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USERS' MANUAL FOR KALKER'S SIMPLIFIED NONLINEAR CREEP THEORY

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Last, but certainly not least, we would like to thank Professor J. J. Kalker of Delft who very graciously sent us copies of his papers and computer programs. We have tried, in this Users' Manual, to make the results of his work more widely available to the rail vehicle dynamics community. Although we have checked carefully the Fortran version of Professor Kalker's program, any errors in the conversion are ours and not Professor Kalker's.

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I. INTRODUCTION

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Background

The forces and moments due to shear stresses in the contact area between wheel and rail play a major role in rail vehicle dynamics. These shear stresses arise, in part, due to relative linear and angular motions (lateral, longitudinal, and spin creepage) between the wheel and rail. Hobbs [1] presents a review of the analytical and experimental work concerned with the creep force/creepage phenomenon.

For many problems in rail vehicle dynamics a linear creep force/ creepage relationship has been used. Typical of these are eigenvalue/ eigenvector analyses of lateral stability, lateral forced response studies, and estimation of slip and flange contact boundaries for steady state curving. It is widely recognized that the best available linear creep law is that due to Kalker [2] and called the "linearized theory" (see equations (12) and (13) of [2]). Recently, however, more and more questions are being asked of rail vehicle dynamicists that require more sophisticated models of the wheel/rail interaction process. Factors that should be considered in these models are: (1) the nonlinear wheel/rail geometric constraint functions arising from curved or worn wheel and rail profiles; and, (2) the effects of adhesion limits on the creep force/creepage relationship (i.e. a nonlinear creep law).

[2] J.J. Kalker, "Simplified Theory of Rolling Contact," Delft. Progr. Rep., Series C: Mechanical and Aeronautical Engineering and Shipbuilding, 1 (1973), pp. 1-10.

^[1] A.E.W. Hobbs, "A Survey of Creep", DYN/52, April 1967, British Railways Research Dept., Derby, England.

Attempts have been made to formulate a nonlinear creep law. Johnson's theory [3,4] has been confirmed by laboratory experiments but does not account for spin creepage*. Unfortunately, the effects of spin creepage are expected to predominate for contact areas in the wheel flange region - precisely the situation where a nonlinear creep law is needed. The Levi-Chartet creep law [5,6] used by some researchers is empirically based and does not account for spin creepage.

Professor Kalker of Delft University has formulated two nonlinear creep laws that incorporate the effects of spin creepage and that have been found to compare well with results of laboratory experiments. These two creep laws are generally referred to as the "Simplified theory of rolling contact" [2] and the "exact solution for rolling contact" [7]. The differences in the solutions presented in [2] and [7] lie in two simplifying assumptions made in [2] concerning the tangential displacement-stress relations and the normal stress distribution on the contact surface. These assumptions shorten the computation time required by a factor of approximately 100.

- * Spin creepage is the nondimensional relative angular velocity between wheel and rail in the contact zone.
- [3] K.L. Johnson, "Adhesion", Proc. Inst. Mech. Engrs., Vol. 178, part 3E (1964), pp. 208, 209.
- [4] P.J. Vermeulen and K.L. Johnson, "Contact of Nonspherical Elastic Bodies Transmitting Tangential Forces," <u>J. Appl. Mechanics</u>, Vol. 31 (1964), pp. 338-340.
- [5] R. Levi, "Le roulement avec glissement", Compt. rend. Acad. Science 199, 1934, pp. 119-120.
- [6] A. Chartet, "Proprietes generales des contacts de roulement. Theorie des similitudes." Compt. rend. Acad. Science 225, 1947, pp. 986-988.
- [7] J.J. Kalker, "On the Rolling Contact Between Two Elastic Bodies in the Presence of Dry Friction," Ph.D. Thesis, Delft University of Technology (1967).

A portion of the work being conducted under contract DOT-OS-40018, Freight Car Dynamics, deals with developing models for the lateral dynamic response of North American freight cars during curve entry and negotiation. These models will be used to predict vehicle response and wheel/rail forces during hard curving where severe flange contact is anticipated. Consequently, it is expected that creep forces may approach the limits of adhesion and a nonlinear creep law will be required for accurate modeling.

The object of the work reported in this Users' Manual was to convert the Algol program developed by Professor Kalker for the "Simplified theory of rolling contact" to Fortran and to check the resulting program by direct comparison with the results calculated by the original Algol program and with available experimental results. It is anticipated that a Fortran version of this computer program will prove quite valuable to rail vehicle dynamics researchers in the United States where most scientific programs are written in Fortran.

To further aid in the use of Kalker's theory by rail vehicle dynamics researchers, a subroutine called FØRCES was developed based on the "Simplified theory of rolling contact". This subroutine can be included within Fortran programs that are used to obtain the lateral dynamic response of rail vehicles. This subroutine together with the program for the complete solution of the "Simplified theory of rolling contact" are discussed in this manual.

Summary of Users' Manual

It is intended that Kalker's original paper [2] be read concurrently with this manual. References to equations in [2] are made directly by equation number both in the present text and in the computer code.

The problem analysed in [2] and considered in the computer code is for steady rolling contact of two elastic bodies of equal linearly elastic material properties and having both longitudinal and lateral creepage and spin about an axis normal to the contact surface. The appropriate geometry is given in Figure 1 of [2].

Approximate solutions to three special problems of steady state rolling contact are presented in [2]. The first case is that of infinitesimal slip in which the area of slip is vanishingly small and the resultant tangential creep forces and torsional moment are linearly related to the creepage and spin parameters. This is Kalker's "Linearized theory" widely used by rail vehicle dynamics researchers. It is presented on page 4, equations (11) to (13) of [2]. The second solution, "Steady-state rolling with pure creepage", is presented on page 5, equations (15) to (21) and considers finite slip with a resulting nonlinear relationship between the resultant creep force and the creepage. The present computer code is for the third solution, "Combined creepage and spin: a numerical method", in which finite slip is assumed and the resultant creep forces and moment are nonlinearly related to the creepage and spin parameters.

The problem may be stated as follows. Given two bodies of equal elastic properties and known dimensions, normal force, rolling velocity, creepage and spin, determine the resultant creep forces tangent to the contact surface and the resultant moment about a normal to the contact surface. The region of slip within the contact surface is also determined. In the actual solution, the static Hertzian contact problem is

first solved (see [7] page 55, or [8] page (414) to determine the dimensions of the contact ellipse, a and b. The resultant creep forces and moment, F_x , F_y , and M_z are then determined knowing the parameters a, b, N, G, ν , μ , ν_x , ν_y , and ϕ where:

 F_{X} = longitudinal creep force (in the direction of rolling) F_{y} = lateral creep force

 M_{z} = spin creep moment about normal to contact surface

a = semi-axis of contact ellipse in longitudinal direction

b = semi-axis of contact ellipse in lateral direction

N = resultant normal load on the contact region

G = shear modulus

v = Poisson's ratio

 v_x , v_y = longitudinal and lateral creepage

 ϕ = spin creepage

This is the same problem considered in [7] and referred to as the "exact" solution. The only differences in the solutions presented in [2] and [7] lie in two simplifying assumptions concerning the tangential displacement - stress relations and the normal stress distribution on the contact surface. These two assumptions considerably reduce the complexities in obtaining a numerical solution and shorten the computation time by approximately a factor of 100.

The first assumption regarding the tangential displacement-stress relation is common to all three solutions developed in [2]. This is:

 $u(x,y) = S_X X = -S_X^T xz$ equation (9), [2] $v(x,y) = S_y Y = -S_y^T yz$

^[8] S.P. Timoshenko and J.N. Goodier, <u>Theory of Elasticity</u>, 3rd Ed., McGraw-Hill Book Company (1970).

where u(x,y) and v(x,y) are the tangential displacements in the longitudinal and lateral directions and τ_{xz} and τ_{yz} are the shear stresses. The "exact" relationships for the tangential displacements as given in [7] are

$$u(x,y) = \sum_{\substack{\Sigma \\ m=0}}^{M} \sum_{\substack{n=0 \\ m=0}}^{M-m} a_{mn} x^{m} y^{n}$$
equation (2.2), [7]
$$v(x,y) = \sum_{\substack{\Sigma \\ m=0}}^{M} \sum_{\substack{n=0 \\ m=0}}^{M-m} b_{mn} x^{m} y^{n}$$

The two elastic constants S_x and S_y of [2] are determined explicitly in terms of the elastic properties G and v, the contact ellipse dimensions a and b and the creepage and spin coefficients C_{ij} (see equations (13) and (41) - (47) of [2]. It is important to note that S_x and S_y have different values if forces are to be computed than they have when the moment is to be determined.

The method of determination of the constants a_{mn} and b_{mn} in [7] is much more complicated than that used to determine S_x and S_y in [2] and is the significant difference in the solutions.

The simplified theory also may be used to investigate the effects of a very thin elastic layer covering the bodies and having a tangential displacement-stress relation as given by equation (45) of [2].

$$u_{\ell} = L_{\chi} X = - L_{\chi} \tau_{\chi Z},$$

$$v_{\ell} = L_{\chi} Y = - L_{\chi} \tau_{\chi Z},$$

where L_X and L_y are the inverse stiffnesses of the layer. The combined effective stiffnesses of the wheel-rail with an elastic layer are given by equations (46) and (47) of [2]. These are, for moments

$$S_x = 8b/(15C_{33}G) + L_x$$
 and,
 $S_y = \pi a^{3/2}/(4b^{1/2}C_{23}G) + L_y$

and in the calculations of forces

$$S_x = 8a/(3C_{11}G) + L_x$$
 and
 $S_y = 8a/(3C_{22}G) + L_y$.

If no layer is present one then takes $L_x = L_y = 0$.

The effect of changes in L_x and L_y on the resulting solution has not been investigated; however, some observations should be noted. First, the layer is assumed to be so thin that its presence does not influence the determination of the contact ellipse dimensions or the pressure distribution. That is, a and b are still computed from the static Hertz solution in terms of G, v and N. The effect of a finite thickness work-hardened layer could not then be accounted for by including L_x and L_y . Further, it seems to the writers that if the effect of a contaminated rail is desired, it is more directly accounted for by an appropriate change in the coefficient of friction than in a layer as defined by equation (45). The utility of modifying the elastic properties by adding L_x and L_y is not clear to the writers at this time.

The additional simplification made in the combined creepage and spin solution of [2] is that the normal stress distribution over the contact region is assumed to be of the form given by (14.III) rather than the Hertz stress distribution of (14.I). It should be noted that the

Hertzian distribution is used to determine the contact region dimensions a and b. Equation (14.III) is chosen so as to have bounded derivatives at the edge of the contact region and to still be similar to the Hertzian distribution over most of the contact area. The functions A(y) and B(y) in (14.III) are

A(y) = 0.5
$$(1-(y/b)^2)^{-\frac{1}{2}}(1-(0.9)^2)^{-\frac{1}{2}}$$
 and
B(y) = -0.5 $(1-(y/b)^2)^{\frac{1}{2}}(1-(0.9)^2)^{\frac{1}{2}}$.

Numerous changes were made in the computer code in order to make the program more convenient to use. The Algol version was, however, fundamentally correct and numerous checks were made to insure that the Fortran and Algol codes gave the same results. The use of the Fortran code is considered in the next sections. The complete solution is discussed first, followed by the subroutine, "SUBRØUTINE FØRCES".

II. DESCRIPTION OF COMPUTER CODE FOR COMPLETE SOLUTION

A. PURPOSE

This program and associated subroutines compute the lateral and longitudinal creep forces and the spin creep moment acting between two elastic bodies in steady state rolling contact. The bodies are of equal linearly elastic material properties and have longitudinal and lateral creepage and spin creepage about an axis normal to the contact region. Kalker's theory of simplified rolling contact [2] is the basis of the program.

B. PROGRAM DESCRIPTION

 Usage: The program consists of a main program and three subroutines.

The main program, MAIN, coordinates the input and outputs the results. Subroutine MAAKZ computes the normal stress as given by equation (14.III). Subroutine RØL is the solution portion of the program and determines the region of slip or adhesion within the contact zone. Subroutine CØNST determines the linear creepage and spin coefficients, C_{ij} , and the normalized modulus GS by linear and quadratic interpolation from Kalker's table [7].

2) Subroutines Required:

SUBRØUTINE MAAKZ (P, Q, WZ, DZ, DZZ, A, B, MUZ) determines the assumed normal stress as given by equation (14.III). SUBRØUTINE RØL (CS, GEL, MUZ, NX, NY, X, Y, VX, VY, G, FX, FY, MZ) determines the region of slip or adhesion and computes the

tangential stresses and relative velocity at points within the contact zone. The resultant creep forces and moment are also computed. Uses subroutine MAAKZ.

SUBRØUTINE CØNST (A, B, NU, C11, C22, C23, C33, GS) determines the linear creepage and spin coefficients, C11, C22, C23, and C33 and the normalized modulus, GS, by linear and quadratic interpotation from Kalker's table, [7]. These values are used in MAIN to determine the normalized stiffness SXN and SYN and the spin constant HC.

- 3) Description of Input Parameters:
 - NVI

NV1 is an integer denoting the number of complete problems to be solved. Input.

A,B A = a/c, B = b/c, where a and b are the actual contact dimensions determined from the static Hertz solution and c = \sqrt{ab} is the normalized unit of length. a is the longitudinal and b is the lateral semi-axis of the contact ellipse. Input.

NU NU = v = Poisson's ratio. Input.

- LXN, LYN LXN = $L_{\chi}\rho N/c^4$, LYN = $L_{\chi}\rho N/c^4$. Inverse stiffnesses of an elastic layer covering the bodies. N = resultant normal force and $1/\rho = 1/4 (1/R_1^+ + 1/R_1^- + 1/R_2^+ + 1/R_2^-)$ with R_1^+ , R_1^- , R_2^+ , R_2^- being the principal radii of curvature of the two elastic bodies. See equation (45). For no layer, take LXN = LYN = 0. Input.
- NX, NY Lattice points in the normalized contact region with X = (I)(A)/NX, Y = (J)(B)/NY and $-NX \le I \le NX$, -NY $\le J \le NY$. Accuracy increases with increasing values of NX, NY. Maximum values NX, NY = 40. Typical values:

A/B = 10.0, NX = 30, NY = 10, A/B = 0.1, NX = 10, NY = 30, A/B = 1.0, NX = NY = 20. Input.

DM DM is an incremental step in the computation. Accuracy increases with decreasing values of DM. Typical value, DM = 0.02A. Input.

- NF If the resultant forces are desired, take NF = 1. For the resultant moment take NF = 2. The appropriate values of SXN, SYN and HC will then be computed. Input.
- NS To print all output including stresses and displacements on the contact region take NS = 1. To suppress all output except the resultant forces or moment take NS = 2. Input.
- NV2 NV2 is the integral number of sets of UXN, UYN, PHN to be considered. Input.
- UXN, UYN $UXN = v_x^{\rho/\mu c}$, $UYN = v_y^{\rho/\mu c}$ where v_x , v_y are the longitudinal and lateral creepages, μ = coefficient of friction. See equation (6). Input.
- PHN PHN = $\phi \rho / \mu$ where ϕ is the spin creepage. See equation (6). Input.

4) <u>Input Format:</u>

A sample deck set up is listed in Appendix A of this manual. The program requires contact region dimensions, elastic properties, wheel/rail creepages and program control information. The following format is for NV1 = 1. If NV1 > 1, there would be NV1 sets of the group of cards after the first card.

Card Number	Input Data
1	NV1 = Integer. Program solves NV1 complete problems, Typical card: 1
2	A, B, NU, LXN, LYN Typical card: 2.5980 0.3849 0.28 0.250 0.125
3	NX, NY, DM, NF, NS Typical card: 30 10 0.04 1 2
4	NV2 = Integer. Program solves NV2 problems for different values of creepage and spin given on NV2 cards starting with 5. Typical card: 1
5 to NV2 Note: The in	UXN, UYN, PHN Typical card: 0.0 2.0 0.4 nput is free format with a space needed between each
input 5) Desc	parameter. cription of Other Parameters in Program:
	, C22, Longitudinal, lateral, lateral/spin, and spin , C33 creepage coefficients, respectively; tabulated in [7].
GS	GS = Gc ³ / ρ N where G = shear modulus. GS may also be computed from GS = 3(1- ν) $\tilde{E}/(4\pi\sqrt{g})$ where \tilde{E} = complete elliptic integral of the second kind, see [7] page 58, and g = axial ratio of the contact ellipse = min (a/b, b/a). GS is determined within

the computer program in terms of A, B and NU.

