inertia ratio, is kept smaller as possible to minimize the harmful inertia effect of the follower on the response.
2. As the mass moment of inertia of the cam set, decreases and as the torsional rigidity of the cam set increases, the deviation errors decrease.
3. In order to minimize the errors, the flexibility ratio is kept sufficiently large by the use of more rigid componants of the follower linkage.
4. The assumption that no damping of the simulated cam mechanism exists, has a significant effect on the functional requirements particularly for the small mass ratio.
5. The nonbenefical changes in the basic parameters may lead to unfavourable effects in the functional requirements of the cam mechanisms such as for example, when the mass ratio becomes larger than unity the values of most errors were found to be proportional with the time ratio of the cam set.
6. The model of the cam mechanism as two degree of freedom system provides sufficiently accurate result for studying the dynamic behavior (the positional and accelerational errors) of a cam mechanism rather than the models given in references (1,2,3,4,5) as indicated in Figures (24).

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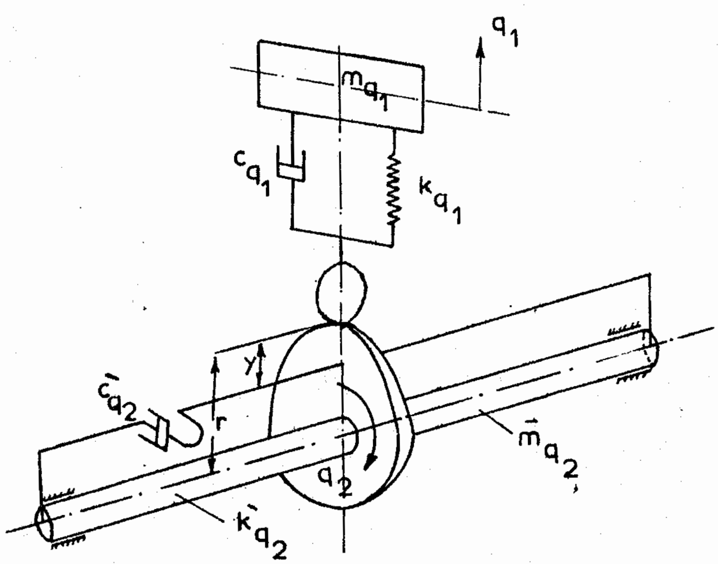


Fig (1) Diagram of 2 DF Cam mechanism

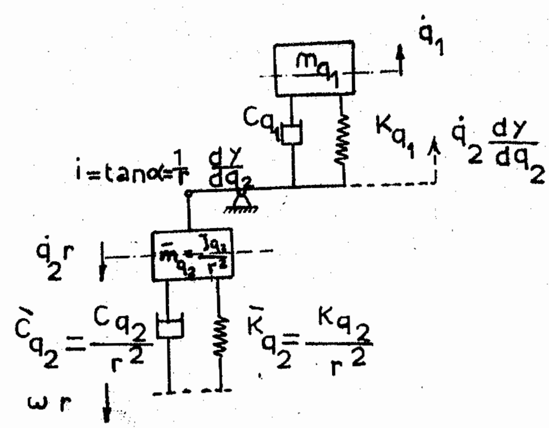


Fig (2) Dynamic model of 2 DF System

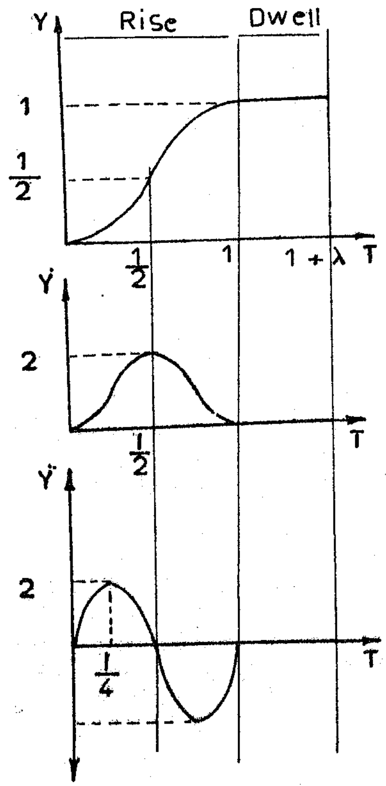


Fig (4) Nondimensional diagram of a cycloidal Cam .

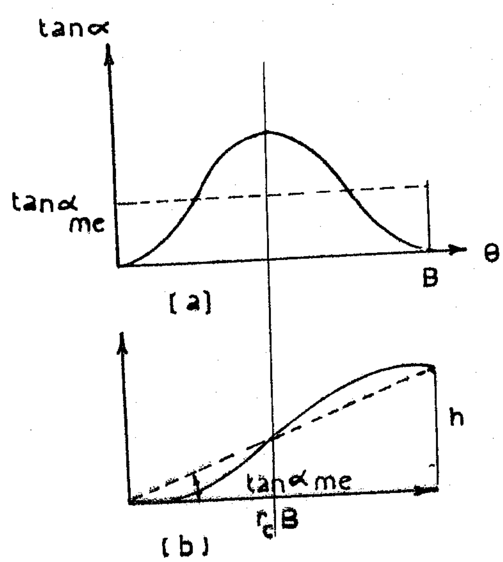


Fig (3)

