

Center for Aircraft Structural Life Extension

Providing Structural Integrity Technology to the Aerospace Community



Use of Bending Stress Intensity Factor Solutions for Wide, Thin Plates

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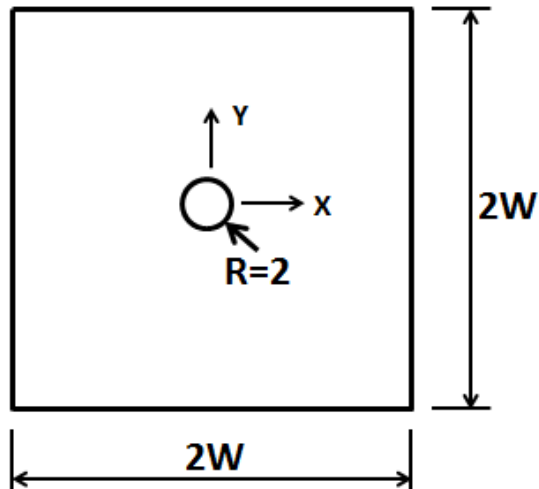
Outline

- Background
- Design & Relevance
- Error Assessment
- Options
- Conclusions



Background

- K solutions created in 2003
- Discretized domain



- 144 FE in xy plane
- Four layers in z -dir

- Cracking scenarios
 - Single & Double
- Geometry
 - $0.1 \leq a/c \leq 10.0$
 - $0.1 \leq a/t \leq 0.99$
 - $10 \geq R/t \geq 0.1$
 - $0.2 \leq t \leq 20$
 - $W/D = 100$
- Loading
 - Tension
 - Bending
 - Pin (bearing)



Errors in *K* Database

- Discovered in 2013
 - Numerical round-off
 - Nonlinear geometry effects
- Cracking scenarios
 - Single
 - Double
- Geometry
 - $R/t > 3.0$
- Loading:
 - Tension
 - Bending
 - Pin (bearing)
- Advanced Models
 - 2-point and multi-point

Loading/Tip	a/t	R/t
Bending/a	0.10	4,5,6,7,10 (all a/c)
Bending/a	0.50	4,5,6,7,10 (all a/c)
Bending/a	0.95	4,5,6,7,10 (all a/c)
Tension/a	0.10	7,8,9,10 (a/c very small)
Tension/a	0.50	7,10 (a/c very small)
Tension/a	0.95	7,8,9,10 (a/c, small mainly)
Bearing/a	0.10	8,9,10 (a/c very small)
Bearing/a	0.50	7,10 (a/c very small) 0.5, a/c very large
Bearing/a	0.95	7,8,9,10 (a/c, small mainly) 0.5, a/c very large
Bending/c	0.10	4,5,6,7,8,9,10
Bending/c	0.50	4,5,6,7,10
Bending/c	0.95	4,7,9,10
Tension/c	0.10	8,9,10 (a/c large)
Tension/c	0.50	7 (a/c =10)
Tension/c	0.95	7,8,9,10 (a/c large)
Bearing/c	0.10	8,9
Bearing/c	0.50	7,8,9
Bearing/c	0.95	7,8,9



Design & Relevance

- Min fastener spacing $\rightarrow 4D^1$
 - Implies $W/D = 4$
- Avoid $R/t > 2.0^{[2:8-15]}$
- Joint Allowables
 - Ultimate Bearing Strength, Solid Rivets
 - $0.125 \leq R/t \leq 2.64^{[2:8-17]}$
 - Static Joint Strength (SJS), A-286/A-286
 - $0.58 \leq R/t \leq 3.125^{[2:8-17]}$
 - SJS, A-286 Blind Rivets, SS, Ti, AA Sheet
 - $1.0 \leq R/t \leq 7.81^{[2:8-39]}$
- SJS, Monel Rivets, SS Sheet
 - $0.78 \leq R/t \leq 6.25^{[2:8-40]}$
- SJS, Blind Monel Rivets, AA Sheet
 - $0.65 \leq R/t \leq 2.50^{[2:8-41]}$
- SJS, Blind AA Rivets, AA Sheet
 - $1.17 \leq R/t \leq 2.50^{[2:8-42]}$
- SJS, Shear Head Ti bolts, AA Sheet
 - $0.65 \leq R/t \leq 1.56^{[2:8-114]}$
- UBS, Threaded Fasteners
 - $0.078 \leq R/t \leq 2.43^{[2:8-131]}$
- SJS, Steel Hi-Lok, AA Sheet
 - $0.625 \leq R/t \leq 1.56^{[2:8-146]}$

¹Niu, Airframe Stress Analysis and Sizing, 2nd Ed., p.277.