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SXN, SYN SXN =
$$S_x^{\rho}N/c^4$$
, SYN = $S_y^{\rho}N/c^4$. Inverse stiffnesses
of the elastic bodies. See equations (9), (43), (44),
and (47) for the form of S_x , S_y to be used to
determine the resultant forces and equations (42)
and (46) for the appropriate form to determine the
resultant moment.

For forces let

 $SXN1 = 8A/(3C_{11}GS), SYN1 = 8A/(3C_{22}GS)$

and

HC1 = $32 \sqrt{B/A} C_{23}/(3\pi C_{22})$, then SXN = SXN1 + LXN SYN = SYN1 + LYN HC = (SYN1 + LYN)/(SYN1/HC1 + LYN).

For moments,

SXN = 8B/(15C₃₃GS) + LYN, SYN = $\pi A/(4\sqrt{B/A} C_{23}GS)$ + LYN, and HC = 1.0

The C_{ij} are the linear creepage and spin coefficients, [7]. SXN, SYN, HC and the C_{ij} are determined within the program in terms of A, B, NU, LXN and LYN.

6) <u>Output</u>: NV2 sub-cases of NV1 cases are calculated. For each of the NV1 cases, the input parameters A, B, NU, LXN, LYN, NX, NY, DM, NF, and NS are printed. The linear creepage

coefficients, calculated within the program, are also printed out as are the normalized shear modulus, GS, and normalized inverse stiffness, SXN and SYN. For each of the NV1 cases, there will be NV2 sets of output corresponding to the NV2 sets of normalized creepages and spin, UXN, UYN, and PHN. For each of the NV2 cases, the inputs UXN, UYN, and PHN are printed out together with the computed values of the normalized longitudinal and lateral creep forces, FXN and FYN, or the computed value of the spin creep moment, MZN (depending on whether NF = 1 or NF = 2). If NS = 2, the output is as described above. If NS = 1, the normalized coordinate points X, Y over the contact region and the values of the stresses (TX, TY, TZH, TZK) and slip components (VX, VY) are given at each point.

The Fortran names used in the program output are the following:

UXN, UYN, PHN	Repeated program input variables.
FXN, FYN	FXN = $F_X/\mu N$, FYN = $F_y/\mu N$. Normalized resultant longitudinal and lateral forces. Computed.
MZN	MZN = M _z c/µN. Normalized resultant moment. Computed.
Χ, Υ	X = x/c , Y = y/c . $-A \le X \le A$, $-B \le Y \le B$. Normalized coordinates where x and y are longitudinal and lateral distances from the center of the contact ellipse.

TX, TY Normalized shear stresses.

TX, TY =
$$-\tau_{XZ}c^3/\rho N$$
, $-\tau_{YZ}c^3/\rho N$,
 $\sqrt{TX^2 + TY^2}$ < TZK for no slip,
 $\sqrt{TX^2 + TY^2}$ = TZK for slip.

TZH

TZK

TZH = $3/(2\pi) \sqrt{1-(X/A)^2 - (Y/B)^2}$ = Normalized Hertzian stress on the contact region. Given for reference only. See equation (14.I). TZK is the assumed normal stress distribution over the contact region, see equation (14.III).

$$TZK = (F)(A) A1(Y)(1-(X/A)^2-(Y/B)^2), X>0.9L(Y)$$

TZK = (F)(A)($\sqrt{1-(X/A)^2-(Y/B)^2}$ + B1(Y)),X<0.9L(Y) where L(Y) = A $\sqrt{1-(Y/B)^2}$

A1(Y) = 0.5 $(1-(Y/B)^2)^{-1/2}(1-(0.9)^2)^{-1/2}$ B1(Y) = - 0.5 $(1-(Y/B)^2)^{1/2}(1-(0.9)^2)^{1/2}$ and (F)(A) = 0.656773, such that the resultant normal force = 1.0.

VX, VY Normalized relative slip components. VX, VY = $v_x \rho/(V\mu c)$, $v_y \rho/(V\mu c)$ where V is the rolling velocity and v_x and v_y are the longitudinal and lateral components of the relative slip velocity.

7) Summary of User Requirements and Recommendations

All input data is on cards in free format as shown. As A and B are normalized, the product of A and B must be unity. LXN and LYN are taken as zero if no elastic layer is to be considered. Maximum values for NX and NY are 40. Accuracy increases with increasing values of NX and NY. Typical values are: A/B = 10.0 NX = 30, NY = 10 A/B = 1.0 NX = NY = 20 A/B = 0.1 NX = 10, NY = 30 DM is an incremental step size in the computation. Accuracy is improved with smaller sizes of DM. A typical value is DM = 0.2*A.

C. TEST PROBLEM

The following test problem is given to demonstrate the program. The calculation were performed on an IBM-370/3165-II computer.

A = 2.598, B = 0.3849, NU = 0.28, LXN = 0, LYN = 0 NX = 10, NY = 10, DM = 0.04, NF = 1, NS = 1 UXN = 0, UYN = -1.4, PHN = 0.8

D. PROGRAM LISTINGS WITH EXAMPLE INPUT AND OUTPUT

A listing of the program for the sample problem with input and output is given in Appendix B.

III. DESCRIPTION OF COMPUTER CODE FOR SUBROUTINE FORCES

The subroutine FØRCES is a version of the complete code discussed in Chapter II that has been converted to subroutine form. All the WRITE statements have been deleted as has the calculation of the pure spin creep moment. In almost all cases of interest to rail vehicle dynamicists, the pure spin creep moment contributions from the two wheels comprising the wheelset are much smaller than the yaw moment about the wheelset center of gravity due to the longitudinal creep forces. Thus, this calculation was deleted in the interests of computational time savings.

The subroutine and its argument list are:

SUBRØUTINE FØRCES (A, B, NU, UXN, UYN, PHN, NX, NY, DM, FXN, FYN) The input parameters are: A, B, NU, UXN, UYN, PHN, NX, NY and DM and are as defined in Chapter II. The outputs are FXN and FYN and are as defined in Chapter II. Stresses and slip values over the contact region are not returned. All discussion of users' requirements and other program descriptive material is as outlined for the complete code in Chapter II.

The purpose of FØRCES is to compute lateral and longitudinal creep forces acting between two elastic bodies in steady rolling contact. The bodies have relative longitudinal and lateral creepage as well as spin creepage about an axis normal to the contact region.

FØRCES may be used as a subroutine within other Fortran programs developed for calculating the lateral dynamic response of rail vehicles. It addresses only one wheel and must be called for each wheel separately.

The input parameters must be evaluated for each wheel/rail contact condition considered and the outputs FXN and FYN are appropriate obviously for only those input parameters.

A listing and a sample test problem using SUBRØUTINE FØRCES is given in Appendix B.

	PAIN	25
ſ		100000560
C	*C23*GS), AND SXN=SXN1+LXN. SYN=SYN1+LYN. HC=1.C	000000590
C	SEE EQUATIONS (42), (43), (46), AND (47).	00000610
C	NS (TO PRINT OUTPUT ON THE CONTACT REGION, NS=1,	00000620
	TU SUPPRESS ALL UUTPUT EXCEPT THE RESULTANT FORCES OR MOMENT, TAKE NS-21, INTEGER	00000630
C C	NOTE: FXN=FX/(MU*N). FYN=FY/(MU*N).	00000650
Ĺ	WZN=MZ*C/(MU*N)	00000660
C .		00000670
C CATA CARE #4	A NV2	08800000
	-TRICAL CANDE 1	00000890
C	SCLVES NV2 PROBLEMS FOR DISTINCT VALUES OF	00000710
C	CREEPAGE AND SPIN GIVEN ON NV2 CARDS 5), INTEGER	00000720
C		00000730
C DATA CARD #		00000740
ι Γ	ITPICAL CARLE U.C. 2.00 U.4	00000750
C	UXN AND UYN ARE NORMALIZED CREEPAGES, PHN	00000770
C	IS THE NORMALIZED SPIN), REAL	00000780
C	UXN=UX*RHO/(MU*C), UYN=UY*RHO/(MU*C),	00000790
	FHV=FH&KHO/WO	00000810
		00000820
C 3	***** NCTE: ALL VARIABLES HAVE BEEN NORMALIZED SUCH	00000830
C ·	**** THAT THE COEFFICIENT OF FRICTION, MU, DOES NOT	00000840
	**** EXPLICITLY APPEAR.	00000850
		00000870
COMMON A,B		03803000
DATA X.Y.Z.Z	ZH,VX,VY,G/6561*C.O,6561*C.O,6561*O.O,6561*C.O,6561*C.	000000890
\$,6561*0.0,81	1C*C•C/	00000900
P1=3+14155 GR=P1/186-0		00000910
READ(1,*)NV		00000930
DO 999 II1=1		00000940
WRITE(3,568		00000950
1040 READ(1,*,E	ND=5959}A,8,NU,LXN,LYN	00000960
f IFTA/B-LI-U		00000980
C		00000990
C	SUBROUTINE CONST COMPUTES THE LINEAR CREEPAGE AN	00001000
C	SPIN COEFFICIENTS, AND THE NORMALIZED MODULUS	00001010
	THE FOR ALKER'S LABLES AND ASTRALLIC EXPANSIONS.	00001020
	THESE VALUES ARE USED BELCW TO COMPUTE THE	00001040
c	INVERSE STIFFNESSES SXN AND SYN.	00001050
C		00001060
C CALL CONST.	N R NU C11 C22 C23 C23	00001070
READ(1.+.F	ND = 9555 NX+NY+DM+NF+NS	00001090
IF(NS.EQ.1)	GC TC 1021	00001100
MX=3+NX		00001110
MY=3*NY		00001120
GO TO 1022		000C1130
1021 MX=1		00001150
M A = 1	· · · · · · · · · · · · · · · · · · ·	00001160

	· ;	
	Ĩ	
	PAIN	26
		·
	LY=1	00001170
1022	MUZ=3.C/(2.C*PI)	
	$\frac{1}{3} \frac{1}{3} \frac{1}$	00001190
	$SYN1=E_00+A/(3_0C+C22+GS)$	00001210
	SYN=SYN1+LYN	00001220
	HCl=32.0*SGRT(B/A)*C23/(3.0*PI*C22)	00001230
	+C=(SYN1+LYN)/(SYN1/HC1+LYN)	00001240
1.125	$\frac{1}{2} \frac{1}{2} \frac{1}$	00001250
1023	SYN=0:0407(12:0403)403)403)403)403)403)403)403)403)403	000001200
	+C=1.0	00001280
1027	GEL(5)=DM	00001290
·	WRITE(3,969)	00001300
	WRITE(3,970)A, B, NU, LXN, LYN	00001310
	3K11E(3,572)NX;NY;DF;NY;NS NDITE(3,672)C11, C22, C22, C22, C5, SVN, SVN	00001320
	RETECS#9757611#622#625#63#378#378	00001330
	CEL(2)=SYN	00001350
	GEL(3)=A	00001360
Ē	GEL (4)=B	00001370
¥-	I=-NX-1	00001360
1074		00001390
, Andrew Alexandrew Al	ALE (I-GI-NX)GC IC 1078	00001400
1075	J=NI-1]= [4]	00001410
	IF(J.GT.NY)GC TE 1074	00001420
	P=1FLOAT(I*I)/FLOAT(NX)/FLCAT(NX)-FLOAT(J*J)/FLOAT(NY)/FLOAT(NY))0CGC144C
	IF(P.GT.C.C) GE TE 1076	00001450
	GO TO 1075	00001460
1076	ZH(I+NX+I,J+NY+I)=MUZ=SWK1(P) D=E1 CAT(I)+A/E1 CAT(A))	00001470
	c = FLOAT(1) + R/FLOAT(NY)	00001480
	GALL MAAKZ(P,G,WZ,DZ,A,E,MUZ)	00001500
	Z([I+NX+1,J+NY+1]=WZ	00001510
• • •	GO TC 1075	00001520
1978	CONTINUE	00001530
	₩±₩U(19*)NV2 - ₩DITE(2 C24) NV2	00001540
	RETE(3,374) = RV2 RO = 997 = T12 = 1.8V2	00001550
1090	READ(1.*.END=SSSS)UXN.UYN.PHN	00001570
	WRITE(3,975)UXN,UYN,PHN	00001580
	PHNN=FC*PHN	00001590
	CS(1)=UXN	00001600
		00001610
	CALL ROLL(CS.GEL.NUZ.XX.XY.X.Y.VX.VY.G.EY.EV.W7)	00001620
	IF(NF.EQ.2) GC TO 1CS1	00001640
	RES=SCRT(FX*FX+FY*FY)	00001650
	WRITE(3, S77)FX, FY, RES	00001660
1001	GO TO 1092	00001670
1000	RK11E139578784 Teing eo 31 co to 1530	00001680
1032	WRITE(3.9004)	00001890
	J=NY	00001710
1260	J=J−L¥	00001720
	IF(J.LTNY+1)GC TC 1345	00001730
	G=FLUAT(J)*E/FLCAT(NY)	00001740

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	PAIN	27
	IF(G(J+NY+1+1)+LT+0+C) WRITE(3+9007)C	00001750
	IF(G(J+NY+1,-1),-GE,-C,-C) write(3,9008) C	00001760
C DOC		00001770
1340	GO TO 1260	00001780
1345	5 CONTINUE	00001790
	IF(MY.GT.2*NY)GC TC 1530	00001800
	J=NY S	00001810
1350	ſ₩−L=L	00001820
	IF(J.LI.J-NY)GC TO 1520	00001830
	C=FLCAT(J)*B/FLCAT(NY)	00001840
,	WRITE(3,9005)	00001850
	WRITE(3,9006)C	00001860
	WRITE(3,9009)	00001870
	I=-NX-MX	00.001880
1400	I=I+MX	00001890
•	IF(I.GT.NX)GO TC 1515	00001900
	IF(Z(I+NX+1,J+NY+1).LT.1.E-8*MUZ)GD TO 1510	00001910
	P=FLOAT(I) + A/FLCAT(NX)	00001920
	$F[X] = Z[I + NX + L_{y} + NY + 1]$	00001930
	FIX6=ZH(I+NX+1,J+NY+1)	00001940
	1X=X(1+NX+1,J+NY+1)	00001950
	$I Y = Y (I + N X + I_y) + N Y + I J$	00001960
·		00001970
	UT=VT(1+NX+1,J+NT+1) ETV=_CODT/TV+TV+TV+TV+	00001980
	F1X2=3WKI(IX+IX+IX+IT)	00001990
	AKU=1.0U TE/TV 1.T. C. C.NADC+1. C	
4	TETTALISUSUIARU-TISU ADC-ADC±ATANITV/IARCITY)IN E_GNN/CDICA C±IN C_ADCN	00002010
	FIY3=ADC	00002020
	ADC=1.0	00002030
	$IF(UX_1 T_0,0) ARG=-1_0$	00002040
	$ARG = ARG + ATAN (UY/(ABS(UX)+1,F-8))/GR+GO_C+(1,O-ARG)$	00002050
	FIX4=SORT(UX+UX+UY+LY)	00002070
	FIX5=ARG	00002080
	WRITE(3,9010)P,FIX6,FIX1,FIX2,FIX3,FIX4,FIX5	00002050
C VER	DER:	00002100
1510	GO TO 14CO	00002110
1515	GO TC 1350	00002120
1520	WRITE(3,9001)	00002130
C NEX	(1:	00002140
1530	CONTINUE	000C2150
997	CONTINUE	00002160
	GO TO 999	00002170
998	kRITE(3,979)	000C21EC
999	CONTINUE	00002190
9999	WRITE(3,9998)	00002200
	STOP	00002210
969	FURMAIL'1',//, T63, PROGRAM WITA-SRT',/, T53, SIMPLIFIED THEORY OF	00002220
	SRULLING CLNIACI',/,164, BY J.J. KALKER',/,156, MCDIFIED AT CLEMSON	
04.0	DUNIVERSITY \$/\$101, UEPT. UP MECH. ENGR. \$/\$166, ULEMSON, SC \$//)	00002240
202 070	- FUNITHIN/////)DDスッ*ササササー INPUL PAKAMELEKS サササササ***///) - FUDMAT/16Y, INCONALIZED CONTACT DIMENSIONS	00002250
710		00002260
	+ H-H+ZOLA U-DIZULA HEENC UI-JWNITHITDIZY'Y/YJZAY'YUAKU #27" \$-11X+*R=4-10F11_4_1CX_V(A1_R1 ARF ACTUAL CONTACT DINENCTONS+ //	00002270
	S 30X. PETSSON S RATIO NUL=1. 10F11_4_1.33Y. 1/CADD #21	00002200
:	\$*•//•28X•*LAYER STIFFNESSES 1.XN=*•19F11_4-/-33x•*(CARD #2)*-	00002300
	\$ 8X, 1LYN= 1, 1PE11.4./)	00002310
972	FORMATE 26X, NUMERICAL CONSTANTS NX= , I3, /, 31X, (CARD #3),	00002320