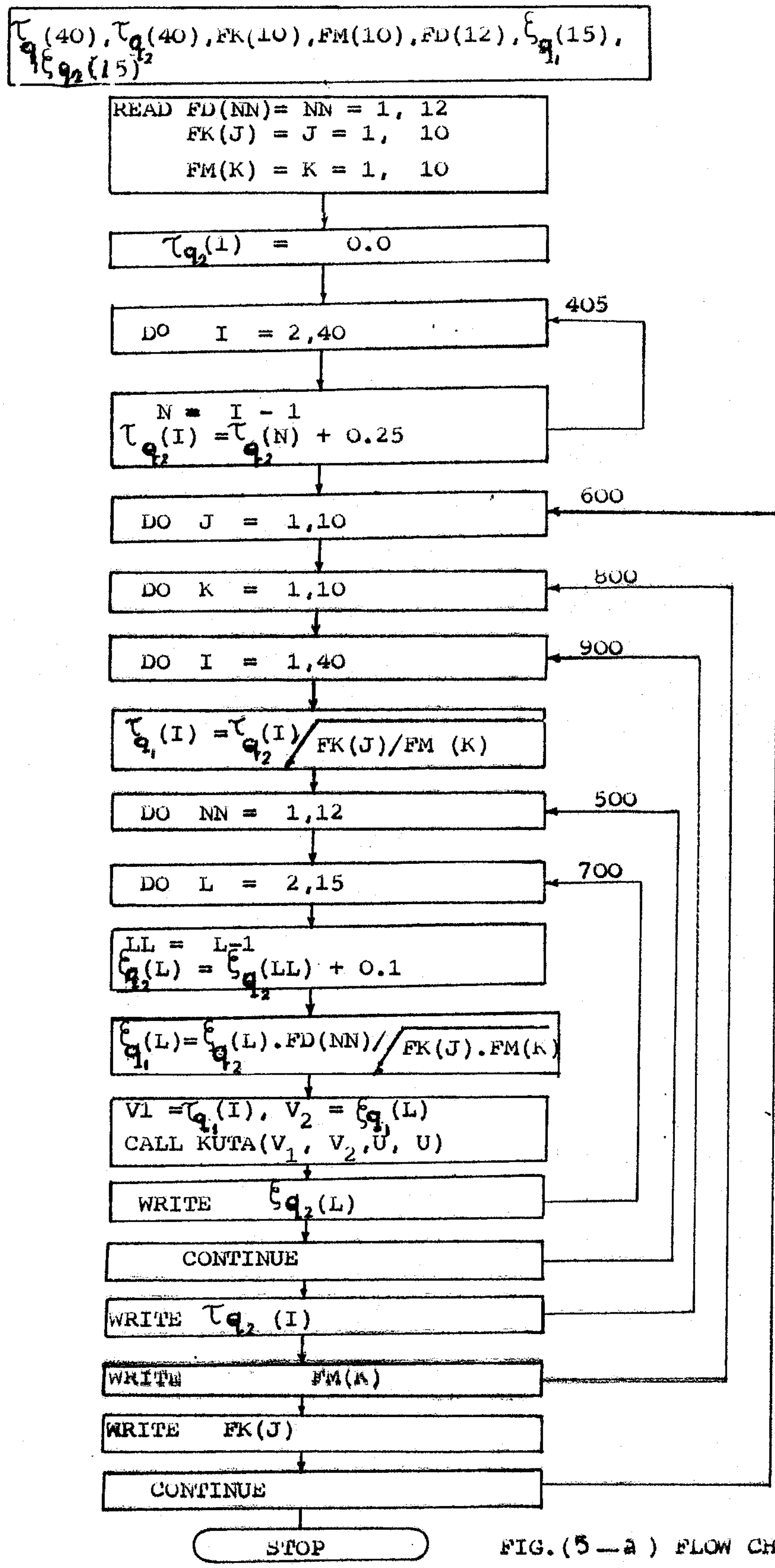


FIG. (5 — a) FLOW CHART

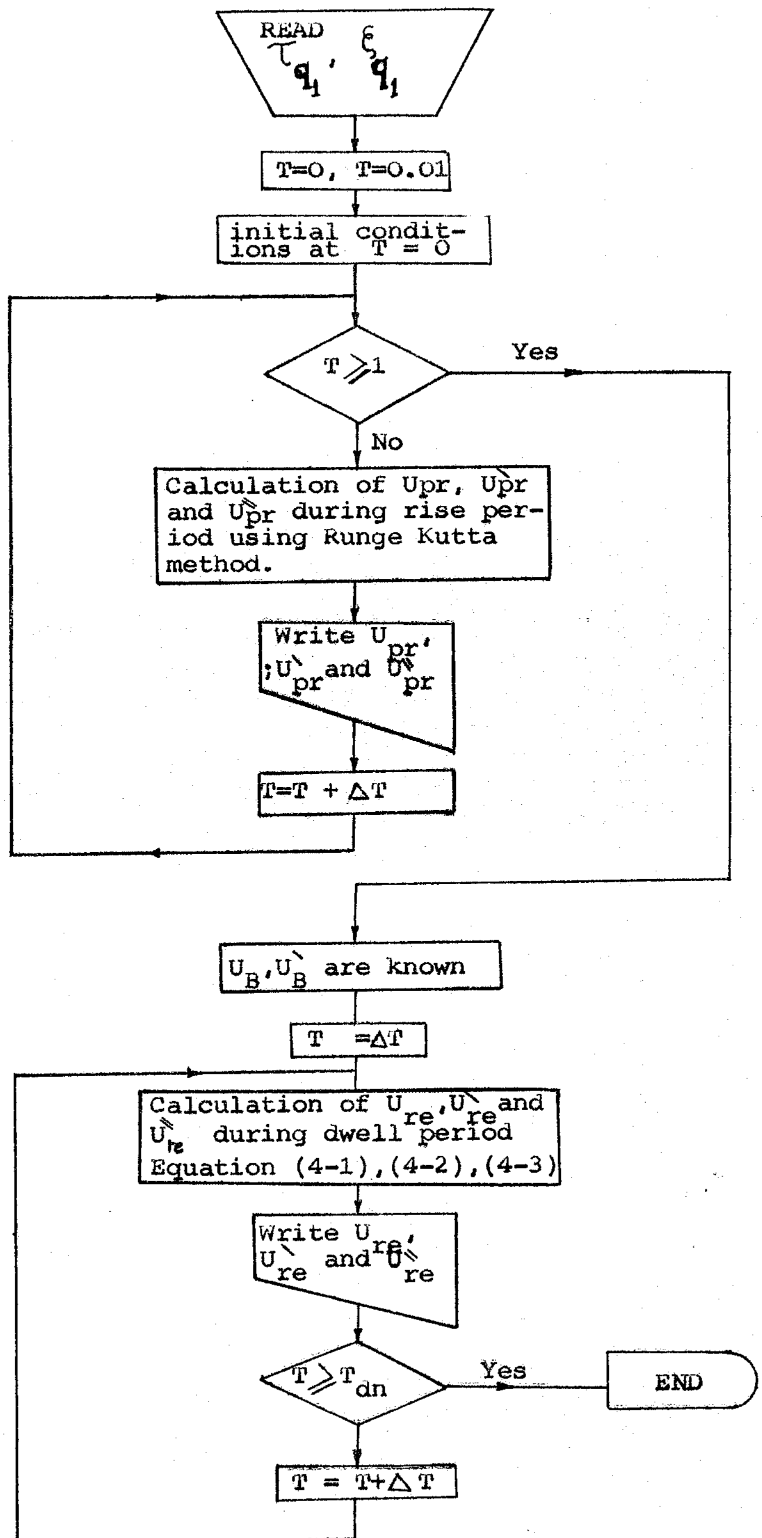
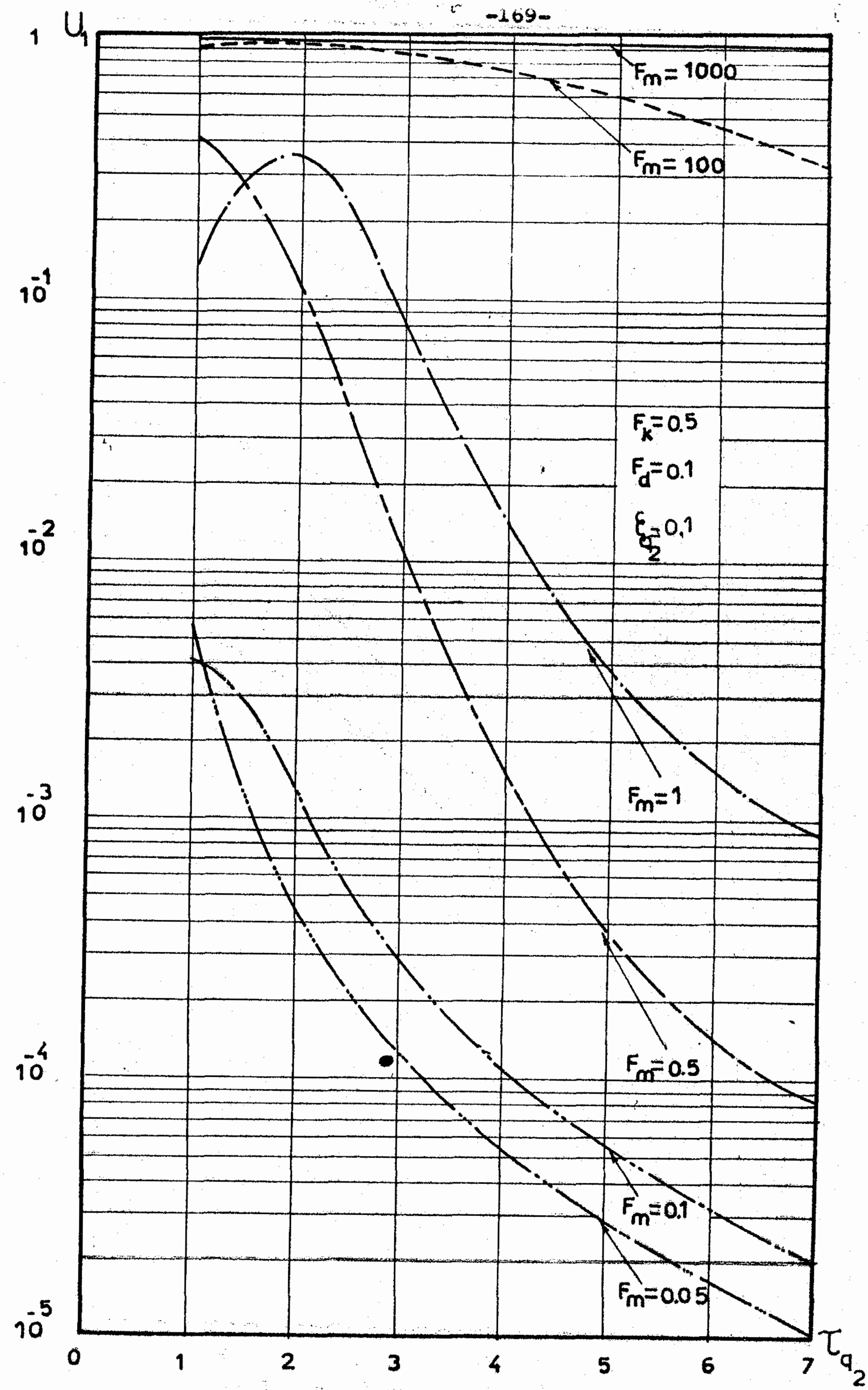
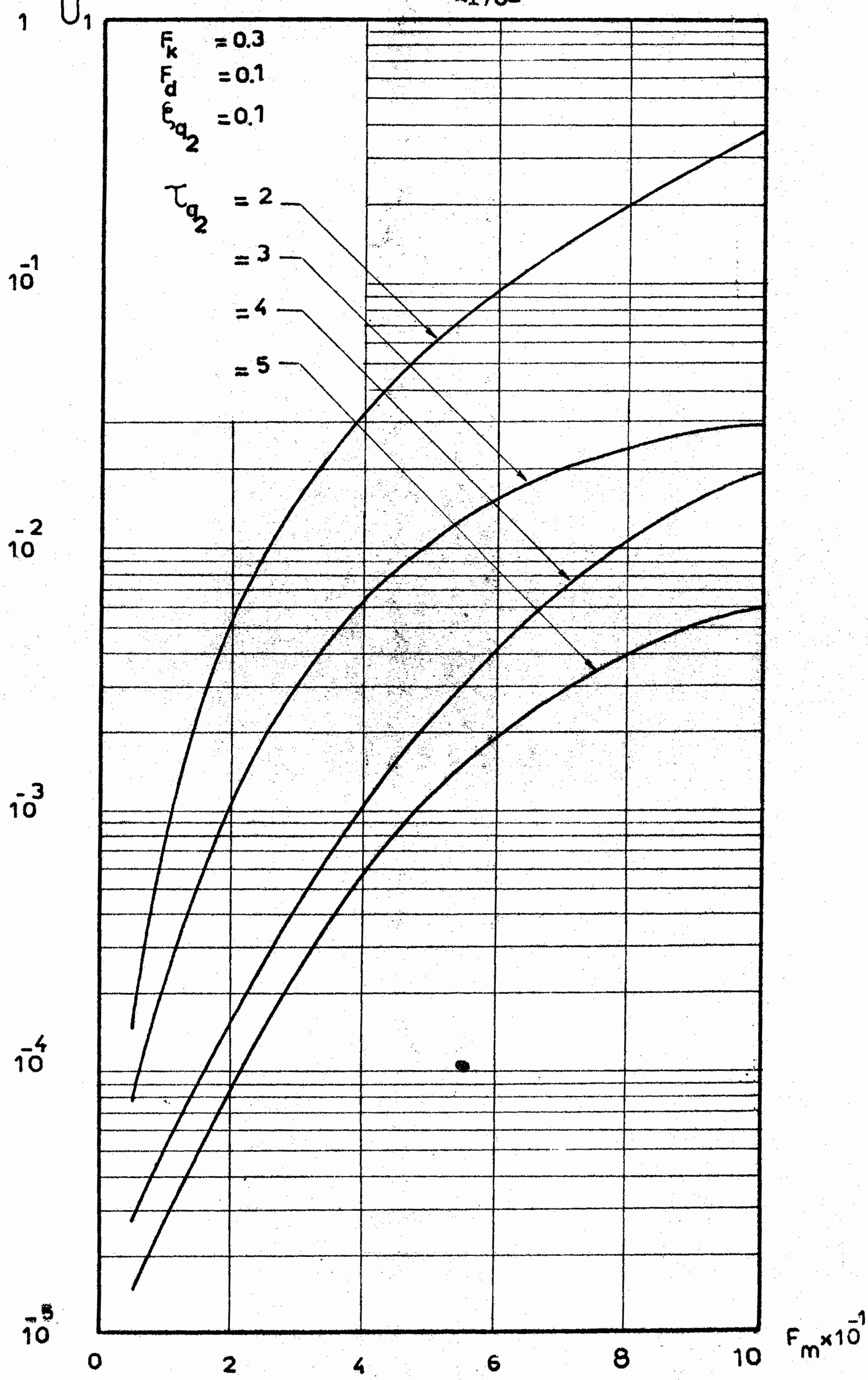