²MMPDS-04.



Error Control - 2003

- Used a large domain to avoid finite height/width effects
 - Rely on AFGROW finite width correction
- Through the thickness mesh design
 - Graded (aka “ hp ”) – higher accuracy for small R/t
 - Uniform – 4 equal layers for large R/t
- Polynomial order, $p = 6$



Error Analysis

- Solving the linear system of equations

- $\{F\} = [K]\{u\}$

- $\{F\}$ - generalized loads
 - $[K]$ - stiffness matrix
 - $\{u\}$ - N unknown displacements

- Error, e

- $$e = \frac{\sqrt{\sum_{i=1}^{i=N} (u_i - v_i)^2}}{\sqrt{\sum_{i=1}^{i=N} v_i^2}}$$

- v - approximation to u



hp Mesh Errors

- $p = 8$
- $W = 200$

R/t	Tension	Bending	Wedge
0.04	0.1E-13	0.1E-12	0.6E-13
0.1	0.9E-10	0.6E-08	0.3E-09
0.2	0.2E-9	0.3E-07	0.7E-09
0.5	0.1E-8	0.6E-6	0.4E-8
1.0	0.6E-8	0.3E-5	0.2E-7
2.0	0.2E-7	0.4E-4	0.7E-7
3.0	0.6E-7	0.2E-3	0.9E-7
4.0	0.1E-6	0.2E-3	0.3E-6
5.0	0.2E-6	0.5E-3	0.5E-6
6.0	0.3E-6	0.8E-3	0.5E-6
7.0	0.4E-6	0.1E-1	0.2E-5
8.0	0.4E-6	0.2E-2	0.2E-5
10.0	Singular	Singular	Singular

- Red highlights unacceptable errors
- For small R/t – errors are within machine precision
- For increasing R/t – errors increase quickly
 - Especially for bending
- Must use uniform mesh to minimize round-off errors



Uniform Mesh Errors-Tension

- Tension, $p = 8$
- $10 \leq W \leq 200, R/t=10$

Z	W=10	W=25	W=50	W=100	W=200
-0.200	3.3569	3.0519	3.0108	3.0005	2.9991
-0.195	3.3574	3.0524	3.0112	3.0010	2.9991
-0.190	3.3578	3.0528	3.0116	3.0014	2.9992
-0.180	3.3587	3.0536	3.0124	3.0022	2.9998
-0.160	3.3603	3.0549	3.0137	3.0035	3.0011
-0.140	3.3614	3.0559	3.0147	3.0045	3.0019
-0.120	3.3620	3.0565	3.0153	3.0050	3.0025
-0.100	3.3622	3.0567	3.0155	3.0052	3.0027
-0.080	3.3620	3.0565	3.0153	3.0050	3.0025
-0.060	3.3614	3.0559	3.0147	3.0045	3.0019
-0.040	3.3603	3.0549	3.0137	3.0035	3.0009
-0.020	3.3587	3.0536	3.0124	3.0022	2.9996
-0.010	3.3578	3.0528	3.0116	3.0014	2.9988
-0.050	3.3574	3.0524	3.0112	3.0010	2.9984
0.000	3.3569	3.0519	3.0108	3.0006	2.9980
Error →	0.8E-10	0.7E-9	0.2E-8	0.9E-8	0.5E-7

- Red highlights loss of symmetry
 - Problem is perfectly symmetric though
- Error is small
- **Errors will not affect K**



Uniform Mesh Errors-Tension

- Tension, $2 \leq p \leq 8$
- $W = 25, R/t=10$

- Green highlights 5 digits accuracy
- Uniform mesh in the thickness direction gives accurate K solutions for $p > 5$