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\$11X, "NY=", I3, /, 51X, "DM=", 1PE11.4, /, 51X, 00002330 \$*NF=*,I3,10X,*(NF=1,FORCES COMPUTED; NF=2,MCMENTS COMPUTED)*, 00002340 00002350 \$/.51X. \$'NS=',I3,10X,'(NS=1, FULL OUTPUT; NS=2 ONLY FORCES OR MOMENTS)',/ 0)002360 00002370 \$///) FORMAT(47X, ***** PARAMETERS COMPUTED AND USED IN FRCGRAM ****** 00002380 973 15X, CREEPAGE AND SPIN COEFFICIENTS Cll=*,1PE11.4,/, 00002390 \$,//, \$50X, *C22=*, 1PE11.4, /, 50X, *C23=*, 1PE11.4, /, 50X, *C33=*, 1PE11.4, //, 00002400 \$21X, NORMALIZED SHEAR MODULUS GS=', 1PE11.4, //, 15X, - _____OCCC2410 **\$NORMALIZED INVERSE STIFFNESSES** SXN=", 1PE11.4,/,50X, "SYN=", 00002420 \$1PE11.4.////// 00002430 FORMAT(42X, ***** NV2=*, I2, * DISTINCT PROBLEMS FOLLOW FOR DIFFERENOGOOC2440 974 \$T *****,/,45X,****** VALUES OF NORMALIZED CREEPAGE AND SPIN *****00002450 \$1,//) 00002460 975 FORMAT(//,17X, NORMALIZED CREEPAGE AND SPIN UXN=",1PE11.4,/, 00002470 \$23X,"(INPUT ON CARC #5)", 00002480 \$ 9X, "UYN=", 1PE11.4, /, 5CX, "PFN=", 1PE11.4, //) 00002490 977 FORMAT(24X, NORMALIZED FORCES ARE FXN=*,1PE11.4,/,29X, 00002500 \$*(COMPUTED)*,11%,*FYN=*,1PE11.4,//,24%,*RESULTANT FGRCE 000C2510 \$RES= ', 1PE11.4, /, 24X, '(RES= SCRT(FXN**2+FYN**2)) ', //) 00002520 978 FORMATE 25X, 'NORMALIZED MOMENT IS MZN=*,1PE11.4,/, 00002530 \$30X, *(COMPUTED) *,//) 00002540 FCRMAT(//.58X, ***** A/B LESS THAN 0.1 ******/./. 979 00002550 \$58X, ****** WORK NEXT PROBLEM ****** //) 00002560 9001 FORMAT(1H1) 00002570 FORMAT(//,53X,***** CONTACT REGION FOLLOWS ******,/, 9004 00002580 \$10X, X AND Y ARE NORMALIXED COORDINATES, X IN THE ROLLING ./. 00002590 \$10X, DIRECTION, X, Y=X1/C1, Y1/C1 WHERE X1, Y1 ARE DIM. COORD. ,/, 00002600 \$10X, TZN=HERTZ STRESS =3/(2*PI)*SQRT(P), FOR REFERENCE ONLY",/, 00002610 \$10X, TZK=KALKER NCREAL STRESS AS ASSUMED IN THE PROGRAM ./, 00002620 \$10X, *TZK=F*A*A1(Y)*P, FCR X.GE.U.9*L(Y)*,/, 00002630 \$10X, *TZK=F*A*(SGRT(P)+B1(Y)), FOR X.LE.C.9*L(Y)*,/, 0002640 \$10X, WHERE P=1.C-X*X/(A*A)-Y*Y/(B*B), L(Y)=A*SQRT(1.C-Y*Y/(B*E)), 00002650 \$/,10X, *A1(Y)=C.5/SCRT((1.0-Y*Y/(B*B))*(1.0-(C.9)**2))*,/, 00002660 \$10X, 'B1(Y)=-C.25/A1(Y), F*A=C.656773, SUCH THAT RES NCRMAL FORCE=1'00002670 \$,/,10X, TX AND TY ARE NORMALIZED SHEAR STRESSES',/,10X, TX=-TAUXZ*00CC2680 \$C**3/(RHE*N), TY=-TALYZ*C**3/(RHE*N)*,/, 00002690 \$10X, ABS(TX, TY) LESS THAN TZK FOR NO SLIP, EQUAL TO TZK FOR SLIP', OCOC2700 \$/,10X, VX,VY ARE NGREALIZED SLIP COMPONENTS, VX=VX1/V*RHC/(MU*C)*,00C02710 \$/,10X, VY=VY1/V*RH0/(MU*C), WHERE VX1, VX2=REL. VEL. BETWEEN ,/,10X0GCC272C 00002730 \$, *ADJACENT PCINTS AND V=ROLLING VEL. *,//// 00002740 9005 FORMAT(1H) FORMAT(1X, ***** Y=*, 1F11.4) 00002750 9006 FORMAT(10X, AT Y= , 1F11.4, 5X, THE LEADING EDGE SLIFS') 00002760 9007 FORMAT(10X, "AT Y=", 1F11.4, 5%, "THE LEADING EDGE STICKS") 00002770 9008 FORMAT(7X, "X", 9X, "TZH", 9X, "TZK", 5X, "ABS(TX, TY)", 1X, "ARG(TX, TY)", 0)002780 9009 00002790 1X, *ABS(VX, VY)*, 1X, *ARG(VX, VY)*) \$ 00002800 9010 FORMAT(1CF11_4) 00002810 FORMAT(///16+ INPUT EXHAUSTED///) 9998 00002820 END

NAAK 2

	SUBRGUTINE MAAKZ(P,C,WZ,DZ,C2Z,A,B,MUZ)	00002830
C	MAAKZ COMPUTES THE NORMAL STRESS AS GIVEN BY EQUATION 14-111	00002840
C	AW=L(Y) GF EQ. 14.III	00002850
C	WZ=TZK=ASSUMED NCRMAL STRESS OF EC. 14.III	00002860
C	DZ= FIRST DER. OF TZK WITH RESPECT TO X	00002870
	REAL MUZ	00002880
	AL=0.9	00002890
•	S=SORT(1-0-AL*AL)	00002900
	$AW = A + SORT(1 \cdot C - C + C/B/E)$	00002910
-	PT=3-1415926536	00002920
•	F = MU7 * PI/2 + G/A/(ATAN(A1/S) + 12 + 0/3 + 0 + A1 + A1 + A1 + A1/3 + (1/S)	00002930
	IE(P_LE_AL #AW) GG TG 10	00002940
		00002910
	NZ-FT VANTAN TTF//200/AN/3 NZ-E±0/A¥/C	00002950
		00002980
		00002970
		00002980
10	WZ=F#SQRT(AW#AW-P#P)-F/2.0*AW#S	00002990
	IF(ABS(AW).EQ.ABS(P)) GC TC 12	00003000
	DZ=F*P/SQRT(AW*AW-P*P)	00003010
	GO TO 11	00003020
12	DZ=1.0	00003030
11	RETURN	00003040
	FND	00003050

	SUBROUTINE ROL(CS,GEL,MUZ,NX,NY,X,Y,VX,VY,G,FX,FY,MZ)
	REAL NUZ.WZ.K.NU
	INTEGER PIJL
	REAL LE(81)
	INTEGER E(81)
	COMMON A, E
	CIMENSION X(81,81),Y(81,81),VX(81,81),VY(81,81),
	\$ G(81,10),CS(3),GEL(5)
	UX=CS(1)
	UY=CS(2)
	PH=CS(3)
	DM=GEL(5)
	SX=GEL(1)
	SY=GEL(2)
	A=GEL(3)
	8=GEL(4)
	H=A/FLUAT(NX)
	K=B/F(CAI(NY)
	PI=3.1415926536
380	J=J+L
	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -
	LE(J+NY+1)+A+5QKI(1+0-FLUAI3J+J//FLUAI(N////FLUAI(N////FLUAI
	F-LEIJTNITI/ F/IANVAII-D CC±D/F
401	
	IF(I_GT_NX)GC TO 200
	IF(I.LTE(J+NY+1).CR.I.GT.E(J+NY+1))G0 TC 15
	GO TC 10
15	VY(I+NX+1,J+NY+1)=C.C
	VX(I+NX+1,J+NY+1)=0.C
	Y(I+NX+1,J+NY+1)=C.C
	X([+NX+1,J+NY+1]=C.C
10	GO TO 401
200	CONTINUE
	DC 20 $I=1,10$
20	$G(J+NY+1,I)=-3 \cdot C + A$
	GO TO 380
100	CONTINUE
	IF(UX-PHTB-GE-G-GJ IHV=1-0 The TheATANGER (ADDALLY OUTDIAL C OONLOT(2 OT() OT()
~	1HV=1HV*A1AN(UV/(ABS(UX-PH*E)*1+E-U8))+P1/2+U+(1+U+1HV)
6	
. 70	
410	J=J+1 TE(1 CT NY=1)CC TC 300
	C=.i*K
	$P = \{F_i\}_{i=0}^{N}$
	PG=P
	CUX=UX-PH+Q
	PIJL=2
	CUY=UY+PH*P
	CALL MAAKZ(P,Q,ZN,CZ,CZP,A,E,MUZ)
	XG=0.0
	YG=0.0
	XV=0.0

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	TV=0.C	00003646
	VV=C•C	00003650
	I=E(J+NY+1)	00003660
	G(J+NY+1,1)=1.C	00003670
	IF(CZ*CZ-CUX*CUX/SX/SX-CUY*CUY/SY/SY.GT.G.C) GD TC 1001	00003680
C	SLIP AT THE LEADING EDGE. DETERMINE THETA.	00003690
-	$G(1+NY+1+1) = -1 \cdot G$	00003700
		00003700
		.000013710
	1+(CUX-GE+U+U) 1=1-C	00003720
	T=1*ATAN(CUY/(AES(CUX)+1.E-C8))+P1/2.0*(1.0-T)	0,0003730
C BEP	T	00003740
1002	S=SIN(T)	00003750
	C=CES(T)	00003760
		100003770
		000003700
		00003780
	I = (ABS(NU) - GI - I - E - G3) GC = U = 1002	00003790
	THV≖T	00003800
·	C=COS(T)	00003810
·	S=SIN(T)	00003820
ſ	THE STARTING VALUE OF THAS BEEN FOUND. THE	00003830
c	OPDIVATING THESE CF FINDS CERTICADE THE	00003030
6	DERIVATIVE 15 DETERFINED IN A SPECIAL WAT.	00003040
	1P={PH*C+C2P*{SX-SY}*C*S}/{CUX*C+CUY*S-C2*{{3.0*C*C-1.0}*{SX-SY}}	00003850
	\$ -SX}}	00003860
C NEX	TGL	00003870
1003	D=-DM	00003880
	$IE(P-DM_{+}IE_{+}T*H+1_{+}E-C6)$ $D=I*E-D$	00003890
		00002900
		00003900
		00003910
	IN=1+D*TP	00003920
	S=SIN(TN)	00003930
	C=CQS(TN)	00003940
	CUY=UY+PH*PN	00003950
	TPN=(())+C-()+C-()+C+()+()+()+C+()+C+()+C+()	0.00003960
		01003030
		00003970
	S=SIN(T)	00003986
	C=CUS(T)	00003990
	XN=ZN+C	00004000
	YN=ZN*S	00004010
	V=CUX+SY+C+CUY+SX+S+CZ+SX+SY	00004020
	$IE(V_{0}GE_{0}-4_{0}E-05)$ GC TC 1004	00004030
		000004040
	HIT-VV/XVV-V/ TETADETNIXX AT 1 E 103 AN-0 0	
	$IF(ADS(VV)) LI \bullet I \bullet E - IC) A = 0.9$	00004050
	VV=0.0	00004060
	AV=1.C-AN	00004070
	G(J+NY+1,PIJL)=AV+P+AN+PN	00004080
	PG=G(J+NY+1.PT.11)	00004050
		00004100
		00004100
	rtru Tridi ci ici di la c	00004110
	IFIFIJL-UI-IUJPIJL=10	00004120
	XV=AV+XV+AN+XN	00004130
	XG=XV	00004140
	YV=AV+YV+AN+YN	00004150
	YG=YV	00004160
	GO TO 1006	00004100
1004		00007170
1004		
L	SLIP IN INT NEW PLINI	00004190
	XV=XN	00004200
	YV=YN	00004210

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	Ρ=ΡΛ	00004220
C C: LI		000004230
		00004250
1005		00004240
	1F(F•01•1*H+1•E-(C) & 10 1003	000004250
	X { I + N X + I • J + N Y + I J = XN	00004280
	¥{1+NX+1,J+NY+1}=¥N	00004270
	XP=-ZN*S*TP-CZ*C	00004280
	YP=ZN*C*TP-CZ*S	00004290
	VX(I+NX+1,J+NY+1)=CUX+SX*XP	00004300
	VY(I+NX+1,J+NY+1)=CUY+SY*YP	00004310
	VV=V	00004320
	I = I - 1	00004330
	IF(I.LTE(J+NY+1)) GC TO 1007	00004340
	GO TO 1003	00004350
C ADH		00004360
1.1.11	T=-1.0	00004370
10.01	TE / CH Y CT C AN T+1 C	00004340
	- IF (UUAGUIGUGU) (-160 - TUV- TAATANI/UVADUGO)//ADC/C1VAA1 E00114014/1 0TV/2 0	00006300
	INV=1+A1AN((U)+PD+P)/(ADS(UUA)+1.6E=UC))+P1+(1.6U=()/2.6U	00004390
L AUH		
1006	PN=I+F	00004410
	XN=CUX+(PG-PN)/SX+XC	00004420
	YN=(UY+0.5*PH*(PG+PN))*(PG-FN)/SY+YG	000C443C
	CALL MAAKZ(PN,G,ZN,CZ,CZP,A,E,MUZ)	00004440
	v=ZN-SQRT(XN+XN+YN+YN)	00004450
	IF(V.GE.(-4.E-05)*MUZ)GO TO 1008	00004460
	$\Delta N = VV / (VV - V)$	00004470
	F(ABS(VV), T, T, T, F-1C) $AN=0.5$	00004480
		00004490
		00004500
	r=Av+rtAr+rN Clubblin Dt 11)=C	00004510
		00004520
	VV=0.C	00004520
	PIJL=PIJL+1	00004530
	XV=AV*XV+AN*XN	00004540
	YV=AV+YV+AN+YN	00004550
	IF(PIJL.GT.10) PIJL=10	00004560
	T=-1.0	00004570
	IF(XV.GE.0.0) T=1.0	00004580
	CUY=UY+PH*P	00004590
	$T = T \neq \Delta T \Delta N (YV / (ABS(XV) + 1 - F - 0.8)) + PI / 2 - 0 \neq (1 - C - T)$	00004600
		00004610
		00000000
	S = S IN (1)	00004630
	$\begin{array}{c} LALL FAAK_{L} F_{J} L_{J} L L_{J} L L L_{J} L L L L L L L $	
	GU TU 1005	00004840
1008	VV=V	00004650
	X(I+NX+1,J+NY+1)=XN	00004660
	XV=XN	00004670
	Y(I+NX+1,J+NY+1)=YN	00004680
	YV=YN	00004690
	VY(I+NX+1,J+NY+1)=C.C	00004700
	VX(I+NX+1,J+NY+1)=G.G	00004710
	I=I-1	00004720
	P=PN	00004730
	$1 \in (1 - 6 \in - \in (.1 + NY + 1))$ GO TO 1006	06064746
1007		00004750
2001	CONTINUE	00004760
500 C	THE ADDAVE ADE EILLEN THE TATENDALE ADE	00004700
	INE ARKATO ARE FILLEDO INE INTEURALO ARE Determiner	00004790
L	LEIEKAINEU T-4 Atviz C	
	1=4•U+N/3•L	00004790