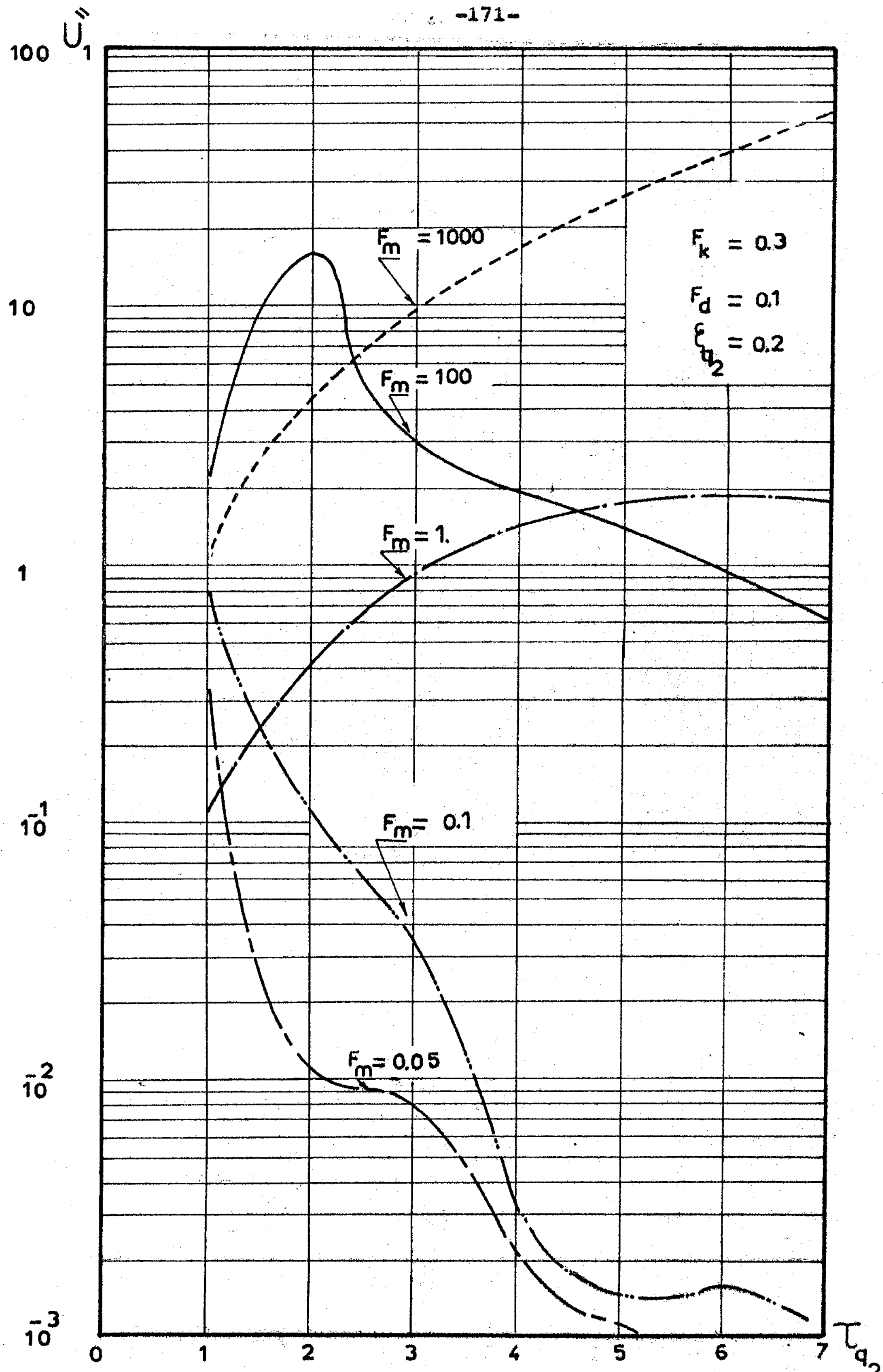
Fig.(5—b) SUBROUTINE KUTA



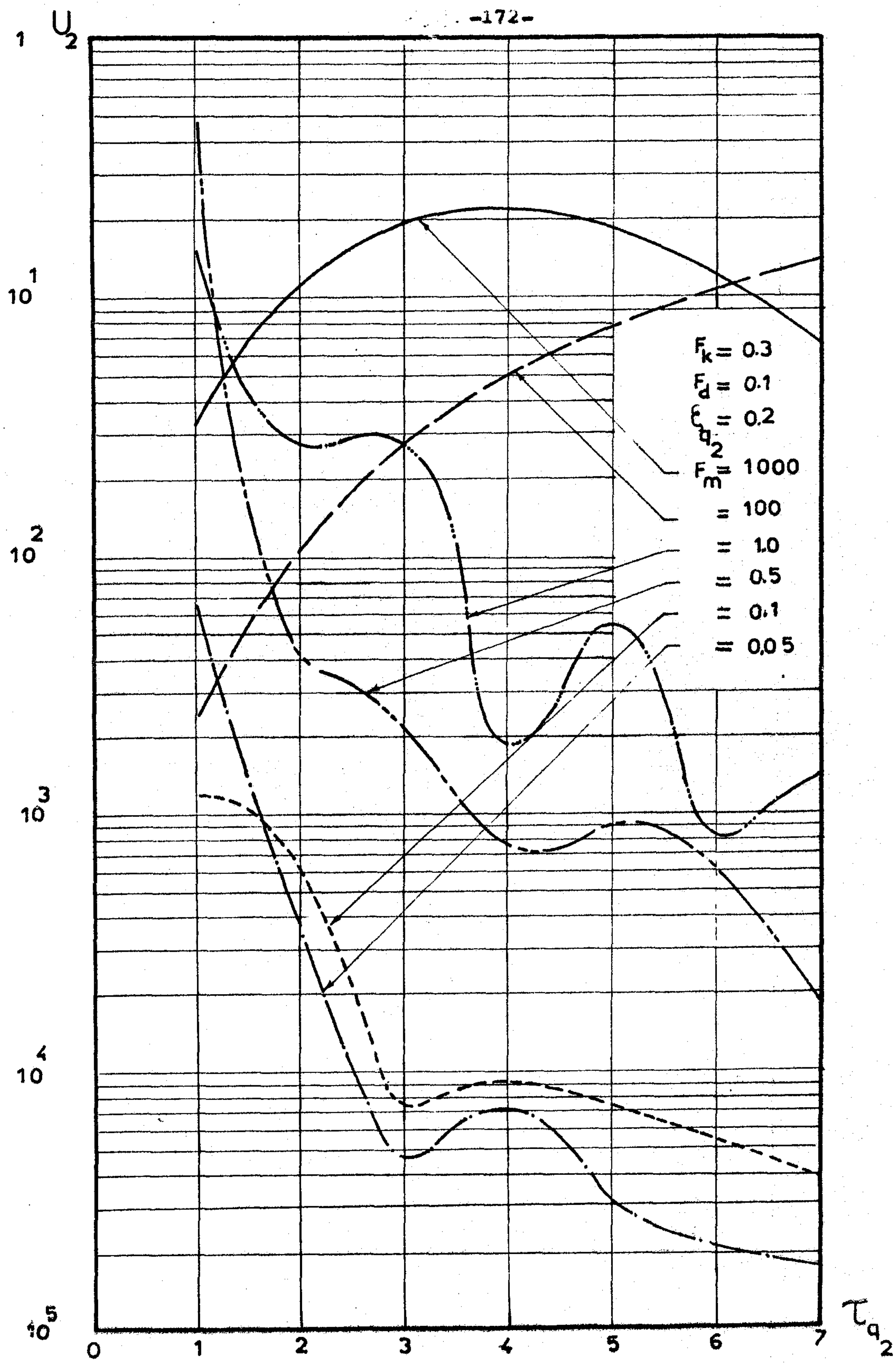
Fig(6) Primary positional Error



Fig(7) Primary positional Error



Fig(8) Primary Accelerational Error



Fig(9) Residual Positional Error

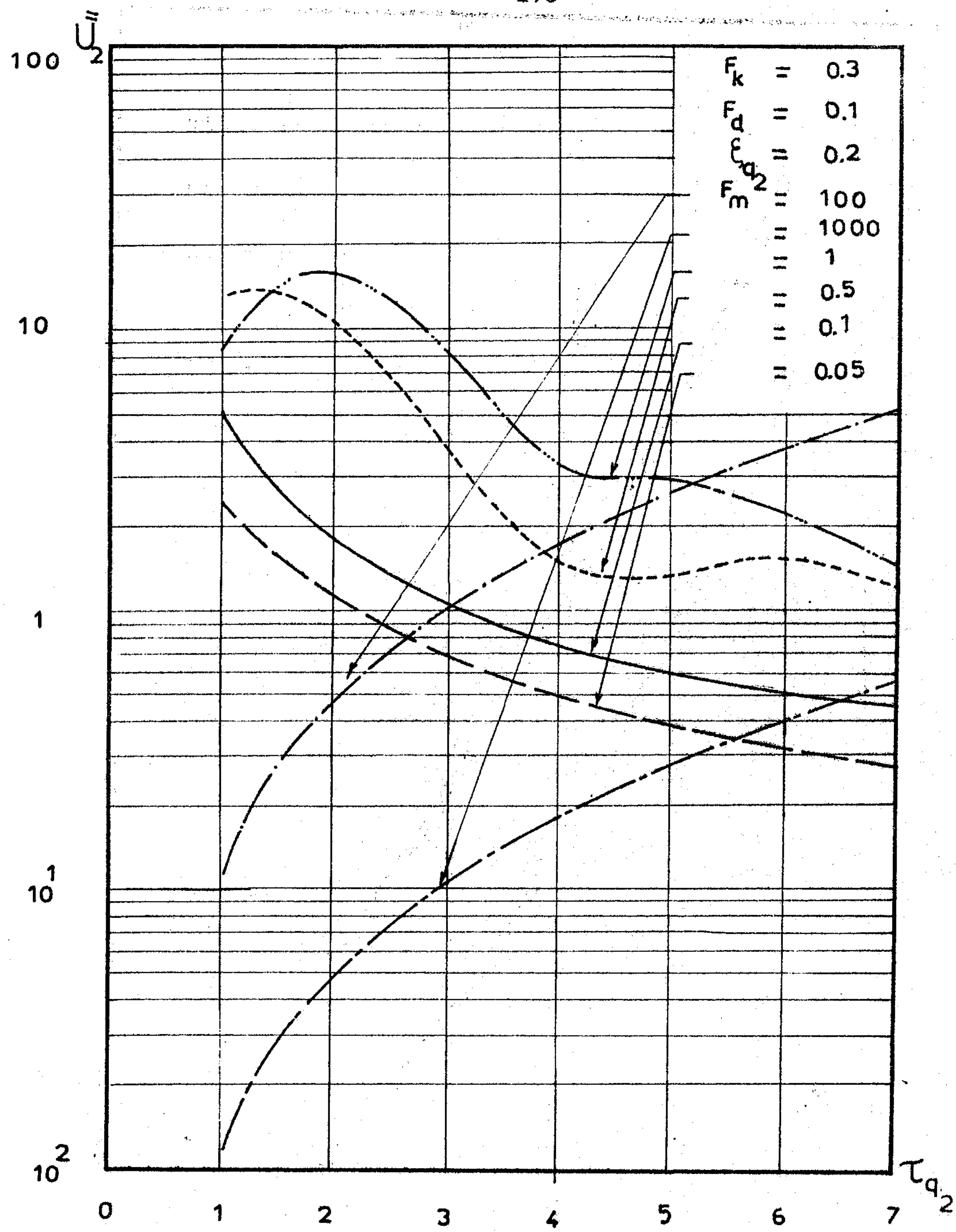
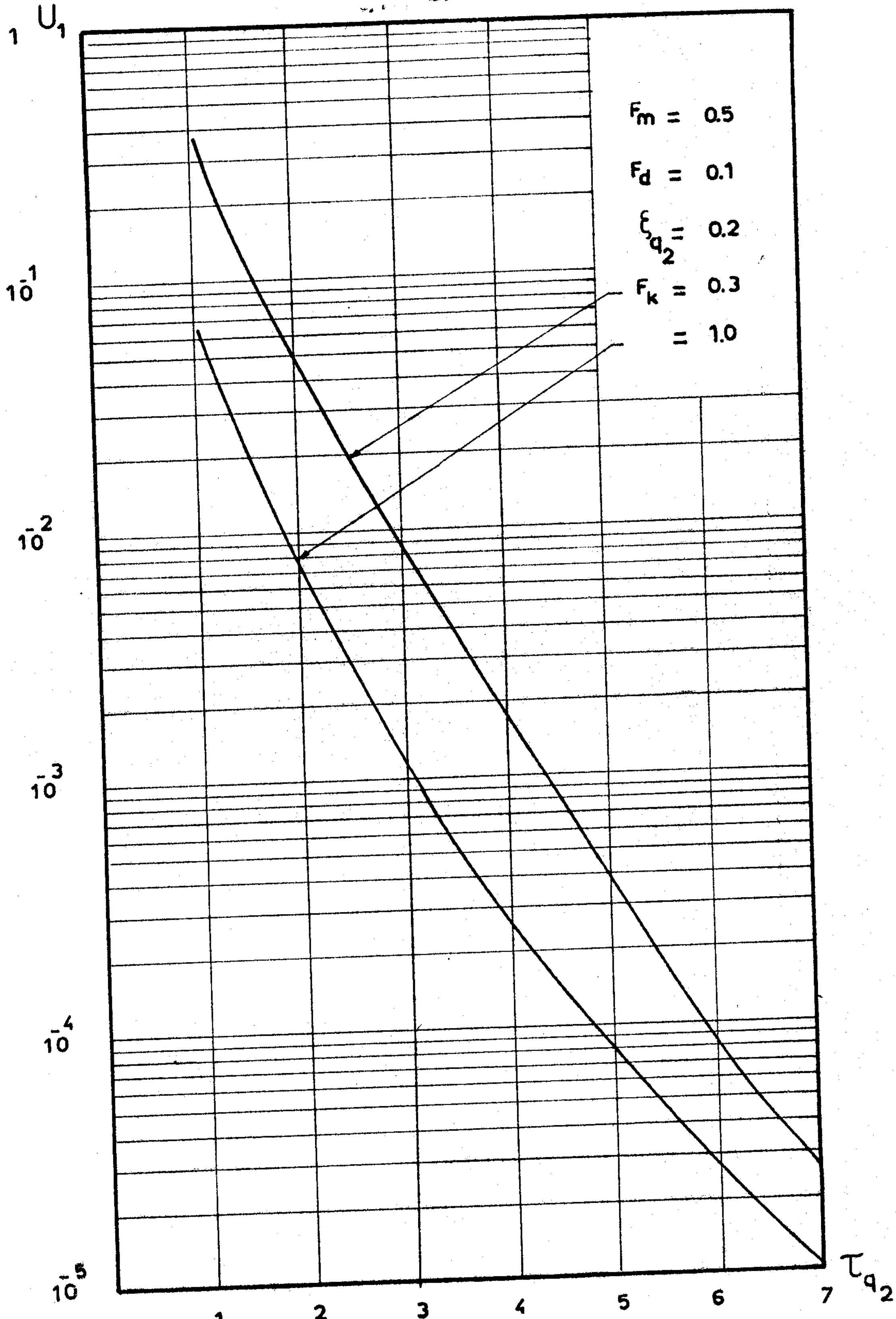
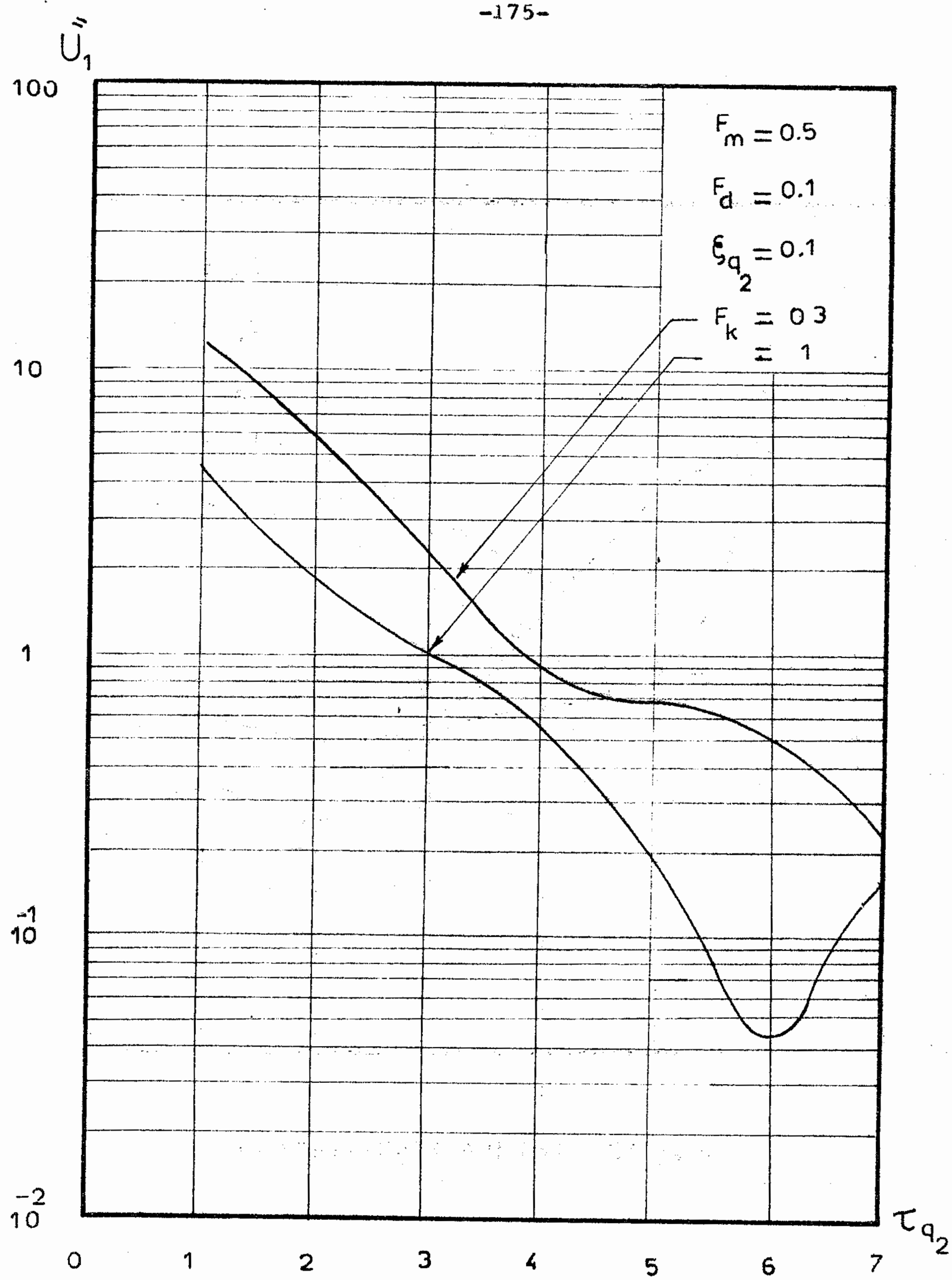