Z	P=2	P=3	P=4	P=5	P=6	P=7	P=8
-0.200	3.0633	3.0621	3.0510	3.0521	3.0520	3.0519	3.0519
-0.195	3.0643	3.0623	3.0514	3.0525	3.0524	3.0524	3.0524
-0.190	3.0650	3.0626	3.0517	3.0530	3.0528	3.0528	3.0528
-0.180	3.0657	3.0631	3.0524	3.0538	3.0536	3.0536	3.0536
-0.160	3.0641	3.0642	3.0537	3.0551	3.0550	3.0549	3.0549
-0.140	3.0674	3.0662	3.0548	3.0561	3.0559	3.0559	3.0559
-0.120	3.0715	3.0669	3.0554	3.0567	3.0565	3.0565	3.0565
-0.100	3.0766	3.0674	3.0556	3.0569	3.0567	3.0567	3.0567
-0.080	3.0715	3.0669	3.0554	3.0567	3.0565	3.0565	3.0565
-0.060	3.0674	3.0662	3.0548	3.0561	3.0559	3.0559	3.0559
-0.040	3.0641	3.0642	3.0537	3.0551	3.0550	3.0549	3.0549
-0.020	3.0657	3.0631	3.0524	3.0538	3.0536	3.0536	3.0536
-0.010	3.0650	3.0626	3.0517	3.0530	3.0528	3.0528	3.0528
-0.050	3.0643	3.0623	3.0514	3.0525	3.0524	3.0524	3.0524
0.000	3.0633	3.0621	3.0510	3.0521	3.0520	3.0519	3.0519
Error →	0.4E-9	0.1E-9	0.1E-9	0.7E-10	0.1E-9	0.1E-9	0.6E-9



Uniform Mesh Errors-Bending

- Bending, $p = 8$
- $10 \leq W \leq 200, R/t=10$

Z	W=10	W=25	W=50	W=100	W=200
-0.200	-1.8776	-1.8190	-1.8002	-1.7641	-4.6761
-0.195	-1.7875	-1.7299	-1.7171	-1.6988	-3.2222
-0.190	-1.6976	-1.6411	-1.6319	-1.6227	-2.4329
-0.180	-1.5134	-1.4633	-1.4570	-1.4540	-1.8132
-0.160	-1.1411	-1.1034	-1.0981	-1.0967	-1.4001
-0.140	-0.7634	-0.7382	-0.7345	-0.7342	-0.6587
-0.120	-0.3825	-0.3698	-0.3681	-0.3686	-0.2863
-0.100	0.00001	0.0001	-0.0001	-0.0002	-0.002
-0.080	0.3825	0.3698	0.3681	0.3679	0.3723
-0.060	0.7634	0.7382	0.7346	0.7338	0.8052
-0.040	1.1411	1.1034	1.0981	1.0970	1.2115
-0.020	1.5134	1.4636	1.4567	1.4549	1.5920
-0.010	1.6976	1.6408	1.6329	1.6305	1.7781
-0.050	1.7874	1.7284	1.7201	1.7173	1.8667
0.000	1.8772	1.8153	1.8067	1.8032	1.9488
Error →	3.5E-8	0.3E-6	0.2E-5	0.2E-4	0.3E-3

- Red highlights loss of unsymmetric properties
- Errors increase with W
 - Errors significant for $W=100$
- For $W > 50, R/t=10, K$ cannot be calculated accurately



Uniform Mesh Errors-Bending

- Bending, $2 \leq p \leq 8$
- $W = 25, R/t = 10$

Z	P=2	P=3	P=4	P=5	P=6	P=7	P=8
-0.200	-2.1781	-2.1625	-1.8152	-1.8148	-1.8151	-1.8147	-1.8190
-0.195	-2.0580	-2.0439	-1.7273	-1.7280	-1.7281	-1.7280	-1.7299
-0.190	-1.9397	-1.9283	-1.6394	-1.6406	-1.6406	-1.6406	-1.6411
-0.180	-1.7085	-1.7048	-1.4629	-1.4639	-1.4637	-1.4637	-1.4633
-0.160	-1.2674	-1.2747	-1.1038	-1.1036	-1.1035	-1.1033	-1.1034
-0.140	-0.8324	-0.8474	-0.7371	-0.7380	-0.7381	-0.7382	-0.7382
-0.120	-0.4125	-0.4215	-0.3698	-0.3699	-0.3698	-0.3698	-0.3698
-0.100	0.001	0.001	-0.0001	0.00003	0.00003	0.00001	0.00001
-0.080	0.4125	0.4215	0.3698	0.3699	0.3698	0.3698	0.3698
-0.060	0.8324	0.8474	0.7371	0.7380	0.7381	0.7382	0.7382
-0.040	1.2674	1.2747	1.1038	1.1036	1.1035	1.1033	1.1034
-0.020	1.7085	1.7048	1.4629	1.4639	1.4637	1.4637	1.4636
-0.010	1.9397	1.9284	1.6395	1.6406	1.6406	1.6407	1.6408
-0.050	2.0580	2.0439	1.7273	1.4639	1.7282	1.7282	1.7284
0.000	2.1781	2.1625	1.8152	1.6406	1.8152	1.8152	1.8153
Error →	0.2E-7	0.2E-6	0.9E-7	0.2E-7	0.6E-7	0.5E-7	0.2E-6