No. of the second se

and the second s

in a firm of the	RCL	J.J.
	TN=2.C*K	00004800
	FX=0.0	00004810
	FY=0.C	00004820
	MZ=0.C	00004830
	YN=2.C*H	06664840
	J=-NY	00004850
940	J=J+1	00004860
	IF(J.GT.NY-1)GC TC 4CO	00004870
	I=E(J+NY+1)	00004880
	PIJL=I	00004890
	P=(LE(J+NY+1)-I*H)/2.0-H/3.C	00004900
	YP=J≠K	06664916
	C=P*(X(I+NX+1,J+NY+1)+X(NX+1-I,J+NY+1))	00004920
	S=P*{`Y{I+NX+1,J+NY+1}+Y{NX+1-1,J+NY+1}}	00004930
	D=P*I*H*(Y(I+NX+1,J+NY+1)-Y(NX+1-1,J+NY+1))	00004940
	P=2.0+H/3.C	00004950
	I=-PIJL-1	00004960
500	I=I+1	00004970
	IF (I.GT.PIJL)GC TC 550	00004986
	C=C+P*X(I+NX+1,J+NY+1)	00004990
	D=D+P+I+H+Y(I+NX+1,J+NY+1)	00005000
	S=S+P+Y{I+NX+1,J+NY+1}	00005010
	P=YN-F	00005020
	GO TO SOC	00005030
550	FX=FX+T*C	00005040
	FY=FY+T*S	00005050
	MZ=MZ+T*(D-YP*C)	00005060
	T = T N - T	00005070
	GO TO 940	00005080
100	CONTINUE	00005090
	RETURN	00005100
	END	00005110

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CENST

SUBRUUTINE CUNST(A, E, NU, CII, C22, C23, C33, GS)	00005120
DIMENSION AL(5),BE(5),D(15),E(15,20),AR(20),CNT(5),D1(15,9),	00005130
\$D2(15,9),C3(15),C4(15)	00005140
***** DATA E(I,J) GIVES LINEAR CREEPAGE AND SPIN COEFFICIENTS***	*00005150
****ANC GS FRCM KALKER REPORT TABLE 1 **********************	00005160
**** VALID FOR A/F GREATER THAN OR FOULAL TO 0.1	00005170
REAL NI	00005180
	00005160
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	000005190
* 2.31, 3.31, 4.83, 2.31, 2.32, 2.33, U.334, U.4/3, U./31, 0.42,	00005200
\$ 8-28, IL.1, C.161G, G.5752, C.3835,	00005210
\$ 2.59, 3.37, 4.El, 2.59, 2.E3, 2.66, 0.483, C.603, 0.809, 3.46,	00005220
\$ 4.27, 5.66, 0.56C8, 0.4206, C.28C4,	00005230
\$ 2.68, 3.44, 4.8C, 2.68, 2.75, 2.81, 0.6C7, C.715, 0.889, 2.49,	00005240
\$ 2.96, 3.72, 0.4775, 0.3584, 0.2390,	00005250
\$ 2.78. 3.53. 4.82. 2.78. 2.88. 2.58. 0.720. 0.823. 0.577. 2.02.	00005260
\$ 2.32. 2.77. C. 4343. C. 3257. C. 2172.	00005270
	00000270
3 2 0 0 7 3 0 0 7 4 0 3 7 2 0 0 7 3 0 1 7 3 1 4 7 0 0 0 2 7 7 0 3 2 3 7 1 0 7 1 1 7 4 7 1 1 7 1 1 7 1 1 7 1 1 7 1 1 7 1 1 7 1 1 7 1 1 7 1 1 1 7 1	06065266
\$ 1.93, 2.22, C.4(89, U.3066, U.2044,	00005290
\$ 2.98, 3.72, 4.91, 2.98, 3.14, 3.31, C.53C, 1.03, 1.18, 1.56,	00005300
\$ 1.68, 1.86, C.3934, C.2950, C.1967,	00005310
\$ 3.09, 3.81, 4.97, 3.09, 3.28, 3.48, 1.03, 1.14, 1.29, 1.43,	00005320
\$ 1.50, 1.60, 0.3840, 0.2880, 0.1920.	00005330
\$ 3,19, 3,91, 5,05, 3,19, 3,41, 3,65, 1,13, 1,25, 1,40, 1,34,	00005340
\$ 1.37, 1.42, 0.3785, 0.2839, 0.1892,	00005350
	00005350
* 30279 40019 30129 30279 30249 30229 10239 10309 10319 10279	000055230
\$ 1.27, 1.27, U.3738, U.2018, U.1879/	00005370
	00005380
\$ 3.40, 4.12, 5.20, 3.40, 3.67, 3.58, 1.33, 1.47, 1.63, 1.21,	00005390
\$ 1.19, 1.16, C.375C, C.2812, C.1875,	00005400
\$ 3.51, 4.22, 5.30, 3.51, 3.81, 4.16, 1.44, 1.59, 1.77, 1.16,	00005410
\$ 1.11, 1.06, 0.3758, 0.2818, 0.1879,	00005420
\$ 3,65, 4,36, 5,42, 3,65, 3,59, 4,39, 1,58, 1,75, 1,94, 1,10,	00005430
\$ /1_04_0_\$54_0_3785_0_2835_0_1892_	00005440
	00005450
# 0.424 40747 JoJCY JOCK A 2000 A 1024	00003450
3 0 , 70 , 0 , 0 , 10	00005400
3 4.00, 4.72, 5.20, 4.00, 4.50, 5.04, 2.01, 2.23, 2.50, 1.01,	00005470
\$ 0.892, 0.751, 0.3934, 0.2950, 0.1967,	00005480
\$ 4.37, 5.10, 6.11, 4.37, 4.90, 5.56, 2.35, 2.62, 2.96, 0.958,	00005490
\$ 0.819, C.650, C.4CE9, C.3O66, O.2O44,	00005500
\$ 4.84, 5.57, 6.57, 4.84, 5.48, 6.31, 2.88, 3.24, 3.70, 0.912,	00005510
\$ 0.747, C.549, C.4343, C.3257, O.2172,	00005520
\$ 5.57. 6.34. 7.34. 5.57. 6.40. 7.51. 3.79. 4.32. 5.01. 0.868.	00005530
\$ 0.674. 0.446. 0.4775. 0.3584. 0.2390.	00005540
\$ 6 66. 7 78. 8 92. 6 96. 8 14. 9 70 6 72 6 42 7 96. 0 920	0000000000
# 00707 10109 00029 00709 00149 70179 30129 00039 10039 00209 * 0 401 0 341 0 5405 0 4304 0 3004/	00003330
D USDUIG USDUIG USDUIC, US4200g US2804/	00000000
UATA L3/	00005570
\$ 10.7, 11.7, 12.9, 10.7, 12.8, 16.0, 12.2, 14.6, 18.0, 0.795,	00005580
\$ 0.562, 0.228, 0.767C, C.5752, 0.3835 /	00005590
DATA D4/	00005600
\$ 11.08, 12.01, 13.10, 11.08, 13.38, 16.90, 13.72, 16.34, 20.20.	00005610
\$ 0.785, C.552, C.2CE, 0.7918, 0.5938, 0.3959/	00005620
DATA AR / 0.1.0.2.0.3.0.4.0.5.0.6.0.7.0.F.C.S.1.C.1.111111.	00005630
<pre></pre>	0000000000
ΔU	00003040 00006450
UU U 1-1917 DO 5 1-1 0	000000000
	00000060
E(1,J)=U1(1,J)	00005670
E(1,J+9)=D2(1,J)	00005680
E(I,19)=C3(I)	00005690

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CC	٨	S	T
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6	E(1,20)=D4(1)	00005700
	PI=3.14155	00005710
	RG=A/E	00005720
	IF(RG.GT.AR(20)) GC TO 14	00005730
	GO TC 15	00005740
14	SG=B/A	00005750
	GAM=ALOG(16.0/(SG*SG))	00005760
	C11=2.0*PI/(SG*(GAM-2.0*NU))*(1.0+(1.6137C6)/(GAM-2.0*NU))	00005770
	C22=((1.613706)*(1.0-NU))/(2.0*NU+GAM*(1.0-NU))	00005780
	C22=2.0*PI*(1.0+C22)/(SG*(2.0*NU+GAM*(1.0-NU)))	00005790
	C23=2.C*FI/((SCRT(SC)*SC*3.C)*((1.O-NU)*GAM-2.O+4.C*NU))	00005800
	C33=P1/4.0*{GAM*{1.C-2.0*NU}-2.0+6.0*NU}/{GAM*{1.O-NU}-2.0+4.0*NU}	00005810
	GS=3.0*(1.0-NU)/(4.C*PI*SQRI(SG))	00005820
	GO TO 80	00005830
15	CC 20 I=2,20	00005840
	IF(RG.LE.AR(I)) GC TO 25	00005850
2J	CONTINUE	00005860
25	J=I	00005870
	DO 30 I=1,15	00005880
30	D(I)=E(I,J-1)+(E(I,J)-E(I,J-1))*(RG-AR(J-1))/(AR(J)-AR(J-1))	00605890
	DO 40 I=1,5	00005900
	AL(I)=8.C*(C(3*1)-2.C*C(3*I-1)+D(3*I-2))	00005910
	BE([)=2.C*(-D(3*I)+4.C*D(3*I-1)-3.C*D(3*I-2))	00005920
40	CNT(I)=AL(I)*NU**2+EE(I)*NU+C(3*I-2)	00005930
	C11=CNT(1)	00005940
	C22=CNT(2)	00005950
	C23=CNT(3)	00005960
	C33=CNT(4)	00005970
	GS=CNT(5)	00005980
80	CONTINUE	00005990
•	RETURN	00060000
	END	00006010

PRCGRAM WITA-SRT SIMPLIFIED THEORY OF ROLLING CONTACT BY J.J. KALKER MODIFIED AT CLEMSON UNIVERSITY DEPT. GF MECH. ENGR. CLEMSON, SC

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***** INPUT PARAMETERS *****

NORMALIZEC CONTACT CIMENSIONS (CARD #2)	A= 2.5980E+00 B= 3.8490E-01	(A=A1/C1, B=B1/C1, WHERE C1=SQRT(A1*B1), (A1,B1 ARE ACTUAL CONTACT DIMENSIONS
PCISSON S RATIO (Card #2)	NU= 2.8000E-01	
LAYER STIFFNESSES (CARC #2)	LXN= 0.0 LYN= 0.0	
NUMERICAL CONSTANIS (CARD #3)	NX= 10 NY= 10 DM= 4.000C0E-02 NF= 1 NS= 1	(NF=1,FGRCES COMPUTED; NF=2,PCMENTS COMPUTEC) {NS=1, FULL CUTPUT; NS=2 ONLY FORCES OR MOMENTS}

***** PARAMETERS COMPUTED AND USED IN PROGRAM *****

CREEPAGE AND SPIN CCEFFICIENTS	C11= 9.2721E+00 C22= 9.9975E+00 C23= 9.6258E+0C C33= 5.56C4E-01		
NURMALIZED SHEAR MCDULUS	GS= 4.5572E-01		
NORMALIZED INVERSE STIFFNESSES	SXN= 1.6396E+00 SYN= 1.5206E+00	•	

***** NV2= 1 DISTINCT PROBLEMS FOLLOW FOR DIFFERENT ***** ***** VALUES OF NORMALIZED CREEPAGE AND SPIN *****

NORMALIZEC CREEPACE AND SPIN (INPUT ON CARD #5)	UXN= 0.0 UYN=-1.40C0E+00 PHN= 8.00C0E-01
NORMALIZED FORCES ARE (COMPUTED)	FXN= 8.9034E-07 FYN=-3.4703E-01
RESULTANT FORCE (RES=SQRT(FXN**2+FYN**2))	RES= 3.4703E-01

******* CONTACT REGION FOLLOWS ******* X AND Y ARE NORMALIXED COORDINATES, X IN THE ROLLING DIRECTION, X, Y=X1/C1, Y1/C1 WHERE X1, Y1 ARE DIM. COORD. TZN=HERTZ STRESS =3/(2*PI)*SCRT(P), FOR REFERENCE ONLY TZK=KALKER NORMAL STRESS AS ASSUPED IN THE FROGRAM TZK=F*A*ALLY)*P, FOR X.GE.C.S*L(Y) TZK=F*A*(SQRT(P)+B1(Y)), FCR X.LE.O.S*L(Y) WHERE P=1.0-X*X/(A*A)-Y*Y/(B*B), L(Y)=A*SQRT(1.0-Y*Y/(B*B)) A1(Y)=0.5/SQRT((1.0-Y*Y/(E*B))*(1.0-(0.9)**2)) B1(Y)=-0.25/A1(Y), F*A=C.656773,SUCH THAT RES NORMAL FORCE=1 TX AND TY ARE NORMALIZED SHEAF STRESSES TX=-TAUXZ*C**3/(RHO*N), TY=-TAUYZ*C**3/(RHO*N) ABSITX, TY) LESS THAN TZK FOR NO SLIP, EQUAL TO TZK FOR SLIP VX, VY ARE NURMALIZED SLIP COMPONENTS, VX=VX1/V*RHO/(MU*C) VY=VY1/V*RHQ/(MU*C), WHERE VX1,VX2=REL. VEL. BETWEEN ADJACENT POINTS AND V=ROLLING VEL.

AT	¥=	0-3464	THE	LEADING	EDGE	STICKS
AT	¥=	0.3079	THE	LEADING	EDCE	STICKS
AT	¥=	0.2694	THE	LEADING	EDGE	STICKS
AT	¥=	0.2309	THE	LEADING	EDGE	STICKS
AT	Y=	0.1924	THE	LEADING	EDGE	SLIPS
A T	¥=	0.1540	THE	LEADING	EDGE	SLIPS
AT	Y=	0.1155	THE	LEADING	EDGE	SLIPS
A T	¥=	0.0770	THE	LEADING	EDGE	SLIPS
AT	Υ=	0.0385	THE	LEADING	EDGE	SLIPS
AT	¥=	0.0	THE	LEADING	EDGE	SLIPS
AT	¥=	-0.0385	THE	LEADING	EDGE	SLIPS
AT	¥ =	-0.0770	THE	LEADING	ECGE	SLIPS
AT	¥=	-0.1155	THE	LEADING	EDGE	SLIPS
AT	Y=	-0.1540	THE	LEADING	EDCE	SLIPS
A T	¥=	-0.1924	THE	LEADING	EDGE	SLIPS
AT	Y=	-0.2309	THE	LEADING	EDGE	STICKS
A T	¥=	-0.2694	THE	LEADING	EDGE	STICKS
AT	¥=	-J.3079	THE	LEADING	EDGE	STICKS
A T	Y=	-0.3464	THE	LEADING	EDGE	STICKS