Fig (10) Residual Accelerational Error



Fig(11) Primary Positional Error



Fig(12) Primary Accelerational Error

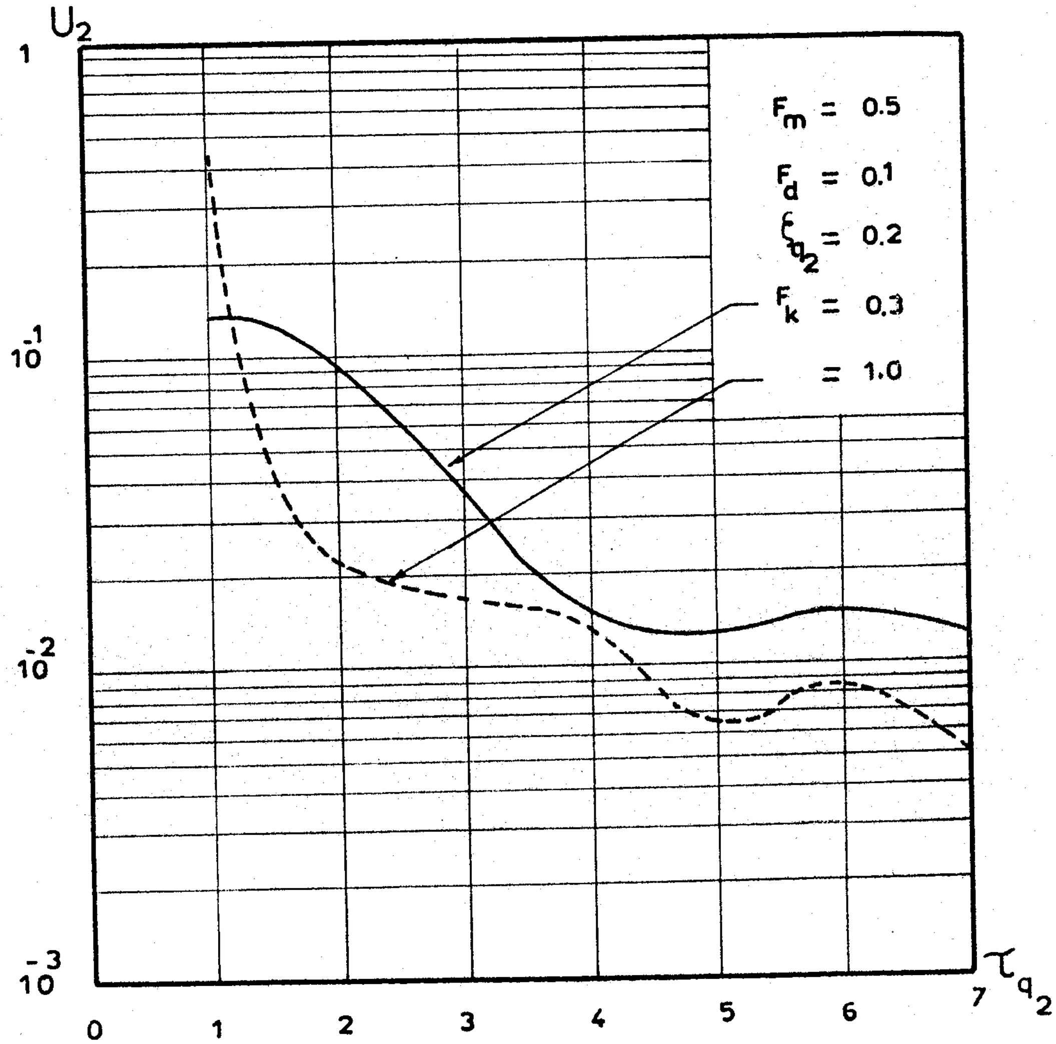


Fig (13) Residual Positional Error

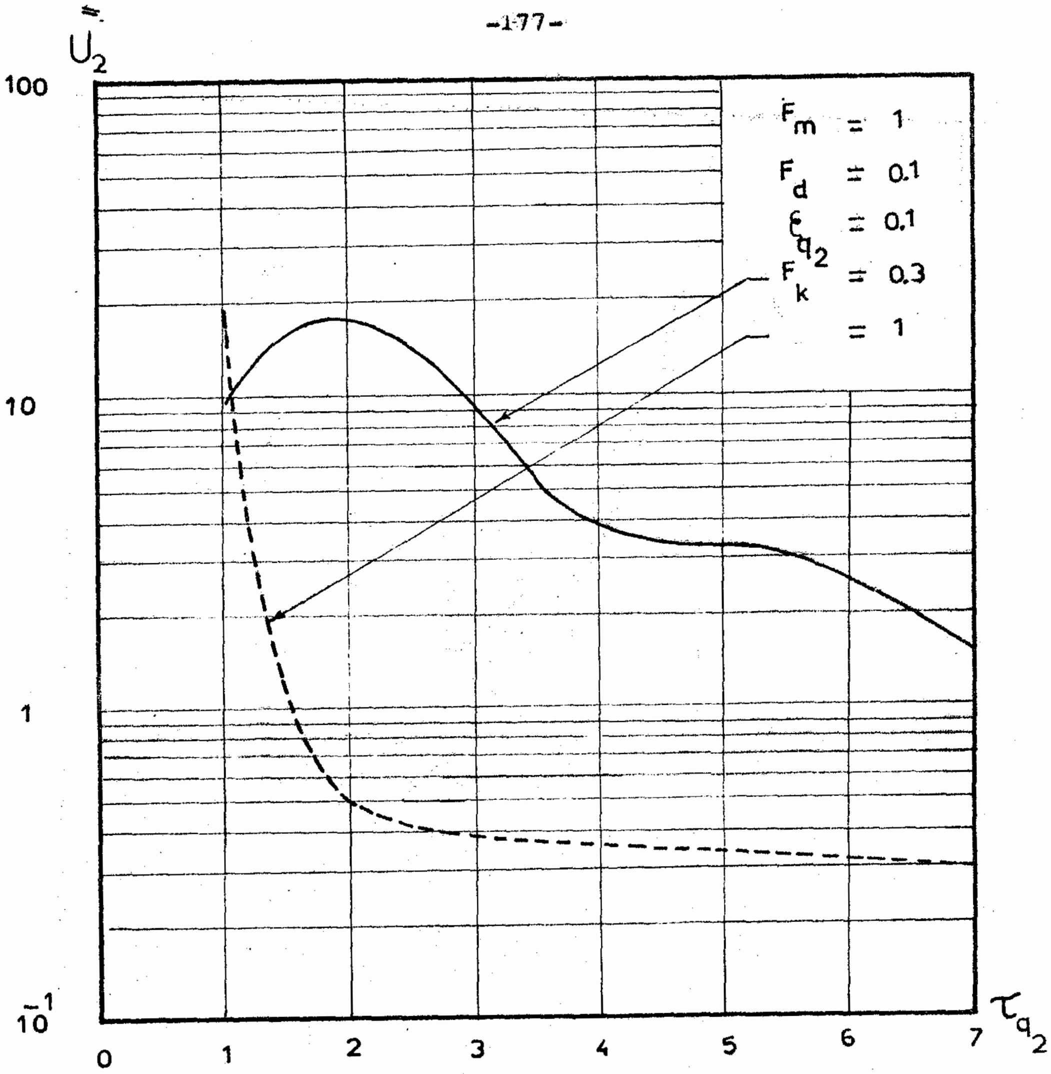
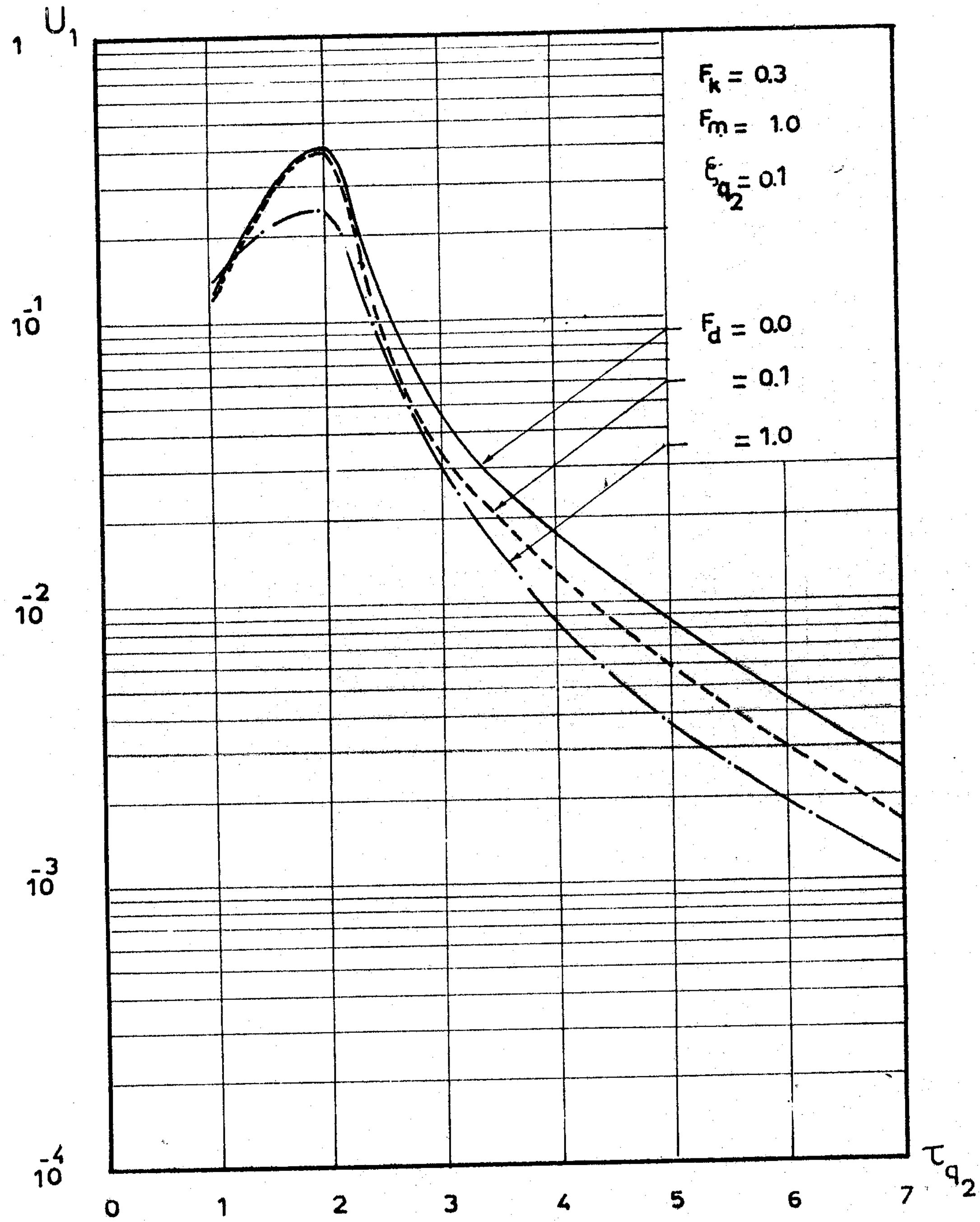
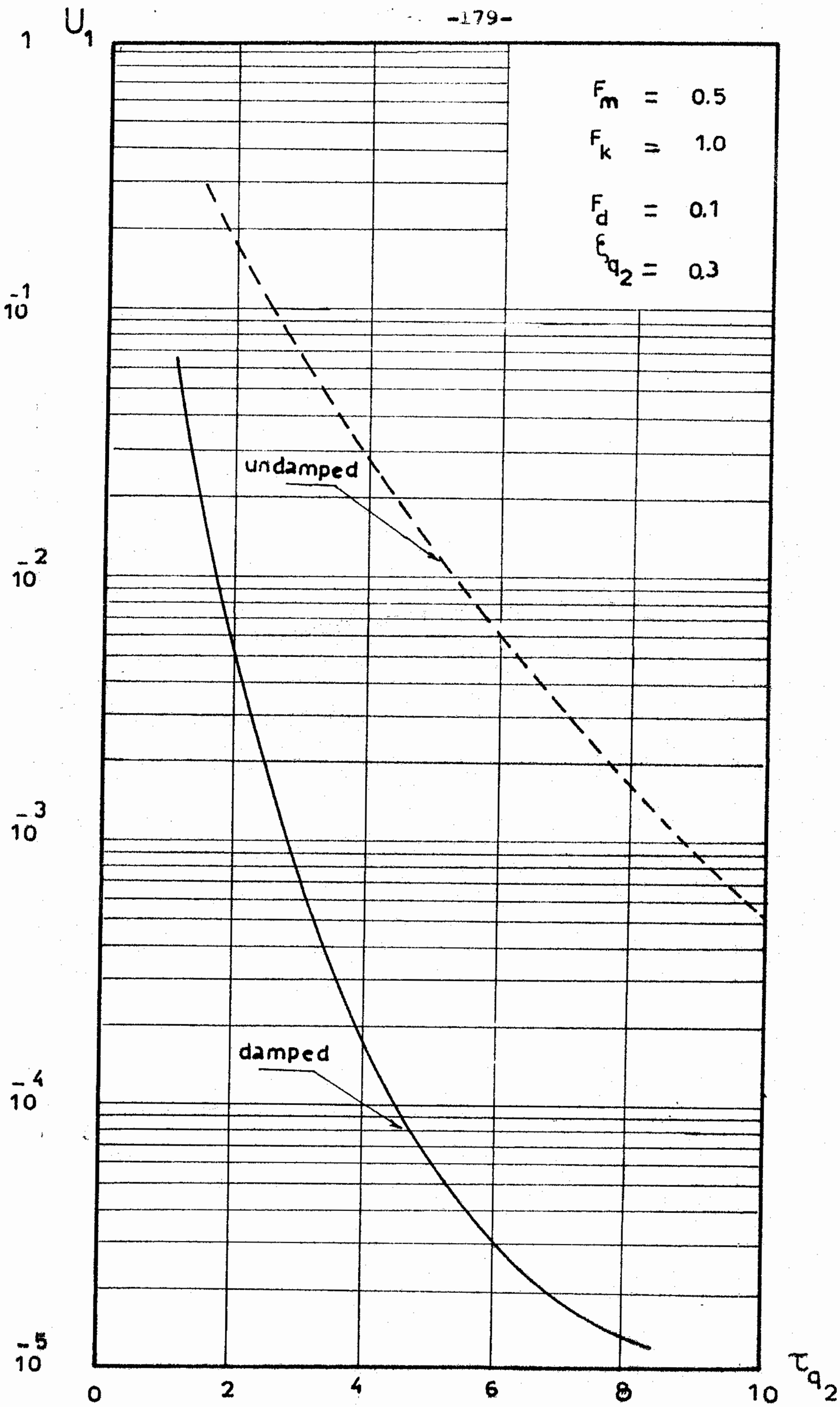