- Red highlights loss of unsymmetric properties
- Errors increase with p
- For $p > 6$, K cannot be calculated accurately
- 2003 solutions used $p = 6$



Error Summary

- Large errors in K when
 - R/t is large ($R/t > 3.0$)
 - Plate is wide
 - Linear analysis - example
 - $\sigma_B = 100$ MPa, $p = 8$
 - $R/t = 8$
 - $E = 71$ GPa
 - $\nu = 0.3$
 - Results
 - $e = 2E-3$
 - $w(0,200) = -800t$
 - $u(200,200) = 192t$





Error Mitigation

- Use smaller W for large R/t
 - $W = 400 / R/t$
 - Would have to reanalyze everything except $R/t = 2$
- Add additional constraints for bending cases
 - At the surface $X=0$, X -displacements are zero due to symmetry
 - At the surface $Y=0$, Y -displacements are zero due to symmetry
 - At the surface $Z=-t/2$, X - and Y -displacements are zero due to anti-symmetry for the bending loading (only)
 - Adding the above decreased the round-off error by $2X$ for $R/t=10$ but $2X$ is not enough
- Implement a new thin-shell FEA formulation
 - Method available since 1992, but no resources available
- Consider geometric nonlinear effects



Options

- Table shows example of geometric nonlinearity parameter, $\rho = \sigma_{B_{NL}} / \sigma_B$ from nonlinear beam theory
- $\sigma_T = 100\text{MPa}$, $\sigma_B \neq 0$, $E = 70\text{ GPa}$

R/t	H=5	H=10	H=20	H=30	H=50	H=100	H=200
0.1	0.9995	0.9979	0.9916	0.9813	0.9494	0.8205	0.5074
0.2	0.9979	0.9916	0.9671	0.9285	0.8205	0.5074	0.1477
0.3	0.9916	0.9285	0.9285	0.8503	0.6604	0.2789	0.0405
0.4	0.9916	0.9671	0.8785	0.7576	0.5074	0.1477	0.0110
0.5	0.9869	0.9494	0.8205	0.6604	0.3791	0.0774	0.0030
0.6	0.9813	0.9285	0.7576	0.6604	0.2789	0.0405	0.0008
0.8	0.9671	0.8785	0.6284	0.4025	0.1477	0.0110	0.0001
1.0	0.9494	0.8205	0.5074	0.2789	0.0774	0.0030	0.0000
2.0	0.8205	0.5074	0.1477	0.0405	0.0030	0.0000	0.0000
3.0	0.6604	0.2789	0.0405	0.0058	0.0001	0.0000	0.0000
5.0	0.3791	0.0774	0.0030	0.0001	0.0000	0.0000	0.0000
10.0	0.0774	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000

Large R/t, H \rightarrow Large error in K's using combined σ_T and σ_B from linear theory



Option 1

- The linear and nonlinear solution differ dramatically
- Effects of the bending moment on the stresses near the hole are almost not visible in the nonlinear solution
 - Stresses near the hole are almost symmetrical with respect to the mid-plane despite the large applied bending stresses
- The stresses in the nonlinear solution are practically the same as for the linear solution without the bending stresses
- The round-off errors in the nonlinear solution are much smaller than in the linear solution due to the geometrically nonlinear effects which kinematically stiffens the plate by mainly preventing out of plane displacements
- For thin, large plates (large W , R/t) the effects of bending on stress intensity factors can be neglected!

$$\sigma_Y(R,0,Z)$$

Z	Linear Tension & Bending	Nonlinear Tension & Bending	Linear Pure Tension
-0.400	208.60	300.24	299.04
-0.390	233.79	300.40	299.21
-0.380	245.56	300.56	299.37
-0.360	254.59	300.85	299.66
-0.320	265.38	301.32	300.14
-0.280	277.47	301.65	300.49
-0.240	289.63	301.84	300.69
-0.200	301.17	301.89	300.76
-0.160	312.13	301.81	300.69
-0.120	323.38	301.59	300.49
-0.080	334.39	301.23	300.14
-0.040	344.86	300.73	299.66
-0.020	349.86	300.42	299.37
-0.010	352.30	300.26	299.21
0.000	354.69	300.08	299.04
Error →	0.4E-5	0.7E-8	0.9E-8