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**** Y=	Ŭ . 3464					38
Χ ·	TZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABS (VX,V)	ARG(VX,VY)
-1.0392	0.0827	0.0514	0.0514	261.5010	3.3606	261.5010
-C.7794	0.1510	0.1453	C.1453	260.1367	2.5782	260.1367
-0.5196	0.1849	0.1920	0-1920	258.2253	2.1538	258.2253
-0.2598	0.2026	0.2163	0-2163	255.5179	1.7885	255.5178
0-0	0.2081	0.2239	0-2235	251.7460	1-4411	251.7460
(-2598	0.2026	0.2163	0-2163	246.7664	1-0954	246-7667
0.5196	0.1849	0.1920	0-1920	240. 7860	0-7374	240.7860
C.7794	0.1510	0.1453	0-1263	233-5065		0.0
1_0392	0-0827	0.0519	6-6273	223.4534		0.0
100572	010021		Cett 17	22307737	U= U	0.0
**** Y=	0.3079					
Х	T ZH	TZK	ABS(TX,T	Y) ARG(TX.TY)	ABS (VX .V	ARG(VX.VY)
-1.2990	0.1584	0.1319	C-1319	263.0781	3.3061	263-0781
-1.0392	0.2135	0.2078	C-2078	262.0066	2.8105	262-0066
-0.7794	0.2481	0.2554	0.2554	260-4182	2,4291	260-4182
-0.5196	0.2701	0.2856	0.2856	257.9551	2.0834	257.0551
-0 2508	0.2825	0.3027	0 3027	254 1517	1 7515	256 1517
0.200	0 2065	0 3003	Ve2021	4J7#1J1# 340 E217	1 / 210	22781211
	0.2005	0.3037	0.3002	240.0005	1.4219	240.0331
6.2058	0.2701	0.3021	0.3021	240.8223	1.0879	240.8285
(.5190	0.2701	0.2000	0.2850	231.2778	0.1493	231-2118
6.7794	0.2481	0.2554	0.1864	217.7482	0.0	0.0
1.0392	0.2135	C.2078	0.1032	197.7118	0.0	0.0
1.2990	0.1584	0.1319	0.0496	172.2837	0.0	0.0
1.5588	0.0002	0.0000	0.0	0.0	0.0	0.0
****	0 2606					
***** 1÷	U-2094	T 7 V	ADCITY T		ADC (MY M	
1 5500	140	0 1531	ADSLIAN	1/ AKGELAJII	AD3 (VA ; V)	11 ARG(VA;VI)
-1,5588	0.2/25	0.1321	0.1521	204+4822	3.3182	204.9022
-1.2990	0.2435	0.2321	0.2321	203.0903	3-0991	203.0503
-1.0392	0-2825	0.2863	0-2863	262.4902	2. 1211	262.4502
-0.1194	0.3094	0.3234	0.3234	260.5039	2.3791	266-5039
-6.5196	0.3213	0.3480	0.3480	257.2070	2.0507	257.2070
-0.2598	0.3376	C.3622	0.3622	251.9587	1.7242	251.9587
G • 0	0.3410	0.3668	3336	244.1799	1.3885	244.1798
C.2598	0.3376	C.3622	0.3622	233.6683	1.0382	233.6683
C.5196	0.3273	0.3480	0.2846	219.0531	0.0	0.0
C.7794	0.3094	0.3234	0.1855	196.2500	0.0	0.0
1.0392	0.2825	0.2863	0.1385	167.1360	00	0.0
1.2990	0.2435	0.2327	0.1150	143.1956	0 . C	0.0
1.5588	0.1849	0.1521	6.0792	128.2595	0.0	0.0
1.8186	0.0675	0.0211	0.0125	119.2185	0.0	0 • C
م حامية م	* ***					
**** * ¥∞	U-23U9		100171		100 1100 10	
X	I ZH	1ZK	ABSTIX,I	Y] ARG(1X,1Y]	ARS (AX + A)	ARGEVX,VYJ
-1.8186	0.1849	0.1399	C.1399	265.6860	3.9349	265.6860
-1.5588	0.2527	0.2330	0.2330	265.1428	3.415C	265.1428
-1.2990	0.2982	0.2956	0.2956	264.3091	3.0261	264.3091
-1+0392	0.3308	0.3405	0.3405	262.8872	2.6793	262.8872
-C.7794	0.3541	0-3726	0.3726	260.3867	2.3505	260.3867
-0.5196	0.3698	0.3942	0.3942	256.1316	2.0266	256.131 <i>€</i>
-C.2598	0.3790	C.4068	6.4068	249.3674	1.6948	249.3674
0.0	0.3820	0.4109	0.4105	239.5138	1.3409	239.5138
C.2598	0.3790	C.4068	0.3707	225.91(9	0.0	0-0
C.5196	0.3698	0.3942	0.2403	203.0654	0.0	0.0
C•7794	0.3541	0.3726	0.1872	169.7594	0.0	6.0
1.0392	0.3308	0.3405	C.1876	141.7920	0.0	0.0
1.2990	0.2982	0.2956	G.1896	125.6612	0. C	0.0
1.5588	0.2527	0.2330	C.1648	116.5637	0.0	0.0
1.8186	J.1849	0.1399	0.1029	110.9889	0.0	C . C

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**** Y=	0.1924 T 74	* 74	ADC/TV T	VI ADOLTY TVI		39
2 0 7 0 /	1 4 0	125	PC311A11	1) ANGLIAJII)		11 MRGLVA9VIJ
-2.0184	U - 1204	0.0939	0.0939	200.1043	4.4277	200.1493
-1.0100	0 209 2	0.2009		200-3412	3.7/5/	200.0472
-1-2000	0.2782	0.2662		202.0178	2. 2470	202.0198
-1.2990	0.3376	0.3404	0.3404	204-9233	2.9870	204-9233
-1.0392	1006.0	0.3805	0.3805	263.2856	2.6536	263.2856
-0.1194	0.3879	0.4096	0.4096	260.3276	2.3308	260.3276
-0.5156	0.4023	0.4254	0.4294	255.2953	2.0065	255-2953
-C.2598	0.4107	0.4410	0.4410	247.4055	1.6657	247.4095
C • C	0.4135	C.4448	0.4448	236.1813	1.2922	236-1813
0.2598	J.41J7	0.4410	0.2952	217.1355	0.0	0.0
C•5196	0.4023	0.42.54	0.2047	181.6965	0.0	C.O
0.7794	0.3879	0-4096	0.2120	145.0798	0.0	0.0
1.0392	ܕ3667	0.3805	0.2493	125.0430	0.0	0.0
1.2990	0.3376	0.3404	C.267C	114.9075	0-0	0.0
1.5588	0.2982	0.2862	0.2493	109.1405	0.0	. C.O
1.8186	0.2435	0.2109	C.1911	105.4884	0.0	0.0
2.0784	0.1584	0.0957	0-0904	102.9887	0.0	C • C
(**** Y=	0-1540					
X	T 7H	T7K	ABSETY-T	Y) ARG(TY.TY)	ABS (VX-V	Y) ARGEVX-VYI
-2.0784	0.2135	0.1625	0.1625	267.3468	4, 1843	267:3405
-1 9196	0 2825	0 2574	0 2574	267 0269	2 6001	267 0786
-1 5599	0 2202 9	0.2014	0.2014	20100200	2 2069	20100200
-1,0000	U + 3300 1 - 2447	0.3733	0.02220	200,0026	2.0000	200.3326
-1-2990	0.2027	0.0133	0.5133	203.0232	2.9021	203.0292
-1.0392	0.3937	0.4104	0.4104	203.9319	2.0300	203.9319
-0.1194	0.4135	0.4370	0.4310	200.0030	2.3114	200.8038
-1.5156	0.4271	0.4362	0.4502	255.7028	1.9940	200.7688
-0.2598	0-4350	0.4672	0.4612	241.1152	1.6515	241-1152
C • C	0.4376	0.4708	0.3962	235.6525	0.0	0.0
0.2598	0.4350	C.4612	0.2275	208-9920	0.0	0.0
C.5196	0.4271	0.4562	0.1850	160.4578	0.0	0.0
_C.7794	0.4135	0.4376	C.2414	128.3532	0-0	0.0
1.0392	0.3937	0.4104	0.2995	114.7184	0.0	0.C
1.2990	0.3667	0.3733	C. 3261	107.9860	0.0	0.0
1.5588	0.3308	0.3238	C.3129	104.0802	0.0	C 🖕 C
1.8186	U.2825	C.2574	C-2573	101.5555	0.0	0.0
2.0784	0.2135	0.1625	0.1623	99.7412	0.0	0 . C
2.3382	0.0827	0.0247	0.0247	98.4557	0.0996	98.4598
**** /=	0.1155					<i>`</i>
Х	TZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABS (VX .V	ARG(VX.VY)
-2.3382	0.1510	0.0711	0.0711	268.1663	4.8506	268.1663
-2.0784	0.2481	0.2047	C.2047	267.99(2	4.0869	267.9902
-1.8186	0.3094	0.2891.	0.2851	267.7378	3.6488	267.7378
-1.5588	0.3541	0.35(5	0.3505	267.3147	3.2831	267.3147
-1.2990	0.3879	0-3970	0-3970	266.5255	2.5471	266-5255
-1.0392	0.4135	0.4322	0-4322	265-0417	2.6257	265-0417
-0.7794	0.4324	0.4582	0.4582	262.3855	2-3102	262.3895
-0.5196	0.4453	0.4761	0.4761	258-0063	1.9924	258 0663
-0 2508	0 4520	0 4945	6 4865	251 2702	1 6619	251 2702
(n	0 4666	0 4000	A 2207	239 2070	0.0	C 0
ι.υ Γ 3600	V - 7373 A Araa	0 4045	186500	23300010 206 7641		
L.Z.770 0 E104	0 4453 0 4453	V.440CJ 0 4744	Lall. 0 1225	2000 (441 122 57/7		0.0
U+2190	V•4473	U.4701	U.1043	117 6779		
U.1194	0.4324	U.4322	L.2710	11104252		0.0
1.0392	0.4135	0.4322	0.3206	107.0421	0.0	U•C
1.2990	0.38/9	0.3970	0.3525	102.9081	0.0	0.0
1.5588	J • 3544	0.3505	0.5422	106-1493	U• U	0.0
1.8186	0-3094	0.2851	0.2891	98.34(3	0.0273	98.3404
2.0784	0-2481	0.2047	C.2047	97.0455	0.1093	97.0495
2,3382	0.1510	0-0790	0_0790	96-1155	0-1288	96,1159

X						
	TZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABS (VX,V)) ARG(VX,VY)
-2.3382	0.1849	0.1141	0.1141	268.7739	4.6488	268.7739
-2.0784	0.2701	0.2313	C . 2313	268.6521	4-0376	268-6521
	0 2070	0.2100		200.0721	2 4240	260 60 221
-1.0100	0.3213	0.5100		200.4121	J. C243	200+4121
-1.5588	0.3698	0.3685	C-3685	268.1626	3.2686	268-1626
-1.2990	0.4023	0.4132	C•4132	267.5765	2.9373	267.5165
-1.0392	0.4271	0.4472	0.4472	266.4773	2.6189	266.4773
-0.7794	0.4453	0.4723	0.4723	264.53(8	2.3070	264.5308
-0.5196	0.4580	0.4897	C-4897	261.3451	1.5956	261-3491
- C 35C9	0.4554	0 4000	0 4666	254 5929	1 6790	256 5628
-0.2090	0.4054	0.5077				200.0020
G • J	0.46/8	0.5033	0.2951	241.0005	0. G	0.0
C •2598	U. 4654	0.4555	C.1167	208.0296	0.0	C • O
C•5196	0.4580	0.4897	0.1483	127.7151	0.0	0.0
(.7794	0.4453	0.4723	C.257C	107.7684	0.0	6.0
1-0392	0.4271	0-4472	C-3341	101.4152	0.0	0-0
1 2000	0 4023	0.4132	0.3655	98.3826	0.0	0.0
1.5500	0.7023	0.34132	0.2(12	50.JUZC		0.0
1.5588	0.3698	0.3025	C.3613	200022	0.0	0.0
1.8186	0.3273	0.3100	C.3100	95.44(2	0.0438	55.44(2
2.0784	0.2701	C.2313	C.2313	94.5983	0.1530	94.5983
2.3382	J-1849	0.1153	0.1153	\$3.9837	0.1473	93.9837
**** V=	0.0385					
·····	17U	T 7 4	APC/TV. T	ADCITY TV	ARSINY-W	
^	128	120	PESTINT		403(4×4×	AROLVANTI
-2.3382	0.2026	0-1362	C.1362	269.3855	4.5703	209-3857
-2.0784	U-2825	0.2461	0.2461	269.3232	4.C13J	269.3232
-1.8186	0.3376	0.3220	C.322C	265.23(0	3.6122	269.2300
-1.5588	J.379J	0.3789	0.3789	269.0657	3.2606	269.0657
-1.2990	0.4107	0-4226	0-4226	268,7522	2,9318	268.7532
1 0202	0.4250	0 4550	0 4550	749 1450	2 4154	269 1490
-1.0392	0.4550	0.4559	0.4009	200+1000	2.0104	200.1000
-0.1154	0+4530	C.4806	0.4806	267-1382	2.3059	267-1382
-0.5196	J.4654	0.4977	0.4977	265.4653	1.9999	265.4653
-(.2598	0.4727	0.5077	0.5077	262.9739	1.6942	262.9739
C.O	0.4751	0.5111	C.2654	257.3675	0.0	0.0
6.2598	0.4727	0.5077	0.0668	219-0571	0.0	0.0
	0 4464	0 /077	C 127C	100 2024	0.0	0.0
0.0190	V. 4024	0.4917	U+137C	109-3054		0.0
C.//94	0 . 453 0	0.4806	0.2005	98.14:3	U. U	0.0
1.0392	0-4350	0.4559	0.3415	95.6179	0•C	0.0
1.2990	0.4107	0.4226	C.3792	94.1317	0.0	C.C
1.5588	0.3790	0.3789	C-3722	93.2624	0.0	0.0
1,8186	0.3376	0.3220	0-3220	\$2.6877	0-0521	92-6873
1.0100	0 1925	0 3443	0 3661	02 07 19	0 17/1	02 2216
2.0784	0.2825	0.2401	0.2401	92.2110	0.1741	92.2110
2.3382	J-2J26	0.1363	0.1363	51.9682	0.1576	91.9662
**** Y=	Ü.O					
**** Y= X	0.0 Tzh	TZK	ABS(TX,T	Y) ARG{TX,TY)	ABS (VX, V) ARG(VX+VY)
₩####¥ X -2.3382	0 • 0 T Z H 0 • 208 1	TZK 0.1431	ABS(TX,T) C.1431	Y) ARG{TX,TY) -90.0000	ABS (VX, V) 4. 5484	/) ARG[VX+VY] -50.0000
++++ Y= X -2.3382 -2.0784	0.0 TZH 0.2081 0.2865	TZK 0.1431 0.2509	ABS(TX,T) C.1431 0.2505	Y) ARG{TX,TY) -90.0000 -90.0000	ABS (VX, V 4.5484 4.0056	<pre>/) ARG(VX+VY) -90+0000 -90+0000</pre>
₩### ¥= X -2.3382 -2.0784 -1.8196	0.0 JZH 0.2081 J.2865 0.3410	TZK C.1431 O.25C9 C.3255	ABS(TX,T) C.1431 0.2505 C.3256	Y) ARG{TX,TY) -90.0000 -90.0000	ABS (VX, V) 4.5484 4.0056 3.6082	<pre>/) ARG(VX+VY) -90.0000 -90.0000 -90.0000 -90.0000</pre>
**** Y= X -2.3382 -2.0784 -1.8186	0.0 TZH 0.2081 J.2865 0.3410	TZK C.1431 O.25C9 C.3259	ABS(TX,T) C.1431 O.2505 C.3259	Y) ARG(TX,TY) -90.0000 -90.0000 -90.0000	ABS (VX, V 4.5484 4.0056 3.6082	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588	0.0 TZH 0.2081 J.2865 0.3410 J.382J	TZK C.1431 O.25C9 C.3259 O.3823	ABS(TX,T) C.1431 O.2505 C.3259 O.3823	Y) ARG{TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581	<pre>/) ARG(VX,VY) - S0.0000 - S0.0000 - S0.0000 - S0.0000 - 50.0000 - 50.0000</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990	U.O JZH 0.2081 J.2865 0.3410 J.382J 0.4135	TZK C.1431 O.25C9 O.3259 O.3823 C.4256	ABS(TX,T) C.1431 O.2505 C.3259 O.3823 C.4256	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00C0 -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301	ARG(VX.VY) -50.0000 -50.0000 -50.0000 -50.0000 -50.0000
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392	U.O JZH 0.2081 J.2865 0.3410 J.382J 0.4135 U.4376	TZK C.1431 O.25C9 O.3259 O.3823 C.4256 O.4588	ABS(TX,T) C.1431 O.2505 C.3255 O.3823 C.4256 O.4588	Y) ARG{TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00C0 -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143	<pre>/) ARG(VX+VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000</pre>
x -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794	U • 0 JZH 0 • 208 1 J • 286 5 0 • 341 0 J • 382 J 0 • 413 5 U • 4376 0 • 455 5	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4588 O.4834	ABS(TX,T) C.1431 O.25C5 C.3255 O.3823 C.4256 O.4588 C.4834	Y) ARG(TX,TY) -SC.00CC -SC.00CC -9C.00CC -SC.00C0 -SC.00CC -9C.00CC -9C.00CC -90.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058	<pre>ARG(VX,VY) -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000</pre>
x -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196	U • 0 IZH 0 • 2081 J • 2865 0 • 3410 J • 382J 0 • 4135 0 • 4376 0 • 4555 0 • 4678	TZK 0.1431 0.2509 0.3259 0.3823 0.4256 0.4588 0.4588 0.4834 0.5004	ABS(TX,T) C.1431 O.25CS C.325S O.3823 C.4256 O.4588 C.4834 C.5CC4	Y) ARG(TX,TY) -SC.00CC -SC.00CC -9C.00CC -SC.00CC -SC.00CC -9C.00CC -90.00CC -90.00CC -90.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017	<pre>ARG(VX,VY) -S0.0000 -S0.0000</pre>
<pre>**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2568</pre>	U • 0 IZH 0 • 2081 J • 2865 0 • 3410 J • 382J 0 • 4135 0 • 4376 0 • 4555 0 • 4678 D • 4751	TZK 0.1431 0.2509 0.3259 0.3823 0.4256 0.4588 0.4588 0.4834 0.5004 0.5103	ABS(TX,T) C.1431 O.25C5 C.3255 O.3823 C.4256 O.4568 C.4834 C.5CC4 C.51C3	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003	<pre>ARG(VX+VY) -S0.0000 -S0.0000</pre>
<pre>***** Y=</pre>	U - 0 IZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4376 0 - 4555 0 - 4678 0 - 4751 0 - 4751	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4588 O.4834 O.50C4 O.51C3	ABS(TX,T) C.1431 O.25CS C.325S O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2565	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0	<pre>ARG(VX,VY) -S0.0000 -S0.000 -S0.0000 -S0.000 -S0.0000 -S0.000 -S0.000 -S0.0000 -S0.0000 -S0.0000 -S0.0000 -S0.0000</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0	U - 0 JZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4135 0 - 4555 0 - 4678 0 - 4751 0 - 4775	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4588 O.4588 O.4834 O.50C4 O.51C3 O.5126	ABS(TX,T) C.1431 O.25CS C.325S O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2548	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -9C.00CC -9C.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000</pre>
x -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C-0 C.2598	U - 0 JZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4135 0 - 4555 0 - 4678 0 - 4751 0 - 4751 0 - 4751	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4588 O.4588 O.4834 O.50C4 O.51C3 O.5126 O.51C3	ABS(TX,T) C.1431 O.25CS C.325S O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2548 O.C38C	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -9C.00CC -90.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -85.9958	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000</pre>
<pre>**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 G.2598 C.5196</pre>	U - 0 JZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4135 0 - 4555 0 - 4678 0 - 4751 0 - 4751 0 - 4751 0 - 4751 0 - 4678	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4588 O.4588 O.4834 O.50C4 O.51C3 C.51C3 C.5CC4	ABS(TX,T) C.1431 O.25C5 C.3255 O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2548 O.2548 O.38C O.1342	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000</pre>
<pre>x +*** Y= x -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 C.2598 C.0 C.2598 C.5196 C.7794</pre>	U - 0 JZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4376 0 - 4555 0 - 4678 0 - 4751 0 - 4751 0 - 4751 0 - 4751 0 - 4678 J - 4555	TZK C.1431 0.25C9 C.3259 0.3823 C.4256 0.4588 0.4834 0.50C4 0.51C3 C.51C3 C.51C3 C.5CC4 0.4834	ABS(TX,T) C.1431 O.25C5 C.3255 O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2548 O.C38C C.1342 O.2616	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SS.99S8 SC.00CC S0.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0 0.0 0.0	<pre>/) ARG(VX+VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 0.0 0.0 0.0</pre>
<pre>**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 C.2598 C.0 C.2598 C.5196 C.7794 L.C392</pre>	U - 0 JZH 0 - 2081 J - 2865 0 - 3410 J - 382J 0 - 4135 0 - 4376 0 - 4555 0 - 4678 0 - 4751 0 - 4751 0 - 4751 0 - 4751 0 - 4678 J - 4555 0 - 4376	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.51C3 C.51C3 C.5CC4 O.4834 C.4588	ABS(TX,T) C.1431 O.25C5 C.3255 O.3823 C.4256 O.4588 C.4834 C.5CC4 C.51C3 C.2548 O.C38C C.1342 O.2616 O.3443	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.70C3 0.C 0.C 0.C 0.C 0.0	<pre>/) ARG(VX+VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 0.0 0.0 0.0 0.0</pre>
<pre>**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 C.2598 C.0 C.2598 C.5196 C.7794 1.C392 1.2990</pre>	U.0 JZH 0.2081 J.2865 0.3410 J.382J 0.4135 0.4555 0.4678 J.4751 0.4751 0.4751 0.4751 0.4751 0.4678 J.4555 0.4376 J.435	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.51C3 C.51C3 C.51C4 O.4834 C.4588 O.4856	ABS(TX,T) C.1431 O.25C5 C.3255 O.3255 O.3256 O.4528 C.4256 O.4528 C.4834 C.50C4 C.51C3 C.2548 O.C38C C.1342 O.2616 O.3443 O.3824	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.70C3 0.C 0.C 0.C 0.C 0.C 0.C 0.C 0.C	<pre>/) ARG(VX+VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 0.0 0.0 0.0 0.0</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 C.2598 C.0 C.2598 C.5196 C.7794 1.C392 1.2990 1.5588	U.0 JZH 0.2081 J.2865 0.3410 J.382J 0.4135 0.4376 0.4555 0.4678 0.4751 0.4751 0.4751 0.4751 0.4751 0.4678 J.4555 0.4376 J.4355	TZK C.1431 0.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.51C3 C.51C3 C.51C3 C.51C3 C.50C4 O.4834 C.4588 O.4256 C.3823	ABS(TX,T) C.1431 O.25C5 C.3255 O.3255 O.3255 O.4256 O.4528 C.4834 C.5CC4 C.51C3 C.2548 O.C38C C.1342 O.2616 O.3443 O.3824 C.3757	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0 0.0 0.0 0.0 0.0 0.0	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 0.0 0.0 0.0 0.0 0.0 0.0 0.0</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 C.2598 C.0 C.2598 C.5196 C.7794 1.0392 1.2990 1.5588	U.0 JZH 0.2081 J.2865 0.3410 J.382J 0.4135 0.4376 0.4555 0.4678 0.4751 0.4751 0.4751 0.4751 0.4751 0.4678 J.4555 0.4376 J.4135 J.3820 0.210	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.51C3 C.51C3 C.51C3 C.51C3 C.4528 O.4834 C.4528 O.4256 C.3823	ABS(TX,T) C.1431 0.25C5 C.3255 0.3823 C.4256 0.4588 C.4834 C.50C4 C.51C3 C.2548 0.2616 0.3824 C.3757 C.2555	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0 0.0 0.0 0.0 0.0 0.0	<pre>ARG(VX,VY) -90.0000 -90.000 -90.</pre>
**** Y= X -2.3382 -2.0784 -1.8186 -1.5588 -1.2990 -1.0392 -C.7794 -C.5196 -C.2598 C.0 G.2598 C.5196 C.7794 1.C392 1.2990 1.5588 1.8186	U.0 JZH 0.2081 J.2865 0.3410 J.382J 0.4135 0.4376 0.4555 0.4678 J.4751 0.4751 0.4751 0.4678 J.4555 0.4376 J.4355 0.3820 U.3410	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.50C4 O.51C3 C.50C4 O.4834 C.4588 O.4256 C.3823 C.3259	ABS(TX,T) C.1431 0.2505 C.3259 0.3823 C.4256 0.4588 C.4834 C.50C4 C.51C3 C.2548 0.638C C.1342 0.2616 0.3443 0.3824 C.3757 C.3255	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0 0.0 0.0 0.0 0.0 0.0	<pre>/) ARG(VX,VY) -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 -90.0000 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0</pre>
<pre>**** Y=</pre>	U - 0 J ZH 0 - 208 1 J - 286 5 0 - 341 0 J - 382 J 0 - 413 5 0 - 4376 0 - 455 5 0 - 4678 J - 475 1 0 - 475 1 0 - 4678 J - 455 5 0 - 4376 J - 413 5 J - 382 0 0 - 341 0 0 - 286 5	TZK C.1431 O.25C9 C.3259 O.3823 C.4256 O.4588 O.4834 O.50C4 O.51C3 C.50C4 O.51C3 C.50C4 O.4834 C.4588 O.4256 C.3823 C.3259 O.25C9	ABS(TX,T) C.1431 0.2505 C.3255 0.3823 C.4256 0.4588 C.4834 C.50C4 C.51C3 C.2548 0.638C C.1342 0.2616 0.3443 0.3824 C.3757 C.3255 0.2505	Y) ARG(TX,TY) -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC -SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC SC.00CC	ABS (VX, V 4.5484 4.0056 3.6082 3.2581 2.9301 2.6143 2.3058 2.0017 1.7003 0.0 0.0 0.0 0.0 0.0 0.0 0.0	<pre>ARG(VX,VY) -90.0000 -90.000 -90</pre>