Fig (14) Residual Accelerational Error



Fig(15) Primary Positional Error



Fig(16) Primary Positional Error

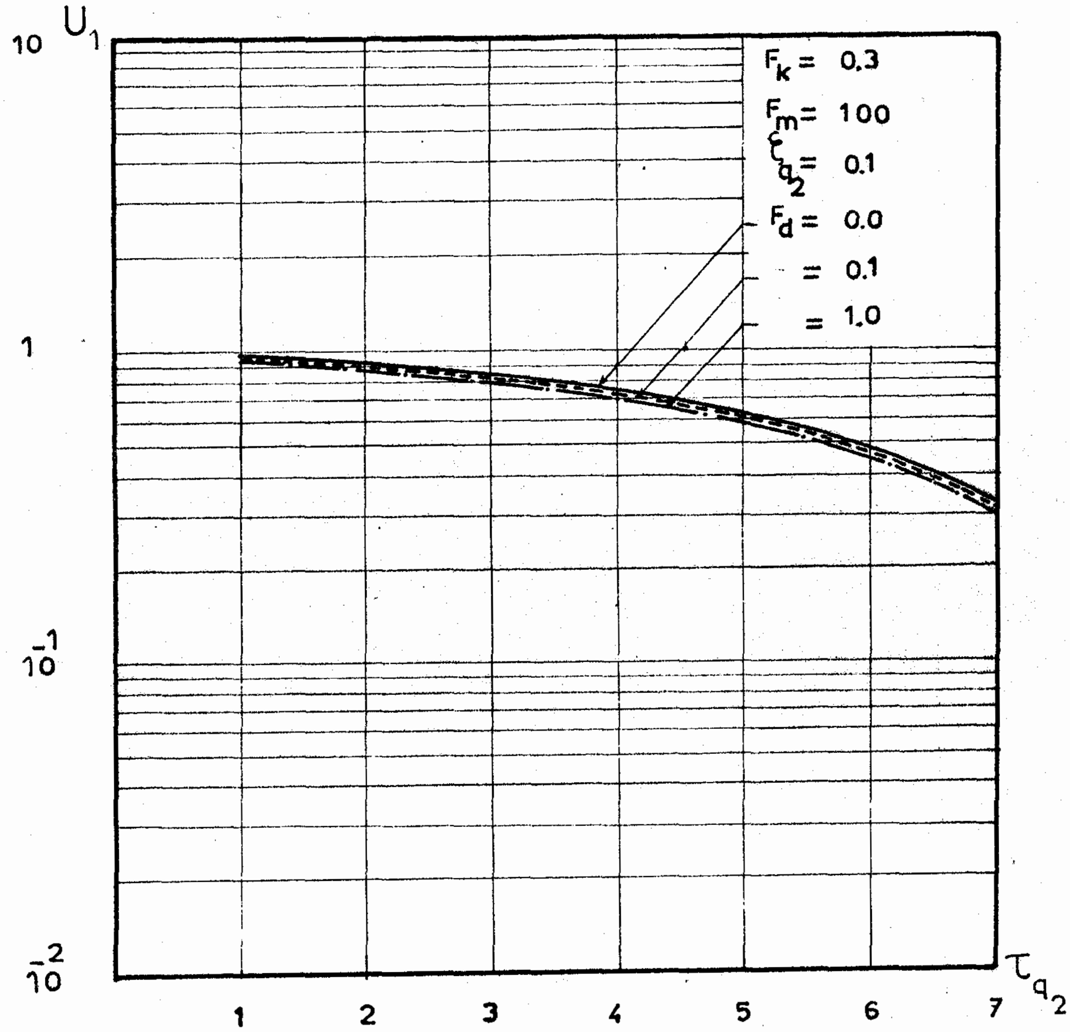
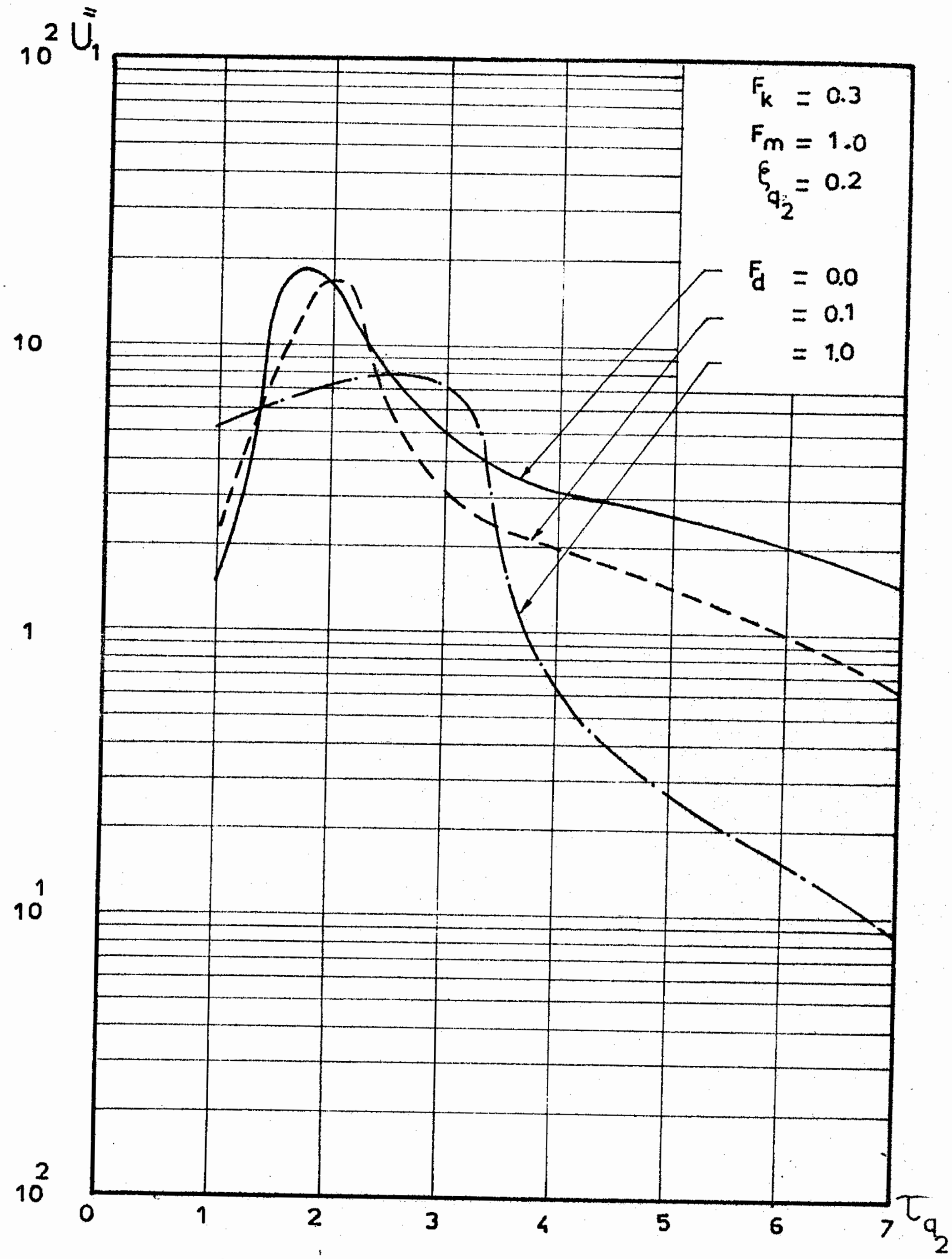
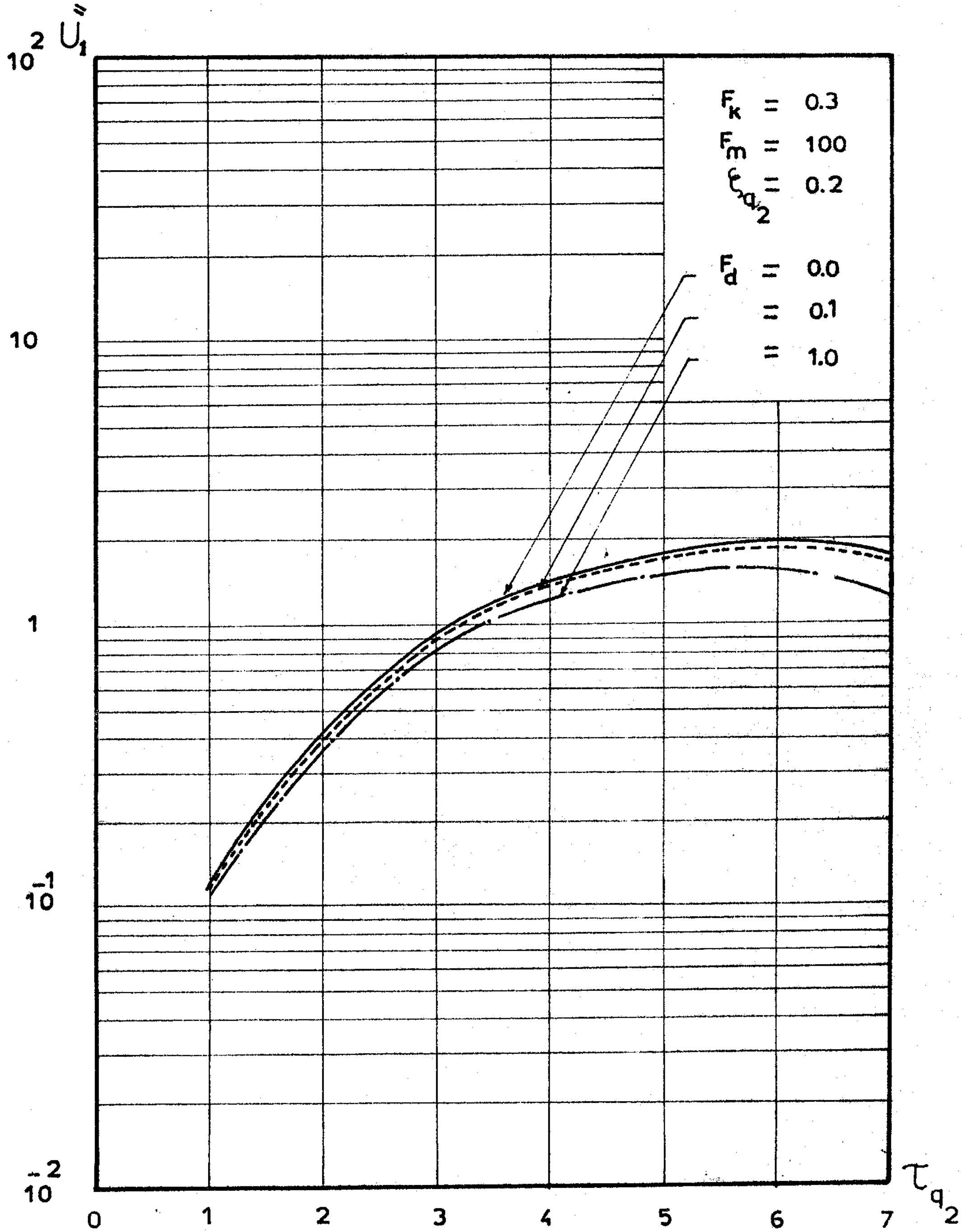