Options

- Table shows example of geometric nonlinearity parameter, $\rho = \sigma_{BNL} / \sigma_B$ from nonlinear beam theory
- $\sigma_T = 100\text{MPa}$, $\sigma_B \neq 0$, $E = 70\text{ GPa}$

R/t	H=5	H=10	H=20	H=30	H=50	H=100	H=200
0.1	0.9995	0.9979	0.9916	0.9813	0.9494	0.8205	0.5074
0.2	0.9979	0.9916	0.9671	0.9285	0.8205	0.5074	0.1477
0.3	0.9916	0.9285	0.9285	0.8503	0.6604	0.2789	0.0405
0.4	0.9916	0.9671	0.8785	0.7576	0.5074	0.1477	0.0110
0.5	0.9869	0.9494	0.8205	0.6604	0.3791	0.0774	0.0030
0.6	0.9813	0.9285	0.7576	0.6604	0.2789	0.0405	0.0008
0.8	0.9671	0.8785	0.6284	0.4025	0.1477	0.0110	0.0001
1.0	0.9494	0.8205	0.5074	0.2789	0.0774	0.0030	0.0000
2.0	0.8205	0.5074	0.1477	0.0405	0.0030	0.0000	0.0000
3.0	0.6604	0.2789	0.0405	0.0058	0.0001	0.0000	0.0000
5.0	0.3791	0.0774	0.0030	0.0001	0.0000	0.0000	0.0000
10.0	0.0774	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000

Option 2a

Option 2b

Option 1



Option 2a

- Accept the $\leq 5\%$ error due to the geometric nonlinearity and use linear superposition as always

- $K_{I_{total}} = K_{I_{Tension}} + K_{I_{Bending}}$

- $K_I = \sigma_{Tension} \sqrt{\pi a} \beta_{Tension} \left(\frac{a}{c}, \frac{a}{t}, \frac{R}{t}, \frac{W}{D}, \varphi \right) +$

$$\sigma_{Bending} \sqrt{\pi a} \beta_{Bending} \left(\frac{a}{c}, \frac{a}{t}, \frac{R}{t}, \frac{W}{D}, \varphi \right)$$

- $\beta_{Tension}, \beta_{Bending}$ from AFGROW



Options

- Table shows example of geometric nonlinearity parameter, $\rho = \sigma_{BNL} / \sigma_B$ from nonlinear beam theory
- $\sigma_T = 100\text{MPa}$, $\sigma_B \neq 0$, $E = 70\text{ GPa}$

R/t	H=5	H=10	H=20	H=30	H=50	H=100	H=200
0.1	0.9995	0.9979	0.9916	0.9813	0.9494	0.8205	0.5074
0.2	0.9979	0.9916	0.9671	0.9285	0.8205	0.5074	0.1477
0.3	0.9916	0.9285	0.9285	0.8503	0.6604	0.2789	0.0405
0.4	0.9916	0.9671	0.8785	0.7576	0.5074	0.1477	0.0110
0.5	0.9869	0.9494	0.8205	0.6604	0.3791	0.0774	0.0030
0.6	0.9813	0.9285	0.7576	0.6604	0.2789	0.0405	0.0008
0.8	0.9671	0.8785	0.6284	0.4025	0.1477	0.0110	0.0001
1.0	0.9494	0.8205	0.5074	0.2789	0.0774	0.0030	0.0000
2.0	0.8205	0.5074	0.1477	0.0405	0.0030	0.0000	0.0000
3.0	0.6604	0.2789	0.0405	0.0058	0.0001	0.0000	0.0000
5.0	0.3791	0.0774	0.0030	0.0001	0.0000	0.0000	0.0000
10.0	0.0774	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000

Option 2a

Option 2b

Option 1



Option 2b

- $K_I = \sigma\sqrt{\pi a}\beta = (\sigma_{ten}\beta_{ten} + \sigma_{ben,NL}\beta_{ben})\sqrt{\pi a}$
 - σ_{ten} - user input
 - β_{ten} - from AFGROW
 - $\sigma_{ben,NL} = \rho\sigma_{ben}$
 - σ_{ben} - user input
 - ρ - from geometric nonlinear stress analysis (FORTRAN code for given R/t , H , E , σ_{ten} provided)
 - Adjust bending stress fraction for ρ
 - β_{ben} - from AFGROW