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**** Y=	-0-0385					41
×	ТZн	TZK	ABS(TX,T	Y) ARG(T),TY)	ABS (VX , V	Y) ARG (VX ,VY
-2.3382	0.2026	0.1362	C.1362	-89.3857	4.5703	-89.3857
-2.0784	0.2825	0.2461	0.2461	-89.3234	4.0131	-89.3234
-1.8186	0.3376	0.3220	0.3220	-89.2301	3.6122	-89.2301
-1.5588	0.3790	0.3789	C-3789	-89.0656	3.2606	-89.0656
-1.2990	0.4107	0.4226	0.4226	-88.7532	2.9318	-88.7532
-1.0392	0.4350	0.4559	C.4559	-88.1679	2.6154	-88.1679
-0.7794	0.4530	0.4806	0-4806	-87.1380	2.3059	-87.1380
-0-5156	0.4654	0.4977	C-4977	-85.4652	1.9999	-85.4652
-6-2598	0.4727	0.5077	0.5077	-82.9735	1.6942	-82.9735
6-6	0.4751	0.5111	0-2654	-77.3665	0.0	0.0
0.2598	J-4727	0.5077	0-0668	-39.0543	0.0	0.0
0.5156	0.4654	0.4977	6-1378	70-6146	0.0	0.0
0.7794	0-4530	0-4866	0-2605	81,2535	0-0	0.0
1.0392	0-4350	0.4559	0.3419	84-3813	0.0	0.0
1 2000	0.4107	0 4226	C.37C2	85.8676	0.0	0.0
1 6699	0.2700	0 2790	0 2722	96 7368	0.0	0.0
1.0100	0.2076	0.3220	0.3722	07 2120	0.0521	97 2120
1.8166	0.3310	0.3220		CI.JIZC	0.1741	01.0120
2.0784	J-2829	0.2401	0.2401	81.1210	0.1141	61.1210
2.3382	0.2026	0.1363	C+1363	88-0336	0.1576	88.0330
**** Y=	-0.0770					
x	T ZH	TZK	ABS(TX,T	Y) ARG(T),TY)	ABS (VX . V	Y] ARG(VX,VY
-2.3382	0.1849	0.1141	0.1141	-88.7741	4.6488	-88.7741
-2.0784	0.2701	0.2313	C+2313	-88,6521	4.0376	-88.6521
-1.8186	U-3273	0.3100	0.3100	-88.4728	3.6245	-88.4728
-1.5588	0.3698	0.3685	0.3685	-88.1628	3.2686	-88,1628
-1.2990	0.4023	0.4132	0.4132	-87.5770	2.9373	-87.5770
-1.0392	0.4271	0.4472	0.4472	-86.4774	2.6189	-86.4774
-0.7794	0.4453	0.4723	0.4723	-84.5309	2.3070	-84.5305
-6.5196	0.4580	0.4897	C.4897	-81.3451	1.9956	-81.3491
-0.2598	0.4654	0.4999	0.4999	-76.5824	1.6790	-76.5824
6.0	0.4678	0.5033	0.2951	-67,0059	0.0	0.0
6.2598	0.4654	0.4959	C.1167	-28.0250	0.0	0.0
0.5196	0.4580	0.4897	0.1483	52.2839	0.0	0.0
0.7794	0-4453	0.4723	C.257C	72.2309	0.0	0.0
1-0392	0.4271	0.4472	0-3341	78.5804	0.0	0.0
1.2990	0.4023	0.4122	0-3695	81-61 69	0_0	0.0
1 5588	0.369.8	0.3685	0.3613	83-3906	0.0	0.0
1 9196	0 2272	0.3100	0.3100	84.5553	0.0438	84.5552
1.0100	0.2701	0 2212	0 2212		0 1530	85 4013
2.0104	0 1940	0.1152	0.1153	86 0161	0.1473	86.0161
2.3382	U. 1049	V=1133	0.1199	60.01C1	0.1413	cose te I
*** Y=	-0.1155				100 (MN - V)	
X	12H	IZK	ADSTIX,	1) ARGUIX, TY)	AD2 (VX + V	TJ ΑΚΟΙVΧ9VY
-2.3382	0.1510	0.0711	0.0711	-88.1665	4.8506	-20.1000
-2.0784	0.2481	0.2047	0.2047	-87.9903	4.0869	-87.9903
-1.8186	0.3094	0.2891	0.2891	-87.7378	3.6488	-87.7378
-1.5588	0.3541	C•32C2	0.3505	-87.3148	3.2831	-87.3148
-1.2990	0.3879	0.3970	C.3970	-86.52€C	2. 5471	-86.5260
-1.0392	0.4135	0.4322	6.4322	-85.0418	2.6257	-85.0418
-0.1794	0.4324	0.4582	C.4582	-82.3900	2.3102	-82.3900
-C.5196	0.4453	0.4761	0.4761	-78.0063	1.9924	-78.0063
-C.2598	0.4530	0.4865	0.4865	-71.3700	1.6618	-71.3700
0.0	J.4555	0.4900	0.3397	-59.8068	C . C	0.0
C_2598	0.4530	0.4865	0.1707	-26.7440	0.0	0.0
C-5196	0_4453	0.4761	0.1645	35.4246	0.0	C. 0
C_7794	0-4324	6-4582	0.2510	62.5763	0.0	0.0
1 0202	0-4135	0-4322	0-3206	72.3575	0.0	0.0
1_0442	0, 2870	0_3970	0-3525	77.0915	0.0	C - 0
1.0392		~~~ ~ ~ ~ ~ ~			-	
1.0392 1.2990 1.5588	0-3541	0-3505	0.3422	79.8503	0. C	0.0

1 8186	A 2005 (1	0 2861	0.2861	81 6562	0 0273	81 6550
2.0784	0.2481	0.2047	$C_{-}2C47$	82.95(3	0.1093	82,9503
2.3382	0.1510	0.0790	0.0790	83.8840	0.1288	83.8840
**** Y=	-3.1543					
X	T ZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABS (VX, VY	() ARG(VX,VY)
-2.0784	U-2135	C.1625	0.1625	-87.3468	4.1843	-87.3408
-1.8186	0.2825	0.2574	0.2574	-87.0250	3.6901	-87.0290
-1.5588	0.3308	0.3238	C-3238	-86.5320	3.3068	-86.532C
-1.2990	0.3667	0.3733	0.3733	-85.6292	2.9627	-85.6292
-1.0392	0.3937	C.41C4	C.41C4	-83.9320	2.6366	-83.9320
-0.7794	J.4135	0.4376	0.4376	-80.8637	2.3174	-80.8637
-C.5196	0.4271	0.4562	C.4562	-75.7088	1.9940	-75.7088
-0.2598	0.4350	0.4672	0-4672	-67.7751	1.6519	-67.7751
C.O	0.4376	C-47C8	0.3962	-55.6524	0.0	0.0
C.2598	0.4350	0.4672	0-2275	-28.9918	0.0	0.0
C.5196	0.4271	0.4562	C.185C	19.5421	0.0	0.0
C.7794	0.4135	0.4376	C-2414	51.6465	0.0	0.0
1.0392	0.3937	0.4104	0.2995	65-2814	0 . C	0.0
1.2990	0.3667	0.3733	C.32E1	72.0138	0.0	0.0
1-5588	0.3308	0.3238	C.3129	75.9196	0 • C	C • C
1-8186	0.2825	0.2574	0.2573	78.4443	0.0	0.0
2.0784	0.2135	0.1625	0.1623	80.2587	0 • C	C • C
2.3382	0,0827	0.0247	0.0247	81.5402	0.0996	81.5401
****	-0 1924					
Y	Т 7н	T 7 K	ARSITY_T	VI ADGETY.TV	ABSIVE	ARGINY-NY)
-2 0784	0 1584	0 0939	0.0030	-86.7044	4.4250	-86.7644
	0 2435	0 2100	6.2100	-86.3472	2,7651	-86.3472
-1 5588	U•∠ ∓ JJ ∂.2982	0 2862	0.2862	-85.8168	3, 3454	-85.8195
-1 2000	0 2276	0.2404	0.3404	-94 9225	30JTJE 2 0870	-0JeCIJC -94 0235
-1 6392	0.3667	0 3805	0,3808	-07-7233	2 6536	-92 7659
-1-6372	0.3870	0.4006	0 2086		2.0350	-80 3276
-0 5196	.). 4.)23	0.4264	0.4254	-75.2952	2.0065	-75.2052
-(2598	0.4107	0.4410	0.4410	-67.4096	1.6657	-67.4096
	0.4135	0.4448	0-4448	-56,1814	1, 2922	-56-1814
6.2598	0.4107	0-4410	0.2952	-37,1355	0-0	0.0
C-5196	0-4023	0-4254	0-2047	-1.6965	0.0	0.0
C.7794	0.3879	0.4056	0-2120	34-9202	0 - C	0.0
1.0392	0.3667	0.3805	C-2493	54.9570	0-0	0.0
1-2990	0.3376	0.3404	0.2670	65-0925	0.0	0.0
1.5588	0.2982	C.2862	0.2453	70.8595	0.0	0.0
1.8186	0.2435	0.2109	C.1911	74.5116	0.0	0.0
2.0784	0.1584	0.0957	0.0904	77.0113	0.0	0.0
· · · · · ·			•			
**** Y=	-0.2309					
X	T ZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABSIVX,VI	ARG(VX,VY)
-1-8186	0.1849	0.1399	C.1399	-85.6862	3.9349	-85.6862
-1.5588	0.2527	0.2330	C-233C	-85.1429	3.4150	-85.1429
-1.2990	0.2982	0.2956	0.2956	-84.3052	3.0261	-84.3092
-1.0392	0.3308	0.3405	0.3405	-82.8813	2.0193	-82.8873
-0.7794	J-3541	0.3726	0-3726	-80.3867	2.3505	-80.3867
-0.5156	0.3698	0.3942	0.3942	- 10.1311	2.0266	- 16 - 131 1
-0.2598	J.319U	0.4068	0.4068	-03.3013	1.0748	-03.3015
L.U 0 2500	0.3820	0.4109	0.4109	-2702139 -45 0144	1.5409	-27.2135
0.5104	0.3790	0.4068	U+3701	-4309165 -23 0464		
U-9196	U- 3098	U. 3942	U-24U3	10 3400	0.0	
0.1194	U-3341 0-3300	V . 312C	L.10/2	100241C 20 2000		0.0
1 2000	ουες η	0.0407 0.2054	C.16C4	J002000 54 3399		
1.5500	U+4704	U+2730	C 1440	J70JJCC 63 6343		
L+JJ00 1 £194	V+C7C1	0 1200	0.1040	60 A111		
1.0100	0. T 04 A	0+1333	じゅよしとう	0700111		U • U