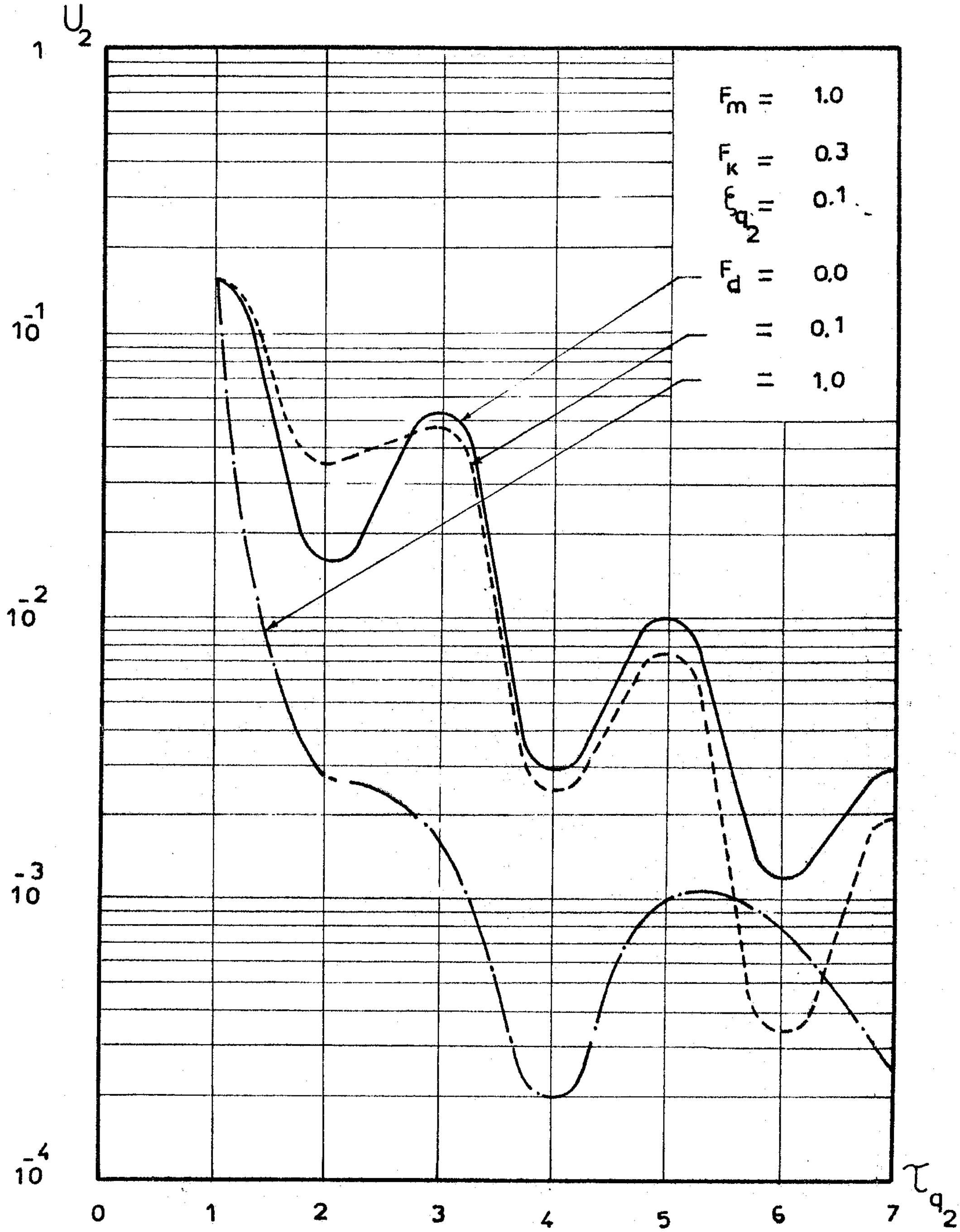
Fig (17) Primary Positional Error



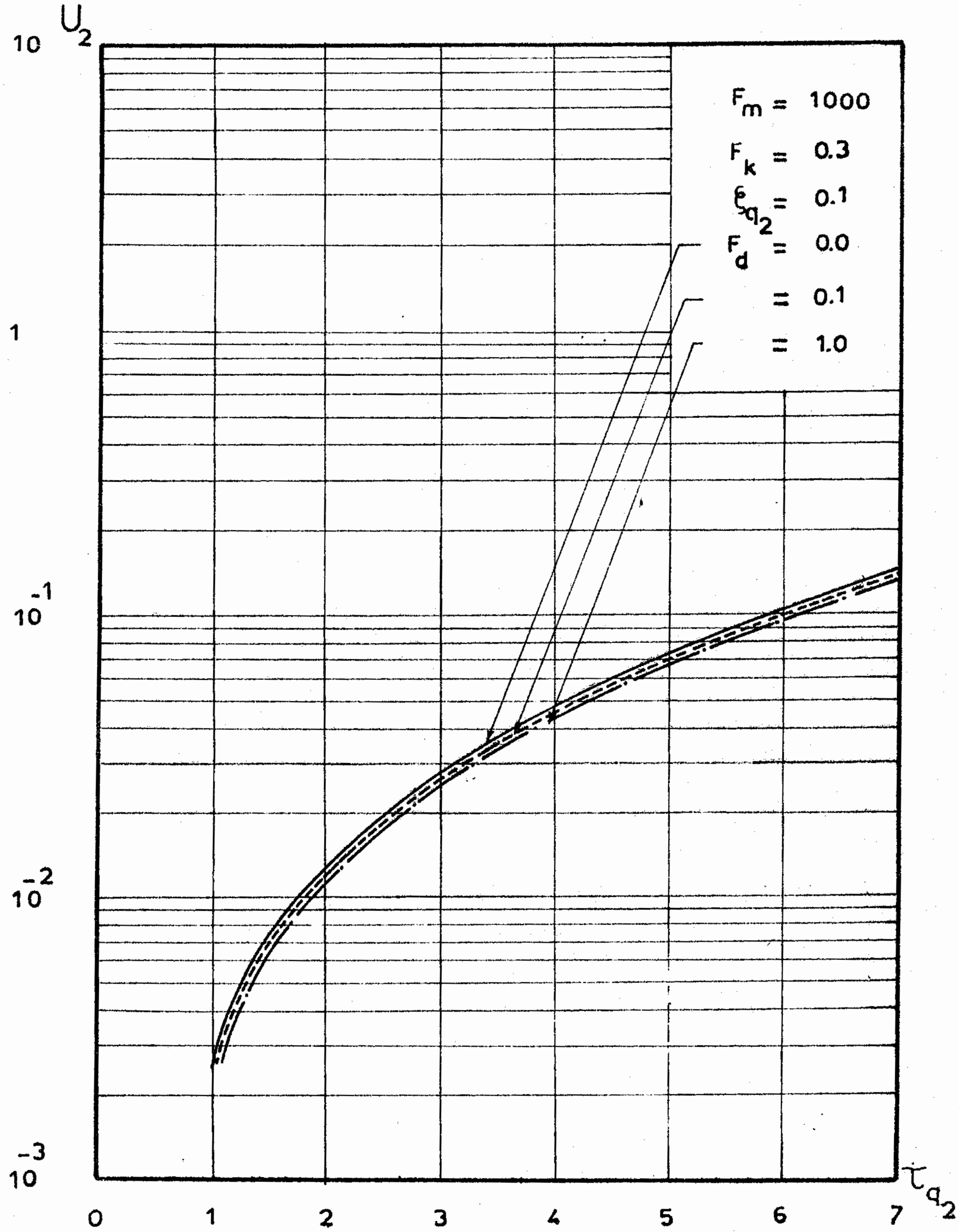
Fig(18) Primary Accelerational Error



Fig(19) Primary Accelerational Error



Fig(20) Residual Positional Error



Fig(21) Residual Positional Error

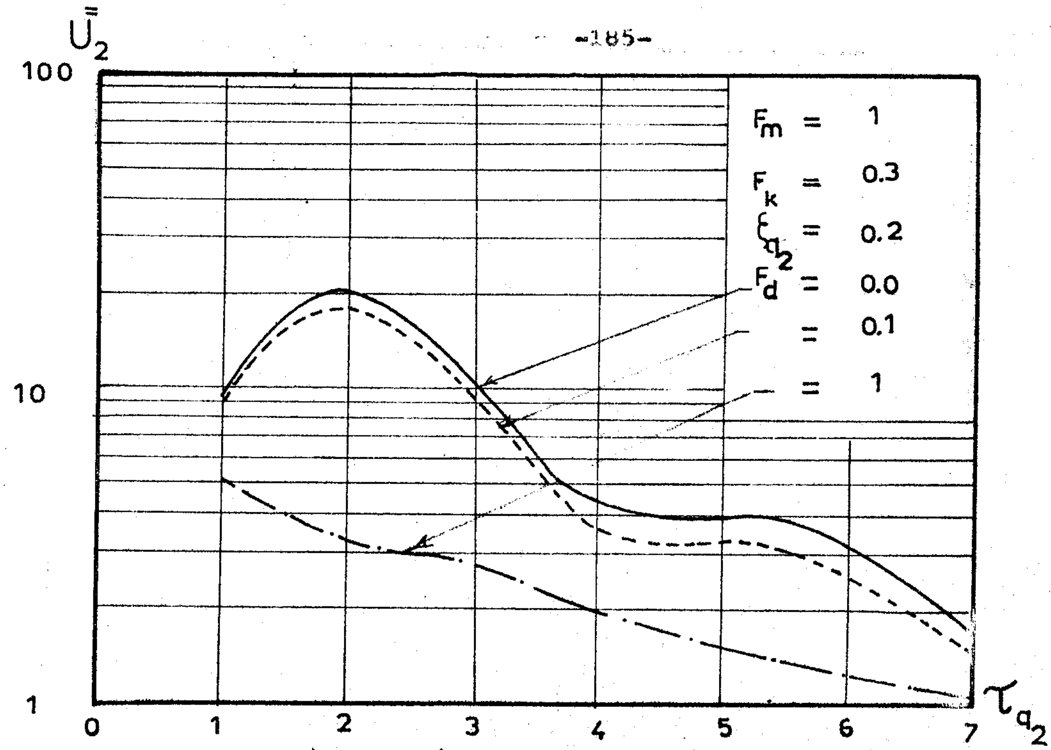


Fig (22) Residual Accelerational Error

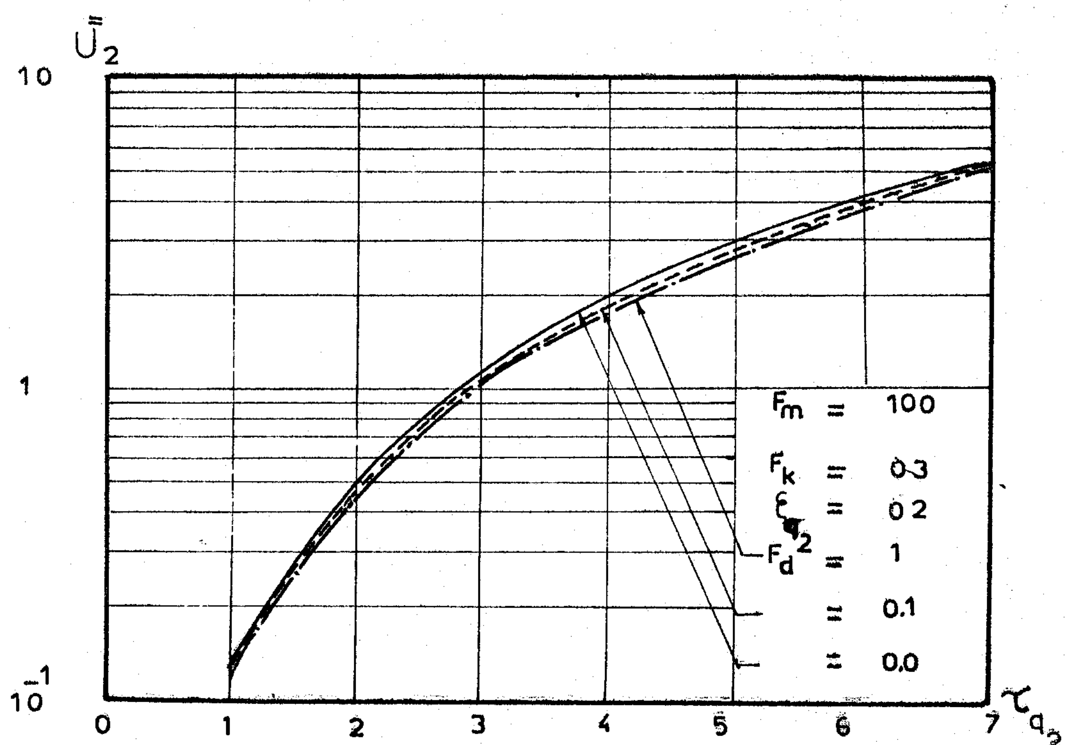


Fig (23) Residual Accelerational Error

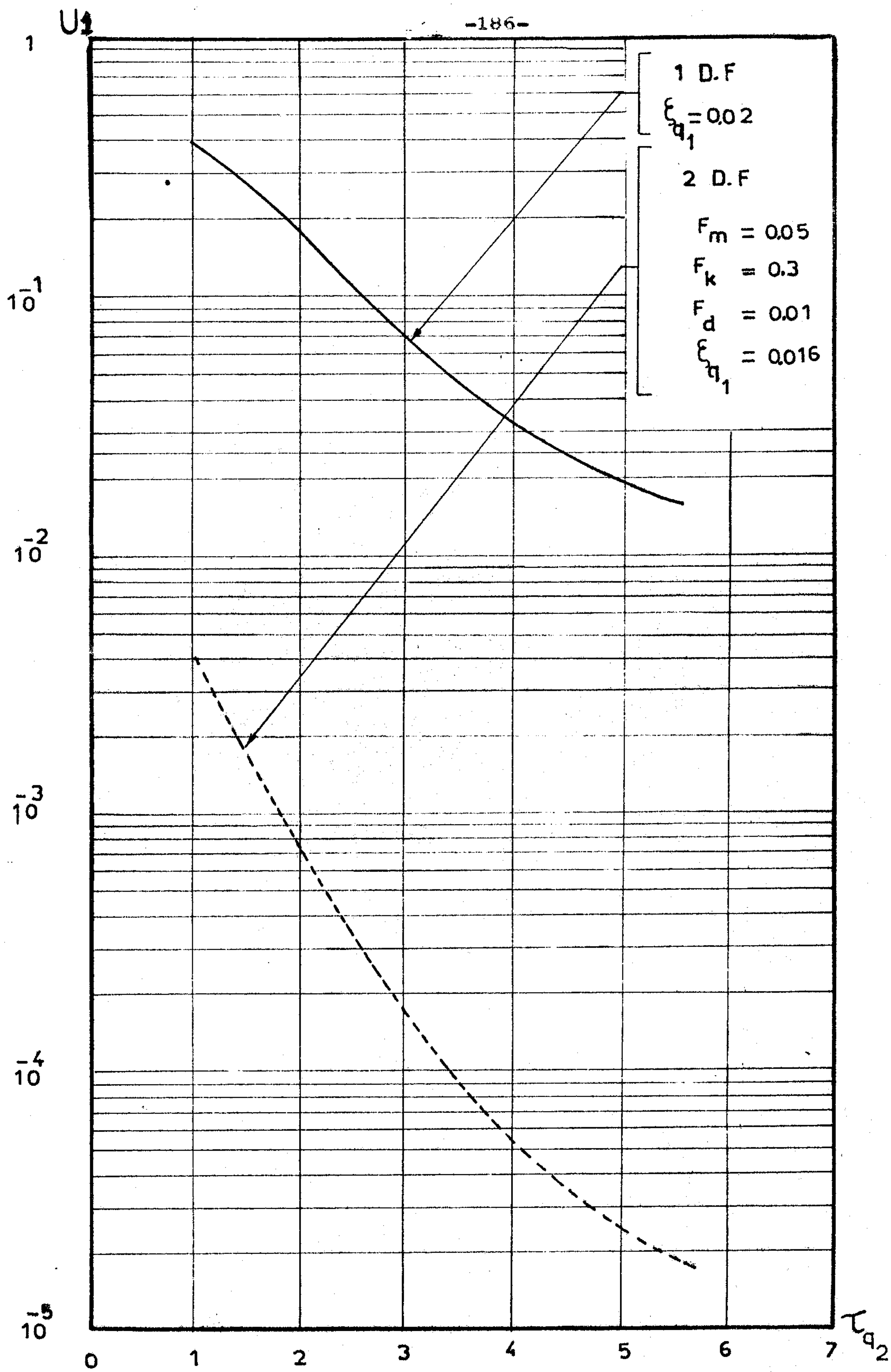


Fig (24) Primary Positional error

Table : (I - 1)

	$F_k = 0.3$, $F_d = 0.1$, $q_1 = 0.2$											
	Residual Positional error $U_2 \times 10^{-2}$						Residual accelerational error $\ddot{U}_2$					
τ_{q_2} / F_m	0.05	0.1	0.5	1	100	1000	0.05	0.1	0.5	1	100	1000
1	0.633	0.116	46.811	15.690	3.201	0.245	2.535	4.99	13.601	8.713	0.116	0.0117
2	0.045	0.065	0.368	2.555	11.992	1.117	1.047	1.782	10.161	16.253	0.464	0.0471
3	0.004	0.007	0.224	2.923	19.855	2.850	0.687	1.033	3.832	8.844	1.035	0.1060
4	0.007	0.009	0.0764	0.188	22.191	5.013	0.502	0.767	3.832	3.198	1.816	0.1882
5	0.003	0.007	0.0914	0.551	17.987	7.810	0.406	0.613	1.491	1.491	2.788	0.2935
6	0.002	0.005	0.0617	0.081	13.209	11.232	0.311	0.508	1.356	1.356	3.929	0.4208
7	0.0018	0.004	0.0182	0.146	6.709	14.299	0.272	0.439	1.213	1.516	5.213	0.5727

Table : (I - 2)

	$F_k = 0.3$; $F_d = 0.1$; $q_2 = 0.2$											
	Primary positional error $U_1 \times 10^{-2}$						Primary accelerational error $\dddot{U}_1$					
τ_{q_2} \ F_m	0.05	0.1	0.5	1	100	1000	0.05	0.1	0.5	1	100	1000
1	0.5801	0.416	45.124	13.100	98.200	99.820	0.334	0.857	11.566	2.205	0.1162	1.186
2	0.0469	0.124	0.7559	36.650	93.170	99.290	0.011	0.102	0.418	16.973	0.440	4.707
3	0.0134	0.0301	0.8920	2.070	85.130	98.440	0.008	0.0356	1.502	2.863	0.903	10.495
4	0.0056	0.0112	0.1690	1.205	74.470	97.26	0.002	0.0003	0.481	2.087	1.402	18.430
5	0.0029	0.0058	0.0352	0.395	61.690	95.76	0.001	0.0051	0.355	1.376	1.811	28.349
6	0.0017	0.0033	0.0079	0.270	47.370	93.95	0.0006	0.0016	0.235	0.986	1.994	40.046
7	0.0010	0.0033	0.0220	0.090	32.150	91.83	0.0004	0.0008	0.111	0.629	1.830	53.272