Options

- Table shows example of geometric nonlinearity parameter, $\rho = \sigma_{B_{NL}} / \sigma_B$ from nonlinear beam theory
- $\sigma_T = 100\text{MPa}$, $\sigma_B \neq 0$, $E = 70\text{ GPa}$

R/t	H=5	H=10	H=20	H=30	H=50	H=100	H=200
0.1	0.9995	0.9979	0.9916	0.9813	0.9494	0.8205	0.5074
0.2	0.9979	0.9916	0.9671	0.9285	0.8205	0.5074	0.1477
0.3	0.9916	0.9285	0.9285	0.8503	0.6604	0.2789	0.0405
0.4	0.9916	0.9671	0.8785	0.7576	0.5074	0.1477	0.0110
0.5	0.9869	0.9494	0.8205	0.6604	0.3791	0.0774	0.0030
0.6	0.9813	0.9285	0.7576	0.6604	0.2789	0.0405	0.0008
0.8	0.9671	0.8785	0.6284	0.4025	0.1477	0.0110	0.0001
1.0	0.9494	0.8205	0.5074	0.2789	0.0774	0.0030	0.0000
2.0	0.8205	0.5074	0.1477	0.0405	0.0030	0.0000	0.0000
3.0	0.6604	0.2789	0.0405	0.0058	0.0001	0.0000	0.0000
5.0	0.3791	0.0774	0.0030	0.0001	0.0000	0.0000	0.0000
10.0	0.0774	0.0030	0.0000	0.0000	0.0000	0.0000	0.0000

Must calculate and assess ρ for each R/t, H, E, σ_{ten}



Conclusions

- Errors in 2003 K database are real
 - Numerical round-off error
 - Geometric nonlinearity
 - Errors in very specific geometry not typically seen in aircraft structure
 - Affect seems minimal – no bug reports to date
 - Using solutions as implemented is conservative
 - Over estimate K by 4 - 650% for examples shown
 - Method provided for mitigating error and correcting for geometric nonlinearity
-



FORTRAN Code for ρ

```
program RHOVALUES
c use quadrupel precision for sinh cosh
  implicit real*16 (a-h,o-z)
  dimension RtValues(12),Harea(7),result(12,7)
  data RtValues/ 0.1, 0.2, 0.3, 0.4, 0.5,
*           0.6, 0.8, 1.0, 2.0, 3.0,
*           5.0,10.0/
  data Harea/ 5.0, 10.0, 20.0, 30.0, 50.0, 100.0,
*200.0/
c  write(6,*) 'Give R/t and H'
c  read(5,*) Rt,H
c.....calculate data in the table
  do 888 i=1,12
    Rt=Rtvalues(i)
  do 888 j=1,7
    H=Harea(j)
    thick=2.0D0/Rt
c  E=210000, steel
    E=71000.0
c  moment of inertia I, (b=1)
    b=1.d0
    realM=b*thick**3/12.d0
c....determine the bending moment
    sigbend=30.D0
c  sigbend=M*(thick/2)/l
c  M=2*I*sigbend/thick
    realM=2.0*realM*sigbend/thick

c.....dragkraft
    sigtens=100.D0
    P=thick*sigtens
c.....parameter n (KTH FS), gamma
    realn = sqrt(P/(E*realM))
    reall = 2.0D0*H
    gamma = realn*reall
c  calculate displacement in the middle
    factor=((qcosh(gamma) - 1.d0)/qsinh(gamma))
    w=(realM/P)*(qcosh(realn*H)-factor*qsinh(realn*H) -1.0)
c.....calculate w"
    wbiss=(-realM-P*w)/(E*realM)
    sigmacrack=-E*thick*wbiss/2.0
    rho=sigmacrack/sigbend
    write(6,120) Rt,H,w,sigmacrack,rho
120  format('R/t=',f5.1,' H=',f5.1,' w(H)=',f12.6,'
Sigma_Crack',
*f12.6,' Rho=',f15.6)
    result(i,j)=rho
888  continue
      write(6,125) (Harea(j),j=1,7)
125  format(4x,7f12.0)
      do 889 i=1,12
        write(6,130) Rtvalues(i),(result(i,j),j=1,7)
130  format(f5.1,7f12.4)
889  continue
      end
```