**** Y=	-0.2694					
X	TZH	TZK	ABS(TX,T	Y) ARG(TX,TY)	ABS (VX . V)	<pre>/) ARG{VX,VY}</pre>
-1.5588	0.1849	0.1521	C.1521	-84.4823	3.5782	-84.4823
-1.2990	0.2435	0.2327	C.2327	-83.6963	3.0991	-83.6963
-1.0392	0.2825	0.2863	0.2863	-82.4903	2.7217	-82.4903
-C.7754	0.3094	0.3234	0.3234	-86.5040	2.3791	-80.504C
-0.5196	0.3273	0.3480	0.3480	-77.2072	2.0507	-77.2072
-C.2598	0.3376	0.3622	C-3622	-71.9587	1.7242	-71.9587
C • O	0.3410	0.3668	0.3668	-64.1800	1.3890	-64.1800
C.2598	0.3376	C.3622	0.3622	-53+6684	1.0382	-53.6684
0.5196	0.3273	0.3480	C.2846	-39.0531	0.0	0.0
C.7794	0.3094	0.3234	0.1855	-16.2500	0.0	0.0
1.0392	0.2825	0.2863	C.1385	12.8640	0.0	0.0
1.2990	0-2435	0.2327	0.1150	36.8044	0 . C	0.0
1.5588	0.1849	0.1521	C.C792	51.7405	0.0	0.0
1-8186	0.0675	0.0211	0.0125	60.7811	0.0	0.0
**** ¥=	-0.3079					
X	TZH	TZK	ABS(TX,T	YI ARG(TX,TY)	ABS (VX,V)	() ARG(VX,VY)
-1.2990	0.1584	0.1319	C.1319	-83.0782	3.3061	-83.0782
-1.0392	0.2135	02078	0.2078	-82.00£7	2.8105	-82.0067
-0.7794	0.2481	0.2554	C.2554	-80.41 82	2.4291	-80.4182
-0.5196	0.2701	0.2856	0.2856	-77.9553	2.0834	77.9553
-C.2598	0.2825	C.3027	6.3027	-74.1517	1.7515	-74.1517
0.0	0.2865	0.3082	0.3082	-68.5338	1.4219	-68.5338
C.2598	0.2825	0.3027	0.3027	-60.8286	1.0879	-60 . 828 6
0.5196	0.2701	0.2856	0.2856	-51.2779	0.7493	-51.2779
C.7794	0.2481	0.2554	0.1864	-37.7482	0.0	0.0
1.0392	0-2135	0.2078	0.1032	-17.7118	0-0	0.0
1.2990	0.1584	0.1319	0.0496	7.7163	00	0.0
1.5588	0.0002	0.0000	C.•C	C. O	0.0	0.0
**** Y=	-0=3464					
· X	TZH	TZK	ABS(TX,T	Y ARG(T), TY	ABS (VX,V)	() ARG(VX,VY)
-1.0392	0. 082 7	0.0514	0.0514	-81.5012	3.3606	-81.5012
-0.7794	0.1510	0.1453	0.1453	-80.1367	2.5782	-80.1367
-C.5196	0.1849	0.1920	0.1920	-78,2255	2.1538	-78-2255
-0.2598	0.2026	0.2163	C.2163	-75.5179	1.7885	-75.5179
C.O	0.2081	0.2239	C.2239	-71.7461	1-4411	-71.7460
C.2598	0.2026	0.21€3	C.2163	-66.7664	1.0954	-66.7664
C.5196	0.1849	0.1920	0.1920	-60.7860	0.7374	-60.7860
C.7794	0.1510	0.1453	C.1263	-53,5065	0.0	0.0
1.0392	0.0827	0.0519	0.0273	-43.4534	0.0	0.0

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APPENDIX B

LISTING AND TEST PROBLEM FOR SUBRØUTINE FØRCES

(FØRTRAN IV G1 RELEASE 2.0)

REAL NU

C

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C C TO USE SUBROUTINE FORCES. THE PARAMETERS TRANSFERRED FROM THE MAIN C PROGRAM ARE (A,B,NU,UXN,UYN,PHN,NX,NY,DN) THE SUBROUTINE THEN C DETERMINES THE NORMALIZED RESULTANT FORCES FXN AND FYN. C THIS PROGRAM CONTAINS SUBROUTINES FORCES, MAAKZ, ROL, AND CONST 0 0 0 (A AND B ARE THE NORMALIZED CONTACT ELLIPSE C CIMENSIONS, WHERE IF A1 AND B1 ARE THE ACTUAL C DIMENSIONS THEN A=A1/SCRT(A1*B1) AND C E=E1/SQRT(/1*E1). NOTE A/B >= 0.1 C NU IS POISSON'S RATIO. THIS IS THE ONLY 0 0 0 INFORMATION NEEDED TO COMPUTE (INTERNALLY) FROM KALKER'S TABLES AND ASYMPTOTIC EXPANSIONS. (SEE SUBROUTINE CONST), THE LINEAR CREEPAGE AND SPIN 000000 CCEFFICIENTS, CIJ, AND THE NORMALIZED MODULUS, GS. THE CONSTANT GS=G*(C***3)/(RHG*N),WHERE C= SGRT(A1*B1), 1/R+O=1/4*(1/R1+ + 1/R1- + 1/R2+ + 1/R2-),AND N=RESULTANT NORMAL FORCE. THESE ARE USED IN THE PROGRAM TO COMPUTE THE INVERSE STIFFNESSES SX AND SY. C THEN SX=8##/(3*C11*GS), SY=8#A/(3*C22*GS), HC=32*SQRT(E/A)*C23/(3*PI*C22) ANC PHNN=HC*PHN C NOTE, THE CPERATION PHNN=HC*PHN IS DONE IN THE C PREGRAM. THE NORMALIZED SPIN PHN=PH*RHO/MU IS 0 0 0 THE VALUE TRANSFERED TO THE SUBROUTINE UXN AND UYN ARE NORMALIZED CREEPAGES, PHN IS THE NORMALIZED SPIN), C UXN=UX*RHO/(MU*C), UYN=UY*RHC/(MU*C), PHN=PH*RHO/MU C C NX, NY (LATTICE POINTS IN CONTACT REGION, (I*#/NX, J*E/NY), -NX<I<NX, -NY<J<NY, ACCURACY 0 0 0 0 INCREASES WITH INCREASING NX, NY TYPICAL VALUES NX =3C,NY=10. MAXIMUM VALUES; NX,NY=40. FOR A/E=10 NX=40,NY=1C, FOR A/8=0.1 NX=10,NY=40, FOR A/8=1 NX=NY=20, ARE TYPICAL VALUES. C CM (AN INCREMENTAL STEP IN THE COMPUTATION, с с ACCURACY INCREASES WITH DECREASING DM, TYPICAL VALUE=C.O2*A) THE NORMALIZED FORCES RETURNED ARE 0 0 0 0 FXN=FX/(MU*N), FYN=FY/(FU*N)******** NOTE: ALL VARIABLES HAVE BEEN NORMALIZED SUCH С С ***** THAT THE CCEFFICIENT OF FRICTION, MU, DOES NOT ***** EXPLICITLY APPEAR. C C REAC(1,*) NV1 DC 995 I=1.NV1 READ(1,*) A.B.NU, UXN, UYN, PHN, NX, NY, DM CALL FOFCES (A+E, NU, UXN, UYN, PHN, NX, NY, DM, FXN, FYN) WRITE(3,850)A,B,NU,UXN,UYN,PHN,NX,NY,OM,FXN,FYN 850 FOR#AT{//,12X, *A=*,1FE11.4,/,12X, *B=*,1PE11.4,/,11×, *NU=*,1PE11.4, \$/,10X, *UXN=*,1PE11.4,/,10X, *UYN=*,1PE11.4,/,10X, *PHN=*,1PE11.4,/, ,/,11X,'DM=',1PE11.4,/,10X,'F \$11X, * NX= *, I3 ,/,11X,'NY=', I3 \$XN=", 1PE11.4,/,1CX,"FYN=",1PE11.4,//} 999 CONTINUE STOP END

FORCES

		•
C	SEE "SIMPLIFIED THEORY OF ROLLING CONTACT", BY J.J. KALKER	0000010
Ĉ.	DELET PREGRA REP. SERIES C: MECHANICAL AND AFRONAUTICAL	0000020
Ē.	ENGINEERING AND SHIPBUILDING. 1 (1973) PP-1-10	00000030
-	SUBROUTINE ECRCES (A . B. NILLIXN . 11YN . PHN . NX . NY . DM. EXN. FYN)	00000040
C.	***** A AND P ARE THE NORMALIZED CONTACT ELLIPSE DIMENSIONS. NU	00000000
c C	***** IS POISSON'S RATIO. NOTE, AVR WIST RE .CE. 0.1	000000000
C C	AXXXX IVN AND IVN ADE THE NODRALIZED ODIEDACES AND DEN IS THE	00000070
r	ATTAT UNN AND UTN AND ITE NUMPELIZED UNDERAGES AND FRN 15 ITE ATTAT UNN AND UTN AND ITE ITE NUMPELIZED UNDER AND FRN 15 ITE	00000000
r r	***** NUMPALIZED STIN. UNN-UN*KNU/(MU*U/) UIN-UI**NU/(MU*U/)	
	ATTAT FONTERTROUTED ATTICE DOINTS IN THE CONTACT DECION	00000090
6	THE WAARD AT ARE LATTICE PUINTS IN THE CUNTACT REGION,	
Ĺ	TTTTT (ITA/NA)JTB/NYJONX OCE. I OLEO NX, -NY OGEO J OLEO NY	00000110-
6	***** ACCURACY INCREASES WITH INCREASING NX, NY. IMPICAL VALUES	00000120
2	***** NX=3C,NY=1C, MAXIMUM VALUES NX,NY=40. EM IS A STEP	00000130
C	***** ACCURACY INCREASES WITH DECREASING DM, TYPICAL VALUE=G.C2*A	00000140
C	***** NORMALIZED FORCES ARE RETURNED WHERE FXN=FX/(MU*N)	00000150
Ũ.	***** FYN=FY/(MU*N) WITH N=RESULTANT NORMAL FORCE	00000160
	REAL X(81,81),Y(E1,E1),VX(81,81),VY(81,81),C(E1,1C)	00000170
	REAL CS(3),GEL(5)	00000180
	REAL CNT(5)	00000150
	REAL HX-HY-PH-SX-SY-A-B-MUZ-EX-EY-MZ-U-U-U-D-DN-AB-AD-AE-TX-TY	.00000200
	<pre>db_cd_cd_dd_still</pre>	00000200
		00000210
	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	00000220
		00000240
		00000250
		00000260
	GR=P1/180.0	00000270
	₩X=3* ħX	00000280
	MY=3*NY	00000290
	LY=3*NY	00000300
102	2 MUZ=3.C/(2.C*PI)	00000310
	SX=8.C*A/(3.0*C11*GS)	00000320
	SY=8.C*A/(3.O*C22*GS)	00000330
	HC=32.0*SGRT(E/A)*C23/(3.0*PI*C22)	00000340
1027	7 GEL(5)=DM	00000350
	GEL(1)=SX	00000360
	GFL(2)=SY	00000370
	GFL (3)=A	00000380
	CEL (A) = R	00000360
		00000400
		00000410
		00000410
		00000420
	CALL DOLLOG OFF MUT AN AN A VIN AN O FM FM MTA	00000430
		00000440
		00000450
	t YN=t Y	UCCCC46C
	RETURN	00000470
	END	00000480

WAAK 2	47
SUBROUTINE MAAKZ(P,G,WZ,DZ,C2Z,A,E,MUZ)	00000490
REAL MUZ	00000500
AL=C.9	00000510
S=SQRT(1.0-AL*AL)	00000520
AW=A*SQRT(1.0-Q*C/B/B)	00000530
PI=3.1415926536	00000540
F=MUZ*PI/2.0/A/(ATAN(AL/S)+(2.0/3.0-AL+AL*AL/3.C)/S)	00000550
IF(P.LE.AL*AW) GC TC 10	00000560
WZ=F*(AW*AW-P*P)/2.C/AW/S	00000570
DZ=F*P/Ak/S	00000580
C2Z=F/AW/S	00000590
GO TO 11	00000600
WZ=F*SQRT(AW*AW-F*P)-F/2.0*AW*S	00000610
DZ=F*P/SQRT(AW+AW-P*P)	00000620
RETURN	00000630
END	0000640

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	RCL	48
	SUBROUTINE ROL(CS,GEL,MUZ,N>,NY,X,Y,VX,VY,G,FX,FY,MZ)	00000650
	REAL NUZ, HZ, K, NU	00000660
	INTEGER PIJL	0000670
	REAL LE(81)	08600000
	INTEGER E(E1)	00000690
	COMMON A,E	00000700
	CIMENSION X(81,81),Y(81,81),VX(81,81),VY(81,81),	00000710
	\$ G(81,10),CS(3),GEL(5)	0000720
	UX=CS(1)	00000730
	UY=CS(2)	00000740
	UM=GEL()) SV-CE())	00000780
		00000770
	A=CEL (2)	00000790
	8=GEL (4)	00000000
	$F=\Delta/FI \cap \Delta T(NX)$	00006810
	K=B/FIGAT(NY)	00000820
	PI=3.1415926536	00000830
	$CZP = MUZ * 2 \cdot C/A/A$	00000840
	J=-NY	00000850
380	J=J+1	00000860
	IF(J.GT.NY-1)GC TC 1CO	00000870
	LE(J+NY+1)=A*SQRT(1.C-FLOAT(J*J)/FLOAT(NY)/FLOAT(NY))	0880000
	P=LE(J+NY+1)	00000850
	E(J+NY+1)=0.99*P/H	00000900
	I = -h X - I	00000910
401		00000920
	IF(I.CLANX)GU IU 200 IF(I.T. F. IIINNII) CD I CT F/IINNII) CO IC 15	
	1711.011.0"E(JTNTTI).(K+1+01.01.01.17NTTI)/00 10 10	00000940
15	00 10 10 VVfT+NX+1, 1+NY+1)=C.C	03600000
1)	$VX \{1 + NX + 1 + NY + 1\} = C_{-}C$	00000970
	$Y(I+N)+1 \cdot J+NY+1 = C \cdot C$	00000980
	$X (I + NX + 1 + J + NY + 1) = C \cdot C$	00000990
10	GG TC 401	00001000
2 JJ	CONTINUE	00001010
	DO 20 I=1,1C	00001020
20	G(J+NY+1,I)=-3.C*A	00001030
	GC TC 38C	00001040
100	CONTINUE	00001050
	THV=-1.0	00001060
	IF(UX-PH*B.GE.C.C) TEV=1.0	00001070
_	THV=THV*ATAN(UY/(ABS(UX-PH*E)+1.E-08))+P1/2.0*(1.0-1HV)	00001080
C	1 6364	
670		00001100
470	15/1 CT NATICO 10 300 1211	0-001120
	C=.1*K	00001120
	P=LF(J+NY+1)	00CC1140
	PG=P	00001150
	CUX=UX-PH+G	00001160
	PIJL=2	00001170
	CUY=UY+PH*P	00001180
	CALL MAAKZ(P,G,ZN,CZ,CZP,A,E,MUZ)	00001190
•	XG=0.0	00001200
		00001210
		00001220