Table : (II)

τ_{q_2} \ F_k	$F_m = 0.5$, $F_d = 0.1$, $q_1 = 0.1$							
	$U_1 \times 10^{-2}$		$\overset{\equiv}{U_1}$		$U_2 \times 10^{-2}$		$\overset{\equiv}{U_2}$	
	0.3	1	0.3	1	0.3	1	0.3	1
1	47.843	6.206	11.815	4.464	49.703	0.938	14.634	15.657
2	0.582	0.534	1.179	1.735	1.824	0.617	11.780	2.344
3	1.084	0.157	2.090	1.0767	0.179	0.039	4.536	1.798
4	0.225	0.042	0.799	0.573	0.042	0.081	1.311	1.596
5	0.103	0.001	0.666	0.200	0.145	0.0003	1.251	0.487
6	0.050	0.002	0.524	0.046	0.105	0.0171	1.828	1.073
7	0.028	0.004	0.243	0.167	0.0198	0.0099	1.581	0.467

Table (III - 1) $F_K = 0.3$

	$U_1 \times 10^{-2}$						U_1''					
f_{e_2}	0.1						0.2					
F_m	1			100			1			100		
τ_{e_2} / F_d	0	0.1	1	0	0.1	1	0	0.1	1	0	0.1	1
1	12.260	12.720	14.250	98.330	98.270	97.710	1.452	2.205	5.008	0.1165	0.1162	0.1160
2	41.000	38.730	24.980	93.410	93.290	92.230	19.423	16.973	6.848	0.4420	0.4400	0.4390
3	4.460	3.180	2.807	85.460	85.300	83.820	4.755	2.863	1.759	0.9910	0.9030	0.8990
4	1.781	1.445	0.919	74.870	74.670	72.900	3.375	2.087	0.593	1.4180	1.4020	1.3940
5	0.891	0.610	0.340	62.120	61.900	59.990	2.640	1.376	0.270	1.8390	1.8110	1.7960
6	0.481	0.353	0.205	47.580	47.580	45.690	2.052	0.986	0.148	2.0380	1.9940	1.9730
7	0.261	0.160	0.113	32.540	32.350	30.630	1.519	0.629	0.089	1.8880	1.8300	1.8010

Table : (III - 2) $F_k = 0.3$

	$U_2 \times 10^{-2}$						$\bar{\bar{U}}_2$					
f_{q_2}	0.1						0.2					
F_m	1			100			1			100		
τ_{q_2} / F_d	0	0.1	1	0	0.1	1	0	0.1	1	0	0.1	1
1	15.400	15.400	16.175	3.238	3.047	3.748	9.721	8.430	5.107	0.118	0.116	0.105
2	1.570	3.495	0.274	12.409	12.200	13.033	20.326	16.254	3.268	0.476	0.464	0.421
3	5.390	4.670	0.167	20.290	20.070	20.110	10.937	8.840	2.788	1.047	1.035	0.938
4	0.280	0.241	0.019	21.321	21.108	20.523	4.080	3.198	1.940	1.837	1.816	1.646
5	1.042	0.765	0.104	18.385	18.185	18.025	3.872	3.978	1.524	2.820	2.788	2.528
6	0.119	0.034	0.080	13.566	13.387	11.831	3.297	2.332	1.241	3.974	3.929	3.562
7	0.296	0.205	0.025	7.009	6.857	5.544	1.750	1.471	1.051	5.273	5.213	4.726

Appendix

Fortran program for Computation

```
C        MASTER CALCULATION OF DYNMIC RESPOMSE OF CAM MECH
         DIMENSION TAUEO(40),FK(10),FM(10),FD(12),ZATAO(15),
        *TAUEF(40),ZATAF(15)
         READ(105,400)(FD(NN),NN=1,3)
         READ(105,400)(FK(J),J=1,2)
         READ(105,400)(FM(K),K=1,3)
     400 FORMAT(3F10.2)
         TAUEO(1)=0.0
         DO405 I=2,10
         N=I-1
     405 TAUEO(I)=TAUEO(N)+1.0
         DO 600 J=1,2
         DO800 K=1,3
         DO 900 I=2,10
         TAUEF(I)=TAUEO(I)*SQRT(FK(J)/FM(K))
         ZATAO(1)=0.0
         DO 500  NN=1,3
         DO 700  L=2,4
         LL=L-1
         ZATAO(L)=ZATAO(LL)+0.1
         ZATAF(L)=ZATAO(L)*FD(NN)/SQRT(FK(J)*FM(K))
         V1=TAUEF(I)
         V2=ZATAF(L)
         CALL KUTA (V1,V2)
     700 WRITE(108,440) ZATAO(L)
     440 FORMAT(40X,(F10.4,15X))
     500 CONTINUE
     900 WRITE(108,420) TAUEO(I)
     420 FORMAT(1X,F10.4)
     800 WRITE(108,450)FM(K)
     450 FORMAT(115X,F10.4)
         WRITE(108,460) FK(J)
     460 FORMAT(100X,F10.4)
     600 CONTINUE
         STOP
         END
```

```
     SUBROUTINE KUTA(TAUE,ZATA)
    REAL K1Z,K2Z,K3Z,K4Z,K1U,K2U,K3U,K4U
    INITIAL PARAMETERS
    WRITE(108,50)TAUE,ZATA
 50 FORMAT(1X,//////20X,'TAUE=',F7.3/20X,'ZATA=',F7.3////)
    CONSTANT PARAMETERS
    H=0.01
    BY=2.*3.141593
    D=BY*TAUE
    C = D * ZATA
    E=D*SQRT(1.-ZATA**2.)
    CALCULATION OF RISE PERIOD USING RUNGE KUTTA
    WRITE(108,51)
 51 FORMAT(1X,2X,'UMAXDURING RISE ARE')
    T=0.0
    L=0
     U=0.0
    Z=0.0
    ISO=1
 65 IF(L.GE.100)GOTO 5
    K1Z=H*(-BY*SIN(BY*T)-2.*C*Z-(D**2.)*U)
    K1U=H*Z
    K2Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K1Z/2.)-D**2.*(U+K1U/2.))
    K2U=H*(Z+K1Z/2.)
    K3Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K2Z/2.)-D**2.*(U+K2U/2.))
    K3U=H*(Z+K2Z/2.)
    K4Z=H*(-BY*SIN(BY*(T+H))-2.*C*(Z+K3Z)-D**2.*(U+K3U))
    K4U=H*(Z+K3Z)
    DELTAZ=(1./6.)*(K1Z+2.*K2Z+2.*K3Z+K4Z)
    DELTAU =(1./6.)*(K1U+2.*K2U+2.*K3U+K4U)
    IF(DELTAU.GE.0.0)GOTO15
    ISN=1
    GOTO 25
 15 ISN =2
 25 IF(ISO.NE.ISN)GOTO 35
    U=U+DELTAU
    GOTO 55
 35 WRITE(108,10) U,T
 10 FORMAT(1X,E24.5,F8.2)
    U=U+DELTAU
 55 T=T+H
    L=L+1
    Z=Z+DELTAZ
    ISO=ISN
    GOTO 65
  5 WRITE(108,20)U,T
 20 FORMAT(1X,'FINALU=',E14.5,F8.2)
                                        KUTA
```

```
      A=U
      WRITE(108,52)
   52 FORMAT(1X,/2X,'UDOTMAXDURINGRISEARE')
      T=0.0
      L=0
      U=0.0
      Z=0.0
      ISO=1
  125 IF(L.GE.100)GO TO 75
      K1Z=H*(-BY*SIN(BY*T)-2.*C*Z-(D**2.)*U)
      K1U=H*Z
      K2Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K1Z/2.)-D**2.*(U+K1U/2.))
      K2U=H*(Z+K1Z/2.)
      K3Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K2Z/2.)-D**2.*(U+K2U/2.))
      K3U=H *(Z +K2Z/2.)
      K4Z=H*(-BY*SIN(BY*(T+H))-2.*C*(Z+K3Z)-D**2.*(U+K3U))
      K4U=H*(Z+K3Z)
      DELTAZ=(1./6.)*(K1Z+2.*K2Z+2.*K3Z+K4Z)
      DELTAU=(1./6.)*(K1U+2.*K2U+2.*K3U+K4U)
      IF(DELTAZ.GE.0.0)GO TO 85
      ISN=1
      GO TO 95
   85 ISN=2
   95 IF(ISO.NE.ISN)GO TO 105
      Z=Z+DELTAZ
      GO TO 115
  105 WRITE(108,30)Z,T
   30 FORMAT(1X,E24.5,F8.2)
      Z=Z+DELTAZ
  115 T=T+H
      L=L+1
      U=U+DELTAU
      ISO=ISN
      GO TO 125
   75 WRITE(108,60)Z,T
   60 FORMAT(1X,'FINALUDOT=',E14.5,F8.2)
      A1=Z
      WRITE(108,53)
   53 FORMAT(1X,/2X,'UDDOT MAX DURING RISE ARE')
      T=0.0
      L=0
      U=0.0
      Z=0.0
      ISO=1
  185 UDDOT=-BY*SIN(BY*T)-2.*C*Z-(D**2.)*U
      IF(L.GE.100)GOTO 135
      K1Z=H*(-BY*SIN(BY*T)-2.*C*Z-(D**2.)*U)
                                    KUTA        09/02/80   13.07.31
```

```
      K1U= H* Z
      K2Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K1Z/2.)-D**2.*(U+K1U/2.))
      K2U=H*(Z+K1Z/2.)
      K3Z=H*(-BY*SIN(BY*(T+H/2.))-2.*C*(Z+K2Z/2.)-D**2.*(U+K2U/2.))
      K3U=H*(Z+K2Z/2.)
      K4Z=H*(-BY*SIN(BY*(T+H))-2.*C*(Z+K3Z)-D**2.*(U+K3U))
      K4U=H*(Z+K3Z)
       DELTAZ=(1./6.)*(K1Z+2.*K2Z+2.*K3Z+K4Z)
      DELTAU=(1./6.)*(K1U+2.*K2U+2.*K3U+K4U)
       Z= Z+DELTAZ
       U= U +DELTAU
       T = T + H
       UDDOT1=-BY*SIN(BY*T)-2.*C*Z-(D**2.)*U
      DUDDOT=UDDOT1-UDDOT
      IF(DUDDOT.GE.0.0) GO TO 145
       ISN=1
       GO TO 155
 145  ISN=2
 155   IF(ISO.NE.ISN)GO TO 165
       L=L+1
       GO TO 175
 165   T2 = T-H
       WRITE(108,70) UDDOT,T2
  70   FORMAT (1X,E24.5,F8.2)
       L =L+1
 175   ISO=ISN
       GO TO 185
 135   WRITE(108,80)UDDOT,T
  80  FORMAT(1X,'FINAL UDDOT=',E14.5,F8.2)
       A2=UDDOT
C     EXACT CALCULATION OF DWELL PERIOD
       B =A1+A*C
       TE1=A*E+C*B/E
       TE2=B-C*A
      TE3=B*E-2.*A*C*E-(C**2.)*B/E
       TE4=2.*C*B-(C**2.)*A+A*(E**2.)
       T =H
      AEXP=EXP(-C*T)
       U= AEXP*(A*COS(E*T)+(B/E)*SIN(E*T))
       DELTAU=U- A
      IF(DELTAU.GE.0.0)GO TO 195
       ISO=1
       GO TO 205
 195   ISO =2
 205    T =H
 245  AEXP=EXP(-C*T)
       U=AEXP*(A*COS(E*T)+(B/E)*SIN(E*T))
```

```
      T3=T  +H
      BEXP=EXP(-C*T3)
      U1=BEXP*(A*COS(E*T3)*(B/E)*SIN(E*T3))
      DELTAU=U1-U
      IF(DELTAU.GE.0.0)GO TO 215
      ISN=1
      GO TO 225
215   ISN=2
225   IF(ISO.NE.ISN) GO TO 235
     ISO=ISN
      T =T+H
      GO TO 245
235   T1 =T+1.0
      WRITE(108,90)U,T1
 90   FORMAT(1X,/2X,'UMAX DURING DWELL=',E14.5,F6.2)
      T=H
     AEXP=EXP(-C*T)
     UDOT=AEXP*(-TE1*SIN(E*T)+TE2*COS(E*T))
     DUDOT=UDOT-A1
     IF(DUDOT.GE.0.0)GOTO 255
     ISO=1
     GOTO 265
255  ISO=2
265  T=H
305  AEXP=EXP(-C*T)
     UDOT=AEXP*(-TE1*SIN(E*T)+TE2*COS(E*T))
      T3 = T +H
      BEXP=EXP(-C*T3)
     UDOT1=BEXP*(-TE1*SIN(E*T3)+TE2*COS(E*T3))
     DUDOT=UDOT1-UDOT
     IF(DUDOT.GE.0.0)GOTO 275
      ISN =1
      GO TO 285
275   ISN =2
285  IF(ISO.N E.ISN)GO TO 295
      ISO=ISN
      T = T +H
      GO TO  305
295   T1= T+ 1.0
     WRITE(108,110)UDOT,T1
110   FORMAT(1X,/2X,'UDOT MAX DURING  DWELL=',E14.5,F8.2)
      T=H
     AEXP=EXP(-C*T)
     UDDOT=AEXP*(-TE3*SIN(E*T)-TE4*COS(E*T))
      DUDDOT=UDDOT-A2
     IF(DUDDOT.GE.0.0) GO TO 315
      ISO=1
```

دراسة التأثيرات الداخلية لعمود السيات الكامات
على أدائهــــــا

١ ـ أ٠د ٠/ عبد الهادى ناصر ٢ـ عميد د ٠ احمد ماهر ٣ـ د ٠سعاد محمد سراج ٤ ـ صبحى غنيم

الخواص الداخلية لعمود السيات الكامات تتمثل بعزم القصور والمرونه والاخمـاد ولدراسة تأثير هذه الخواص على أداء آليات الكامات ثم استنتاج ودراسة مقدار الانحراف الناشـىء بين الحركة الحقيقيـة (q_1) والحركة الاعتبارية (y) وذلك خلال مشوارى الصعود والسكــون "rise and dwell periods" وتم ذلك خلال كامة سيكويديـة "Cycloidal cam" تؤثر على منظومة ذودرجتين للحرية فى حالـة الاخماد ، أحـد هذه الدرجات تتمثل فى الحركة النهائية لتابع والاخرى تتمثل فى دوران الكامة ٠

وتم استنتاج المعادلات التفاضلية التى توصف هذه المنظومة بتطبيق معادلة لأجرانج ووضع هـــذه المعادلات فى الصورة اللابعدية وذلك لسهولة وجعلها أكثر عمومية وهذه المعادلات محتوية على المؤشـرات البارمترية التى تربط بين كتل ومرونة وأخماد كل من مجموعة التابع ومجموعة الكامة ٠

وتم حل هذه المعادلة باستخدام طريقة "Runge-Kutta" لحل المعادلات التفاضلية من الدرجة الثانية وعلاوة على ذلك تم تجهيز برنامج بلغة الفورتران IV وتم تشغيله على الحاسب العلمى ٠

وقد أثبتت النتائج بأن الاقتراح بأهمال عمود أليات الكامات فى تضمينها له تأثير كبير فى دقة النتـائـج كما هو موضح فى هذا البحث ٠

كما أعطيت بعض التوصيات والمقترحات لمصممى اليـات الكامات ٠

```
      GO TO 325
315   ISO =2
325    T=H
365   AEXP=EXP(-C*T)
      UDDOT=AEXP*(-TE3*SIN(E*T)-TE4*COS(E*T))
       T3=T+H
       BEXP=EXP(-C*T3)
      UDDOT1=BEXP*(-TE3*SIN(E*T3)-TE4*COS(E*T3))
       DUDDOT=UDDOT1-UDDOT
      IF(DUDDOT.GE.0.0)GOTO 335
       ISN=1
       GO TO 345
335    ISN=2
345   IF(ISO.NE.ISN)GOTO 355
      ISO=ISN
      T=T+H
      GO TO 365
355   T1=T+1.
      WRITE(108,120)UDDOT,T1
120   FORMAT(,X,/2X,'UDDOT MAX DURING DWELL=',E14.5,F8.2)
      RETURN
      END
                                               KUTA          09/02/80
```