O H 00 -0 -0 0 じ じ く O 800 NE NE ŇŤ × τ PN=P+D CALL PAAK2(P) CALL PAAK2(P) S=SIN(TN) C=COS(TN) C=COS(TN) C=COS(T) N=2N*C V=CUX*SV*C+C IF(V=2N*C) AV=2N*C AV=10.00 AV=1.0-AN C=CUX+VY+1.9IJ C=CUX+VY+1.9IJ C=CUX+VY+1.1---------44 THE STARTING DERIVATIVE I TP=(PH*C+CZP S=SIN(T) C=CCS(T) NU=(CUX*) P=PG XV=A XG=X YV=A YV=A YV=A YV=A YV=A YV=A YV=Y VV=Y C=CO S=SII ຕິ -7 THV= **F** 1F(CZ*CZ-SLIP AT T S(J+NY+1. I=E(J+NY+1) -11 ł CXS-=COS(T) =T-NU = (ABS(NU) -1.C CUX.G T*ATAN (AB ~ - 1 - Ìł {PIJL-(=AV*XV+ =XV Pi XXZ Ó 5 R INUE < AA*A -٠ DM. \sim 00 o سبه -+AN GT-1 +AN# CCC 11 ----6 ~ S + H#PN #S-CUY#C-(D*(TP+TPN) H m T **n** i i i i -Ŭ X t ۰. . C m * * 2 ٠ • L -Ĵ m ъ 70 m G Y ~ . H G * žS 7 -1 YU * V) ~ * -7 >0 IJL m 4 O π -< . ¥ ~ ~ **−** π **∩** + Ĩ • 5. ъ Ś * 0 + NDN Ö ъ · >CO -X-S , in the second ъ 0 0 × -. -. 5 -٤... R ----< m × ٠ m SI ~ N -G * 70 Ē -÷ 0 7 m P 0 1 1 2* E CF T SY)*C* Ð n s N ω× -1 C 45 -+ C . 0 0 ŝ ~ ~ AN* C 6 S × m in فبيبة [*S*[SX-SY]]/ZN/(SY*C*C+SX*S ~ -ON --ត្ត័រ ř AN=0 C G + * E-CUY 100 100 SY)* PZ ZP SD C -Т -< m > m I * 10 -zu 0 # . 4 5 \mathbf{r} ł CUX*C ŝ T C Ô E ~ . Ð 1 -¥ m ERM ERM • τ G in £ ÑN 2 ¥ E + m ~ σ N FOU 75 -CUX #C ~ GUND m v N ~ * ő 0 - 0 IΣ . * # ć₽ 1 m + ÷Y9 **∀** 2***** -10 H ٠ >• ~ m Ŷ -0 ~ r ŝ ----G Ó ٠ O 2# Ď ť # ~ -;# (-S C in ř مينه j 00 1.0)*(SXŝ -)*(C*C Ŧ S S ~ ¥ ŝ حييته 49

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	RCL	50
	P=PN	0000181
C SLI	þ	0000182
1005	TP=(CUX*S-CUY*C-CZ*(*S*(SX-SY))/ZN/(SY*C+C+SX*S*S)	0000183
	IF(P.GT.I*H+1.E-C6) GO TO 1003	0000184
	X(I+NX+1,J+NY+1)=XN	0000185
	Y{I+NX+1,J+NY+1}=YN	0000186
	XP=-ZN*S*TP-CZ*C	0000187
	YP=ZN*C*TP-CZ*S	0000188
	VX(I+NX+1,J+NY+1)=CUX+SX*XP	0000189
	VY(I+NX+1,J+NY+1)=CUY+SY*YP	0000190
	VV=V	0000191
	[=[-]	00001920
	IF(I.LTE(J+NY+1)) GC TO 1007	0000193
	GO TC 10C3	0000194
C ADH		0000195
1001	T=-1.0	0000196
	IF(CUX.GT.C.C) T=1.0	0000197
	THV=T*ATAN((UY+PE*P)/(ABS(CLX)+1.E-08))+PI*(1.G-T)/2.C	0000198
C ADH	RE	0000199
1006	PN=I+H	0000200
	XN = CUX * (PG - PN)/SX + XC	00002010
	YN = (UY + 0.5 * PH * (PG + PN)) * (PG - FN)/SY + YG	00002020
	CALL MAAKZ(PA.C.ZA.CZ.CZP.A.E.MUZ)	00002030
	V = ZN - SORT (XN + XN + YN + YN)	0000204
	IF(V.GE.(-4.E-05)*MUZ)GD TD 1008	0000205
	AN = VV / (VV - V)	0000206
	IF(ABS(VV).LT.1.E-1C) AN=0.9	0000207
	AV=1.C-AN	00002080
	P=XV*P+AN*PN	0000209
	G(J+NY+1,PIJL)=P	00002100
	VV=0.0	00002110
	PIJL=PIJL+1	00002120
•	XV=AV+XV+AN+XN	00002130
	YV=AV*YV+AN*YN	00002140
	IF(PIJL.GT.1C) PIJL=10	00002150
	T=-1.0	000(216)
	IF(XV.GE.C.C) I=1.C	0000217
	€UY=UY+PF*P	0000218
	T=T*ATAN{YV/(ABS(XV)+1.E-08))+P1/2.0*(1.C-T)	00002190
	C=COS(T)	00002200
	S=SIN(T)	0000221
	CALL MAAKZ(P,Q,ZN,CZ,CZP,A,E,MUZ)	00002220
	GO TC 1005	00002230
1008	VV=V	00002240
	X(I+NX+1, J+NY+1) = XN	00002250
	XV=XN	00002260
	Y(1+NX+1,J+NY+1) = YN	00002270
	YV=YN	00002280
	$VY\{1+NX+1,J+NY+1\}=G_{+}G$	00002290
	VX{I+NX+L,J+NY+L}=C+C	0000230
		0000231(
	Y=YN TEAT CE - EA HANNAINN CC TO 1004	
1 1 1 7	IF1100E0-E1JTRYTIJJ 60 10 1000 CO TO 470	00002330
200		00002340
500 C	THE ADDAVE ADD ETTIED. THE TATECOALS ADD	00002350
L	THE ARRATS ARE FILLELS THE INTEGRALS ARE	0000236(
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	PCL	51
	TN=2.C*K	00002390
	FX=0.0	00002466
	FY=0.C	00002410
	MZ=0.C	00002420
	YN=2.C*H	00002430
	J=-NY	00002440
940	1 + L = L	00002450
	IF{J.GT.NY-1)GC TC 4CG	00002460
	I=E(J+NY+1)	00002470
	PIJL=I	00002480
	P=(LE(J+NY+1)-I*H)/2.0-H/3.0	000C2490
	YP=J×K	00002500
	C=P*{X{I+NX+1,J+KY+1}+X{NX+1-1,J+NY+1}}	00002510
	S=P *{Y{I+NX+1,J+NY+1}+Y{NX+1-1,J+NY+1}}	00002520
	D=P*I*H*{Y{I+NX+1,J+NY+1}-Y{NX+1-I,J+NY+1}}	00002530
	P=2.0*H/3.C	00002540
	I=-PIJL-1	00002550
500	I=I+1	00002560
	IF (I.GT.PIJL)GC TC 550	00002570
	$C=C+P*X\{I+hX+1,J+hY+1\}$	00002580
	D=D+P+I+H+Y(I+NX+1+J+NY+1)	00002590
	S=S+P*Y(I+NX+1,J+NY+1)	00002600
	P=YN-P	00002610
	GO TO 50C	00002620
550	FX=FX+T*C	00002630
	FY=FY+T*S	00002640
	$M7 = M7 + T + \{C - YP + C\}$	00002650
	T = TN - T	00002660
	CO TO 940	00002670
400	CENTINUE	00002680
	RETURN	00002690
	ENC	00002700
	ETT W	

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CCNST

SUBROUTINE CONST(A, E, NU, C11, C22, C23, C33, GS)	00002710
DIMENSION AL(5), BE(5), D(15), E(15, 20), AR(20), CNT(5), D1(15, 9),	00002720
\$D2(15,9),C3(15),C4(15)	00002730
***** DATA E(I,J) GIVES LINEAR CREEPAGE AND SPIN COEFFICIENTS****	*00CC2740
*****AND GS FROM KALKER REFORT TABLE 1 *******************	00002750
***** VALID FCR A/E GREATER THAN CR EQUAL TO 0.1	00002760
REAL NU	03002770
CATA C1/	00002780
\$ 2.51, 3.31, 4.85, 2.51, 2.52, 2.53, 0.334, 0.473, 0.731, 6.42,	00002790
\$ 8-28. 11.7. 0.7670. 0.5752. 0.3825.	00002800
\$ 2.59. 3.37. 4.81. 2.59. 2.63. 2.66. 0.483. 0.603. 0.809. 3.46.	00002810
\$ 4.27. 5.66. G.56CR. 0.4206. C.2804.	00002820
\$ 2.68. 3.44. 4.80. 2.68. 2.75. 2.81. 0.607. 0.715. 0.689. 2.49.	00002830
\$ 2.96. 3.72. 0.4776. 0.3584. 0.2360.	00002860
\$ 2.78. 3.53. 4.87. 2.78. 2.89. 2.56. 0.720. 0.823. 0.577. 2.02.	00002040
42.32, 2.77 , 6.4342 , 0.3257 , 0.2132 .	00002860
= 2 + 3 + 2 + 1 + 3 + 5 + 3 + 3 + 3 + 3 + 3 + 3 + 3 + 3	00002800
# 2 009 Je029 9e0J9 2e009 Je019 Je199 Vec219 Ve7279 Levis lei99	00002070
\$ 2090; 3072; 4091; 2090; 3014; 3031; U0931; 1003; 1010; 1030;	00002890
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	00002900
\$ 3.099 3.819 4.979 3.099 3.289 3.489 1.639 1.149 1.299 1.439	00002910
$\begin{array}{c} \bullet 1 \bullet 2 \bullet 1 \bullet 1 \bullet 1 \bullet 1 \bullet 2 \bullet 1 $	00002920
* 3-19; 3-91; 3-005; 3-19; 3-41; 3-65; 1-13; 1-25; 1-40; 1-34;	00002930
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	00002940
3 3•299 4•019 3•129 1•299 3•349 3•829 1•239 1•309 1•319 1•279	00002950
\$ Lo2(g Lo2(g Uo3(38g Uo2818g Uo18/9/	00002960
	00002970
3 3.40, 4.12, 7.20, 3.40, 3.67, 3.58, 1.33, 1.47, 1.63, 1.21,	00002980
¥ 1.19, 1.10, 0.3700, 0.2812, 0.1875,	00002990
\$ 3.51, 4.22, 5.30, 5.51, 3.81, 4.16, 1.44, 1.59, 1.77, 1.16,	00003000
$\begin{array}{c} 1 \\ $	010010010
\$ 3.00; 4.30; 5.42; 3.00; 3.59; 4.39; 1.50; 1.70; 1.94; 1.10;	00003020
1 .04, 0.554, 0.3785, 0.2839, 0.1892,	00003030
3 3.82, 4.34, 5.58, 3.82, 4.21, 4.67, 1.70, 1.50, 2.10, 1.00,	00013040
3 U.967, U.872, U.384U, U.288U, U.192U,	00003050
\$ 4.00, 4.72, 5.80, 4.00, 4.50, 5.04, 2.01, 2.23, 2.50, 1.01,	00003060
4 0.892, 0.751, 0.3934, 0.2950, 0.1967,	00003070
\$ 4.37, 5.10, t.11, 4.37, 4.50, 5.56, 2.35, 2.62, 2.96, 0.958,	00003080
\$ 0.819; 0.650; 0.4025; 0.3026; 0.2044;	00003030
\$ 4.84, 5.57, 6.57, 4.84, 5.48, 6.31, 2.88, 3.24, 3.70, 0.912,	00003100
\$ 0.747, 0.549, 0.4343, 0.3257, 0.2172,	00003110
\$ 5.57, 6.34, 7.34, 5.57, 6.40, 7.51, 3.79, 4.32, 5.01, 0.868,	00003120
\$ 0.6/4, 0.446, 0.47/5, 0.3584, 0.2390,	00003130
\$ 6.96, 7.78, 8.82, 8.96, 8.14, 9.79, 5.72, 6.63, 7.89, 0.828,	00003140
\$ 0.601, 0.341, 0.5608, C.42CE, 0.2804/	000C3150
DATA C3/	00003160
\$ 10.7, 11.7, 12.5, 10.7, 12.8, 16.0, 12.2, 14.6, 18.0, 0.795,	03003170
\$ 0.562, C.228, C.161C, C.5752, 0.3835 /	00003180
DATA D4/	00003190
\$ 11.08, 12.01, 13.10, 11.08, 13.38, 16.90, 13.72, 16.34, 20.20,	00003200
5 U. (85, L. 552, C. 2CE, U. /918, U. 5938, U. 3959/	00003210
UAIA AK / C.1,0.2,0.3,0.4,0.5,0.6,C.7,C.8,C.9,1.C,1.11111,	00003220
\$1.25,1.428571,1.6666667,2.0,2.5,3.33333335.C,1C.0,11.C/	00003230
$UU \circ I=I + I \circ$	00003240
DU D J=[43]	00003250
C(1+J)=U1(1+J) C(1+J)=D2(1+J)	00003260
EllgJ772=U2llgJ7 Elt_101=02l1)	
Cl11177=U3111	10069580

С С С

5

80 Đ 30 N Б 25 o 5 END **CONTINUE** GS=CNT(5) D([]=E([,J-1)+(E([,J]-E([,J-1])*(RG-AR(J-1))/(AR(J)-AR(J-1)) GC TC RETURN C23=CNT(3) CNT(I) = ALBE(1)=2.C*(-D(3*1)+4.O*D(3*[-1)-3.O*D(3*1-2)) **CONTINUE** C22=CNT(2 AL(1)=8.0*(D(3*1)-2.C*D(3*1-1)+D(3*1-2)) <u>د</u> ۲ IF(RG.LE.AR(I)) GC TC 25 GS=3.0*(1.0-NU)/(4.C*P[*SQRT(SG)) C33=PI/4.C*(GAM*(1.C+2.O*NU)-2.O+6.O*NU)/(GAM*(1.C-NU)-2.O+4.O*NU)000C3400 C23=2.0*P1/((SCRT(SE)*SE*3.C)*((1.0-NU)*GAM-2.0+4.C*NU)) C22=2.0*PI*(1.C+C22)/(SG*(2.0*NU+GAM*(1.C-NU))) C22=((1.6137C6)*(1.0-NU))/(2.0 *NU+CAM*(1.0-NU)) C11=2.0*PI/(SG*(GAM-2.0*NU))*(1.0+(1.613706 GAM=ALCG(16.0/(SC*SC)) SG=B/A RG≡A/B PI=3.14159 E(I,20)=D4(I) IF(RG.GT.AR(20)) GO TO 14 C33=CNT(4) II=CNT(I 30 20 40 I=1,5 10 09 I=2,20 I=1,15 5 ([) #NU##2+BE([)#NU+C(3* [-2] CCNS (GAM-2.0*NU)) 00003590 00003580 00003570 00003560 00003550 00003350 00003360 000003600 00003540 00003530 00003520 00003510 00003500 000003490 00003480 0 3 0 0 3 4 7 0 00003460 000003450 00003440 00003430 00003420 000003410 08550000 00203370 00003350 00003340 00003330 00003310 00003300 00003290 00003320 ភួ

Α=	2.5980E+00
θ=	3.8490E-01
NU=	2.8000E-01
UXN=	0.0
UYN=-	-1.4000E+00
PHN=	8.0000E-01
NX=	10
NY=	10
DM=	4.0000E-02
F XN=	8.9034E-07
FYN=-	-3.4703E-01

A=	2.5980E+00
8=	3.8490E-01
NU=	2.8000E-01
UXN≔	0.0
UYN=-	-1.4000E+00
PHN=	8.0000E-01
NX=	40
NY=	20
DM=	4.0000E-02
FXN=	8.6427E-07
FYN=-	-3.4689E-01

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